Hackathon-Based Learning Approaches for Mechanical Engineering

[1]Arun C Dixit, [2]Prakasha K N, [3]Harshavardhan B, [4]Anand A
[1,2]Vidyavardhaka College of Engineering, Mysuru
[3,4] The National Institute of Engineering, Mysuru
[1] arundixitu@vvce.ac.in [2]prakasha@vvce.ac.in [3]harshavardhanb@nie.ac.in, [4]anand@nie.ac.in

***Abstract*—Hackathons present a practical and collaborative learning exposure to the engineering student in general. They also enhance the problem-solving skills amongst the students. In specific, Mechanical engineering was chosen for this study as hackathons are mostly common in IT and circuit branches and the students of mechanical do not get to participate in such hackathons if they are not proficient in coding and other IT skills. We conducted a survey for the students of mechanical engineering to identify their interest and need towards the hackathons within their domain. The responses from the students were analyzed using correlation and clustering methods. This analysis gave us insights on the preferences of the students. Based on these insights, we have proposed four hackathon models specially for the mechanical domain: Industry-Based Hackathon, Product Development Hackathon, Innovation through Reverse Engineering, and a 1-credit Hackathon Course for Societal Solutions. We designed each model to address specific challenges and real-world applications. We implemented the "Innovation through Reverse Engineering" at our institution to get an actual experience of our proposed model and receive feedback from participants. The hackathon was well received by the students, and they were able to complete the tasks. With rapid changes taking place in the education and industrial domains, these approaches will ensure that the academic learning of the students are associated with industry needs with respect to fostering creativity, team working and problem-solving skills. These models also ensure that students are prepared well for the growing demand of their future careers, with the much-needed skills and experiences to excel in the rapidly evolving industrial space.**

***Keywords*— Hackathon-based learning; mechanical engineering education; innovative pedagogy; hands-on experience; problem-solving; industry readiness**

***ICTIEE* Track*:* Technology Enhanced Learning**
ICTIEE Sub-Track: Technology assisted Collaborative Learning

I. INTRODUCTION

Hackathon-based learning is a modern educational approach that is gaining popularity in the engineering education sector. In a typical hackathon, the student teams come together to discuss and come up with creative solutions to real life or industrial problems according to the theme of the event, in a short span of time. For example, students' teams may be given a time span of 24 hours, within which they may be asked to completely design a new tool, or they can improve an existing design to make it more efficient. This kind of time constrained activity in group will give them the much needed practical exposure, insights on team dynamics, and improve their technical problem solving skills (Garcia, 2023; Miličević et al., 2024; Nolte et al., 2020).

It has been proven that participation in hackathons will improve the student's ability to handle their capstone and research projects. They inculcate both technical skills like coding and designing along with soft skills such as communication and teamwork (Garcia, 2022). Hackathons if integrated into the courses, will provide a new path for teaching and its assessment, helping the students to be job ready (Steglich et al., 2020).

For evaluating the complex learning that happens in hackathon settings, data mining and multimodal analysis are being increasingly recognized as valuable tools. For example, these tools can track how the student team progresses through different tasks which provide insights about their learning approach. Educators can use and analyze this data to for getting a better understanding of the learning path and areas of improvement needed for them (Dixit, Arun C et al., 2024; Gama et al., 2018; Hogan, 2020).

The above tools also convey to the educators how students interact with each other in a team and the pattern in which they work. Using this data, they can step in and offer help to teams that are struggling to ensure that all students are benefited. This approach guided by data provides a win-win situation making the learning experience better and allows for continuous improvement of the hackathon format(Afshar et al., 2022; Kumalakov et al., 2018; Sharma et al., 2023).

From the above, it is clear that hackathon-based learning is a promising approach to acquire knowledge in engineering. Despite its many benefits, this method has been limited mainly to the IT and the circuit branches. Hackathon based learning in core branches such as Mechanical and Civil engineering is not popular due to the perception of coding tag attached to the method. Hence, it is necessary to understand the challenges, identify the gaps and come out with new methods of hackathon tailored to these disciplines. (García-Castanedo et al., 2024; Rennick et al., 2023).

II. HACKATHON FOR MECHANICAL ENGINEERING STUDENTS – CHALLENGES AND GAPS

In India, the popularity of mechanical engineering is decreasing every year. More students are choosing IT and related fields because they believe mechanical engineering is outdated and has limited job opportunities with the surge of AI and ML domains. This belief is fueled by the greater opportunities for collaboration and teamwork found in IT courses, which are often lacking in traditional mechanical and civil engineering programs (Dixit et al., 2020; Kelly et al., 2023).

Mechanical engineering students often feel disadvantaged compared to their IT peers, who regularly participate in hackathons that enhance their practical skills and prepare them for their careers. In contrast, mechanical engineering students mainly focus on theoretical studies and machine drawing, with little exposure to design thinking and product development. This lack of practical experience becomes a significant hurdle when they reach their final year and need to work on complex projects, leaving them unsure of how to start or proceed(Medina Angarita & Nolte, 2020; Panth & Maclean, 2020).

To address the above challenges, this study proposes incorporating hackathon-based learning into mechanical engineering education. By integrating hackathons into the curriculum, we aim to make mechanical engineering education more dynamic and connected to industry needs.

The absence of hackathons in mechanical engineering can be credited to several factors. Firstly, the traditional hackathon format often does not align well with the core competencies of mechanical engineering. Additionally, hackathons are usually focused on domains like software development, where they are more commonly utilized. There's also a lack of awareness or acceptance of hackathons as an effective educational tool within mainstream engineering education. However, incorporating hackathons into the mechanical engineering curriculum holds significant potential for skill development and fostering industry collaboration. It is essential for educators and industry professionals to engage in further research and dialogue to understand how best to implement hackathons in mechanical engineering education to maximize their benefits.

III. DIFFERENCES AND CHALLENGES BETWEEN SOFTWARE AND MECHANICAL ENGG HACKATHONS

The idea of hackathons originated in the software engineering domain. Since then, they have gained immense popularity over time. These events involved bringing together programmers, coders, and tech enthusiasts to collaboratively develop innovative software solutions within a limited time duration (Dixit et al., 2019; Happonen et al., 2022).

Organizing hackathons specific to mechanical engineering students presents a distinctive set of challenges compared to their counterparts in software engineering. Table I provides the comparison between software hackathons and mechanical engineering hackathons with respect to various characteristic features observed in a typical hackathon (Flus & Hurst, 2021).

Given the differences highlighted in the comparison and the challenges posed by mechanical engineering hackathons, it's important to rethink how we approach hackathons for mechanical engineers. The goal is to make them practical to organize, easy to fit into the curriculum, and beneficial for all students. Building upon the insights from the comparison, we can develop new ideas that cater specifically to mechanical engineering. In the next section, we will explore these innovative approaches, which aim to address the challenges effectively and ensure that the integration of mechanical engineering hackathons into the academic program is both smooth and highly valuable for students.

TABLE I
CHARACTERISTICS OF SOFTWARE HACKATHONS VS. MECHANICAL ENGINEERING HACKATHONS

Characteristic	Software Hackathon	Mechanical Engineering Hackathon
Problem statements	More abstract and open-ended	More specific and technical
Required skills	Programming, software design, and user experience	Engineering design, CAD, and manufacturing
Knowledge Resources	Wide range of resources available	Fewer resources available, such as access to specialized equipment or materials
Time constraints	Typically lasts for 24-48 hours	May last for a longer period, such as 72 hours or even a week
Teamwork	Requires teamwork	May require a higher level of teamwork, as projects often involve multiple disciplines
Evaluation	Based on the creativity and innovation of the solutions	May also be evaluated on the technical feasibility and robustness of the solutions
Infrastructure	Participants typically need to have their own laptops and programming skills	Participants may also need access to specialized equipment and materials, such as 3D printers, laser cutters, and machining tools

IV. NEED ANALYSIS FOR HACKATHON

In order to formulate effective strategies for the implementation of hackathons in the domain of mechanical engineering education, it is necessary to conduct a thorough need analysis. The purpose of this need analysis is to gain insights into students' perspectives, expectations, and requirements regarding hackathons. By understanding the specific needs and aspirations of mechanical engineering students, we can adapt our hackathon approaches to align with their educational and career goals.

A comprehensive survey was conducted among sixth-semester mechanical engineering students in South Karnataka to gauge their familiarity with hackathons and their perspectives on integrating such events into their curriculum. The survey explored various aspects, including students' awareness of hackathons, their views on hackathons as effective problem-solving tools, and their interest in participating in these events. Furthermore, students were questioned about their understanding of current industry challenges and their readiness to engage with industry professionals. Responses were collected from 310 students (students responded) across different colleges through a Google Forms questionnaire. The questionnaire circulated to students is shown in Table II. Participants were asked to rate their responses on a 5-point Likert scale: Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree.

TABLE II
QUESTIONNAIRE CIRCULATED TO THE STUDENTS

Q.No	Question
Q1	I feel I receive enough exposure to problem-solving through hackathons, similar to my peers in software and circuit branches.
Q2	I regularly engage in problem-solving activities outside of my regular coursework.
Q3	I have participated in hackathon-style events related to mechanical engineering during my academic journey.
Q4	I believe that hackathons can enhance problem-solving skills in mechanical engineering.
Q5	I am interested in participating in a hackathon focused on mechanical engineering challenges.
Q6	I prefer hackathons to be integrated into the regular curriculum rather than offered as extracurricular activities.
Q7	I believe hackathons can help bridge the gap between academia and industry in mechanical engineering.
Q8	I am aware of the current challenges and problems faced by industries in mechanical engineering and my role after graduation.
Q9	I would be interested in participating in hackathons that focus on solving real-world industry problems in mechanical engineering.
Q10	I think integrating hackathons into mechanical engineering education will improve my readiness for the professional world.

Survey questionnaires and responses: The survey questionnaires deployed to gather valuable insights from mechanical engineering students and the responses obtained from the survey are shown in Table III.

TABLE III
RESPONSES RECEIVED TO THE QUESTIONNAIRE

Q. No	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Q1	23	48	91	102	46
Q2	45	78	93	56	38
Q3	35	72	104	54	45
Q4	51	99	80	45	35
Q5	40	83	85	61	41
Q6	60	103	71	46	30
Q7	47	102	72	55	34
Q8	36	64	85	71	54
Q9	58	102	65	48	37
Q10	45	94	84	53	34

Descriptive statistics analysis: To gain a comprehensive understanding of the distribution of responses, we conducted a descriptive statistical analysis. Table IV summarizes the key metrics for each response category across all survey questions.

The mean values indicate the average number of responses in each category, while the standard deviation provides insight into the variability of the responses. For instance, the "Agree" category shows a higher average response (84.5) with significant variability (std dev 18.88), suggesting diverse opinions among students. In contrast, the "Strongly Disagree" category has the lowest average (39.4) and the least variability (std dev 7.18), indicating a more consistent response pattern.

These insights are crucial for understanding the overall sentiment of the students towards hackathons and their integration into the curriculum. The unevenness in responses highlights areas where students have strong, divergent opinions, necessitating targeted strategies to address their concerns and expectations.

Correlation Analysis of Survey Responses: To understand the relationships between different response categories, a correlation analysis was performed. The correlation matrix in Figure 1 illustrates the strength and direction of these relationships.

The correlation coefficients range from -1 to +1, where values close to +1 indicate a strong positive relationship, values close to -1 indicate a strong negative relationship, and values around 0 indicate no relationship.

The key insights from the analysis are as follows:

- Strong Positive Correlation Between "Strongly Agree" and "Agree": The strong positive correlation (0.92) between "Strongly Agree" and "Agree" responses suggests that questions with higher "Strongly Agree" responses also tend to have higher "Agree" responses. This indicates a consistent pattern of agreement among students who strongly support certain statements.
- Negative Correlations Between Positive and Negative Responses: The strong negative correlations between "Strongly Agree" and "Disagree" (-0.85) and "Strongly Disagree" (-0.76) responses, as well as between "Agree" and "Disagree" (-0.87) and "Strongly Disagree" (-0.84) responses, suggest that students who agree with a statement are unlikely to disagree with it. This highlights a clear division in student opinions, with strong and moderate agreements opposing disagreements.
- Positive Correlation Among Negative Responses: The positive correlation (0.64) between "Disagree" and "Strongly Disagree" responses indicates that questions with higher disagreement tend to see both forms of disagreement. This suggests that students who disagree with a statement tend to have a consistent level of disagreement.
- Moderate Positive Correlation Between "Neutral" and Negative Responses: The moderate positive correlations between "Neutral" responses and both "Disagree" (0.38) and "Strongly Disagree" (0.55) responses suggest that students who are neutral may have a slight tendency towards disagreement. This indicates that neutral responses might lean towards a lack of strong agreement.

These insights provide a deeper understanding of student perspectives and how they relate across different response categories. By identifying these relationships, we can better interpret the overall sentiment and design targeted strategies for integrating hackathons into the curriculum.

TABLE IV
DESCRIPTIVE STATISTICS OF SURVEY RESPONSES

Response Category	Count	Mean	Std Dev	Min	25%	Median	75%	Max
Strongly agree		44	11.13	23	37	45	50	60
Agree		84.5	18.88	48	73.5	88.5	101.25	103
Neutral	10	83	11.6	65	74	84.5	89.5	104
Disagree		59.1	16.89	45	49.25	54.5	59.75	102
Strongly Disagree		39.4	7.18	30	34.25	37.5	44	54

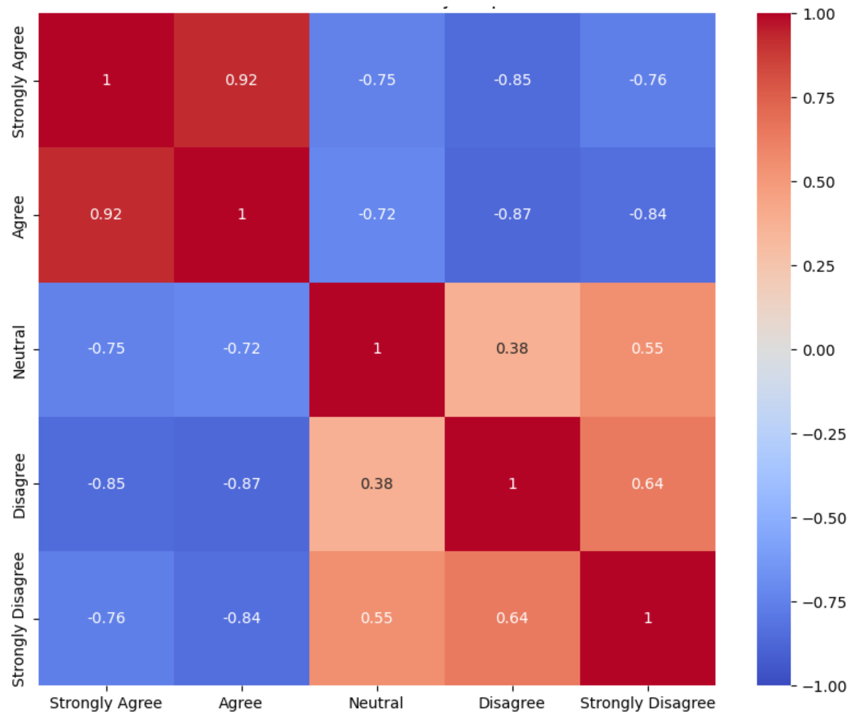

Fig. 1. Correlation Matrix of Survey Responses

Clustering Analysis of Survey Responses: To identify distinct groups of students based on their survey responses, a K-means clustering analysis was performed. The clustering results are visualized in Figure 2, with the first two principal components (PCA) representing the data in a reduced dimensional space. PCA is used to reduce the dimensionality of the data while retaining most of the variance, making the clusters more visually interpretable.

The X-axis and Y-axis represent the first two principal components from PCA:

- PCA Component 1: Captures the maximum variance in the data, summarizing the most important features that differentiate the responses.
- PCA Component 2: Captures the second highest variance, providing additional dimensions to distinguish between the clusters.

The significance of the different clusters that were identified are as follows:

- Cluster 0 (Blue): This cluster includes the students who have mix of agreement and disagreement with the survey views differ, approaches can be developed to better engage them thus improving their learning experience.
- Cluster 1 (Red): Students in this cluster have extreme opinions. They have either strongly agreed or strongly disagreed with the survey statements. Developing the approaches to align with their preferences can increase their satisfaction.
- Cluster 2 (Green): This cluster has students who have given more neutral responses. More comprehensive approaches can be developed to suit their needs.

The above clustering analysis revealed the different student groups based on their responses to the questionnaire. With the above grouping, we can have specific approaches to each group of students ensuring their preferences are met effectively.

V. INNOVATIVE HACKATHON MODELS FOR MECHANICAL ENGINEERING DOMAIN

Our comprehensive survey of mechanical engineering students revealed distinct clusters, each with specific needs and preferences for practical, industry-aligned learning experiences

All Clusters	Innovation through Reverse Engineering	Universally adaptable, enabling students to analyse and improve existing products hands-on.

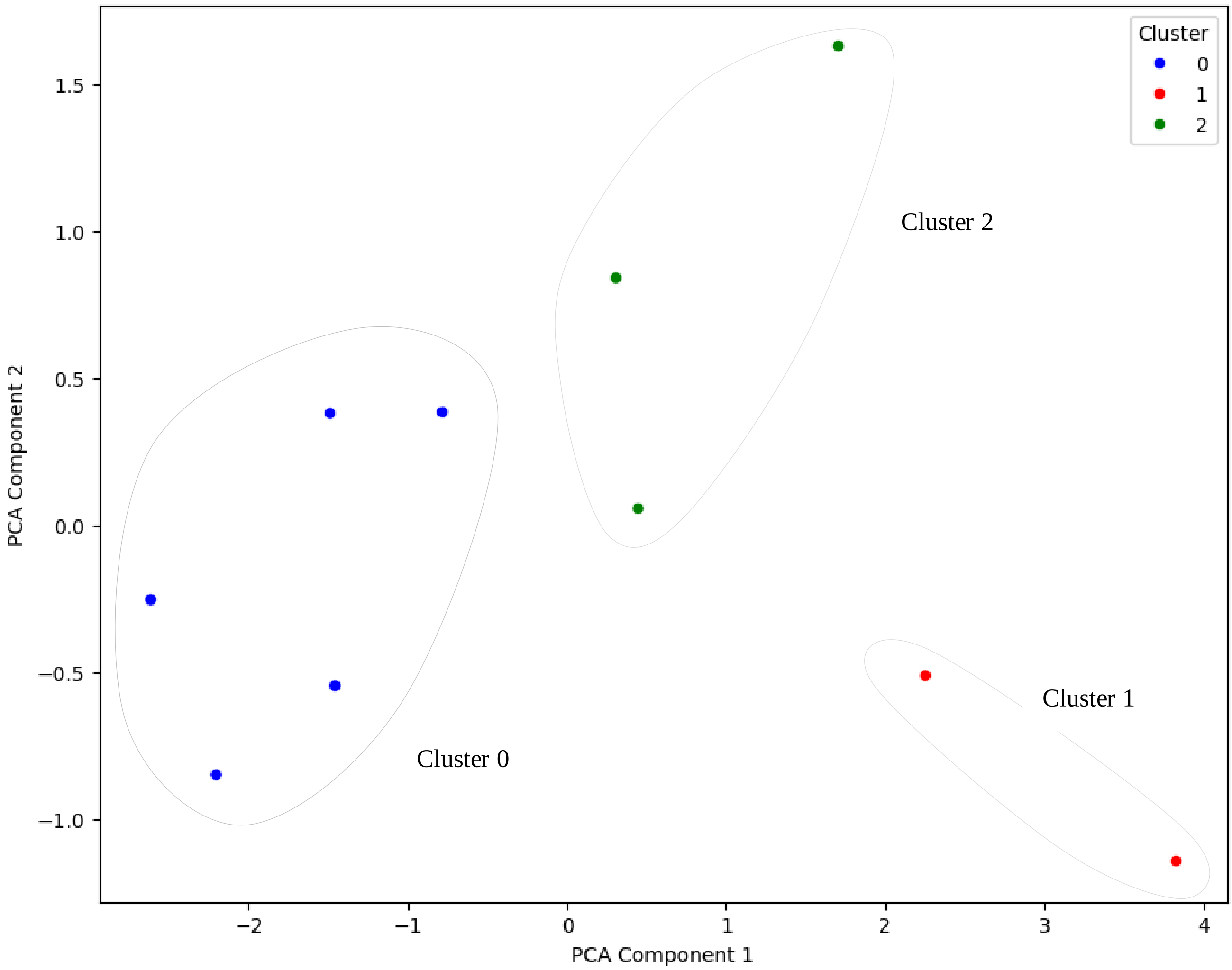

Fig. 2. k-means clustering of Survey Responses

TABLE V
MAPPING OF CLUSTERS TO THE HACKATHON APPROACHES

Cluster	Mapped Hackathon Approach	Justification
Cluster 0 (Blue)	Product Development Hackathon	Allows students to explore various aspects of mechanical engineering, catering to diverse interests.
Cluster 1 (Red)	Industry-Based Hackathon	Engages students with strong preferences by aligning with real-world industry challenges.
Cluster 2 (Green)	1-Credit Hackathon Course for Societal Solutions	Provides a flexible platform to explore societal challenges, suited for students with neutral views.

Based on these insights, we propose four innovative hackathon models tailored to these clusters. Table V shows the mapping of the clusters to these approaches and Table VI summarizes these four approaches, describing their objectives, steps, and the benefits they offer.

These innovative hackathon models provide structured, practical, and industry-aligned learning experiences tailored to the specific needs and preferences of the identified student clusters. They aim to equip mechanical engineering students with the skills and knowledge required to meet contemporary engineering challenges effectively.

Of the four approaches suggested, we implemented one activity at our institute. The details, implementation, outcomes, and analysis of the "Innovation through Reverse Engineering" approach are detailed in the next section. The above approach was considered because it provides hands-on learning opportunities, encourages critical analysis of existing designs, and enhances technical documentation skills, making it highly relevant for addressing the specific needs identified in our survey.

TABLE VI
NEW APPROACHES FOR MECHANICAL ENGINEERING HACKATHONS

Sl. No	Approach	Objective	Steps	Benefits & Impact
1	Industry-Based Hackathon	Bridge the gap between theoretical knowledge and practical industry applications.	1. Organize industry tours for students to identify real-world problems. 2. Develop problem statements based on observations during the tours. 3. Facilitate brainstorming sessions for solution development. 4. Engage with industry professionals to present and refine solutions. 5. Incorporate feedback from professionals to refine solutions iteratively. 6. Implement selected solutions with industry support. 7. Provide ongoing mentorship from industry experts.	1. Provides real-world exposure and collaboration with industry. 2. Ensures hands-on experience through practical implementation. 3. Continuous feedback from industry professionals.
2	Product Development Hackathon	Foster innovation and product development skills.	1. Introduce the product development process. 2. Form groups and select product categories. 3. Conduct market surveys to generate ideas. 4. Develop and select the best concepts. 5. Create detailed designs considering manufacturing constraints. 6. Develop 3D models using CAD software. 7. Present designs to an expert panel for evaluation. 8. Refine designs based on expert feedback. 9. Develop physical prototypes. 10. Conduct a final evaluation by a jury.	1. Customizable challenges for varying experience levels 2. Structured expert feedback enhances design quality. 3. Emphasizes both innovative thinking and practical skills.
3	Innovation through Reverse Engineering	Understand and improve existing products through reverse engineering.	1. Disassemble consumer products to study and document components. 2. Analyse technical aspects, strengths, and weaknesses of the disassembled products. 3. Brainstorm and develop improved versions of the original designs. 4. Create enhanced 3D models incorporating innovative improvements. 5. Present the improved designs to experts for appraisal and feedback.	1. Promotes understanding and critical analysis of existing designs. 2. Enhances technical documentation and creativity. 3. Suitable for varying skill levels, providing guided exploration
4	Hackathon as a 1-credit Course for Societal Solutions	Develop solutions for societal challenges through technical innovation.	1. Form interdisciplinary teams to tackle societal challenges. 2. Identify pertinent technical challenges with significant societal impact. 3. Develop detailed blueprints and innovative solutions. 4. Refine solutions with guidance from experienced mentors. 5. Create functional prototypes and develop implementation strategies. 6. Present solutions in a public forum for evaluation. 7. Assess the potential impact, feasibility, and sustainability of the solutions. 8. Reflect on the learning experience and broader implications.	1. Integrates hackathons into the curriculum for widespread participation. 2. Emphasizes sustainability and long-term societal impact. 3. Provides mentorship and practical implementation strategies.

VI. IMPLEMENTATION OF INNOVATION THROUGH REVERSE ENGINEERING APPROACH

To bridge the gap between classroom knowledge and real-world applications, we implemented the "Innovation through Reverse Engineering" approach at our institute in South Karnataka. This event aimed to enhance creative thinking and practical skills among mechanical engineering students, providing them with hands-on experience in disassembling and analyzing everyday mechanical products.

Event Overview: Approximately 30 sixth-semester mechanical engineering students participated in the hackathon, divided into six teams. The primary objective was to dissect and understand products like hair dryers, electric screwdrivers, and hair trimmers. The process was designed to foster a deeper understanding of mechanical design principles and promote innovative thinking. The Hackathon was conducted for a duration of 13 hours after the inaugural program. Students were allowed to use all the resources available on the internet during the Hackathon.

Implementation Stages:

Stage 1: Preparation and Briefing

- Introduction: Students were briefed on the objectives, process, and evaluation criteria of the program. Pre-program questionnaire responses (Table 8) were considered during the briefing.
- Industry Insights: An alumnus from Philips India Pvt. Ltd. provided insights into the importance of reverse engineering in the corporate sector.

Stage 2: Disassembly and Analysis

- Hands-On Disassembly: Students disassembled the products meticulously documenting each subcomponent (Figure 3a). This stage provided valuable insights into the materials and mechanisms involved.

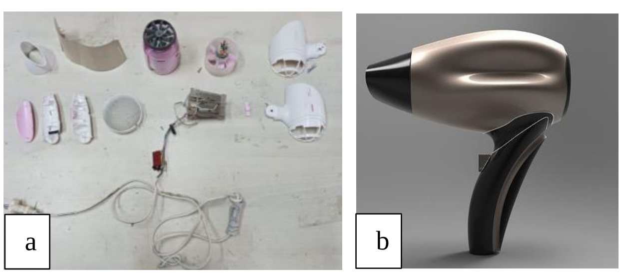

Figure 3 a) Disassembled Hair Dryer b) Improvised 3D Model of Hair Dryer

Stage 3: Brainstorming and Design Improvement

- Collaborative Brainstorming: Teams identified strengths and weaknesses of the products and proposed innovative improvements.
- 3D Modeling: Using CAD software, students created enhanced 3D models incorporating their proposed improvements (Figure 3b).

Stage 4: Presentation and Feedback

- Expert Evaluation: Teams presented their designs to experts who assessed creativity, feasibility, and practical implementation potential. Evaluation criteria and scores are presented in Table VII.

TABLE VII
EVALUATION CRITERION AND TEAM SCORE CARDS

Evaluation Criterion	T1	T2	T3	T4	T5
Clarity of Presentation (15 points): • Structure, and Articulation • Inclusion of Key points	11	10	13	13	11
Technical Content (15 points): • Demonstration of deep understanding of the disassembled product • Technical details and literature review • Application if engineering principles and concepts	12	9	12	14	10
Creativity and Innovation (15 points): • Creative solutions proposed to improve the disassembled product • Demonstration of innovative thinking • Originality and inventiveness in the proposed enhancements	13	10	12	13	12
Practicality and Feasibility (15 points): • Feasibility and practicality of the proposed enhancements • Consideration for real-world implementation • Addressing of potential challenges	9	11	9	12	11
Market Relevance (10 points): • Alignment of enhancements with market needs • Considerations of consumer preferences • Clear value proposition for potential users	6	8	8	6	6
Quality of 3D Models (15 points): • Detailing and Quality of 3D Models • Effective communication of proposed enhancements • visually appealing and craft	12	12	10	14	13
Q&A Session (15 points): • Response to questions from the judges • Confidence and validity of information • Roles and responsibilities of members	11	9	11	13	12
TOTAL (100)	74	69	75	85	75

TABLE VIII
DESCRIPTIVE FEEDBACK QUESTIONNAIRE FOR INNOVATION THROUGH REVERSE ENGINEERING ACTIVITY

Stage 1: Pre-program Questionnaire	**Stage 2: Mid-Program Questionnaire**
1. How familiar are you with the concept of reverse engineering?	1. Describe your experience with disassembling and analysing the assigned mechanical products. What challenges did you encounter?
2. Have you participated in any hackathons or engineering design competitions before?	2. How has the collaborative group work enhanced your understanding of mechanical design principles?
3. What motivated you to join this program? (Interest in mechanical design, passion for innovation, desire to learn new skills, etc.)	3. What were the key strengths and weaknesses you identified during the RE process?
4. Do you have any prior experience with disassembling and analysing mechanical products?	4. How did your team approach the task of proposing innovative solutions to the identified weaknesses?
5. What do you hope to gain from this program in terms of skills and knowledge?	5. How comfortable do you feel with using CAD software to create 3D models?
Stage 3: Post-Program Questionnaire	**Stage 4: Long-Term Impact Questionnaire (Sent after 1 month of the program):**
1. Reflect on your overall experience in the program. How has it contributed to your understanding of mechanical design and innovation?	1. Have you applied any of the skills or concepts learned from the program in your courses or other projects?
2. Describe the impact of receiving feedback from expert mentors on your proposed modifications and 3D models.	2. Reflect on how the program influenced your perception of mechanical engineering and its potential for innovation.
3. Did the program help you develop skills such as critical thinking, problem-solving, and collaboration? Please provide examples.	3. Have you shared your experiences and insights gained from the program with your peers or mentors?
4. How confident are you in identifying design flaws and proposing solutions in real-world products after completing this program?	4. Do you believe the program has contributed to your personal and professional growth? How would you describe the value of the "Innovation through Reverse Engineering" program in your academic and career journey?
5. Would you consider participating in similar hackathon-based programs in the future?	

Feedback analysis: Feedback on the program was collected at four stages as shown in Table VIII. The consolidated responses are as below:

1. Pre-Program: Most students had limited familiarity with reverse engineering and lacked hackathon experience but were motivated by an interest in mechanical design and innovation.

2. Mid-Program: Students reported positive experiences, gained insights into complex mechanisms, and benefited from collaborative problem-solving.

3. Post-Program: Students highlighted the program's positive influence on their understanding of mechanical design, appreciated expert feedback, and gained confidence in identifying and solving design flaws.

4. Long-Term Impact: Students applied acquired skills in subsequent projects and endorsed the program's contribution to their personal and professional development.

TABLE IX
RESPONSES FOR PROGRAM OUTCOMES (PO) BASED QUESTIONNAIRE FOR THE HACKATHON

Feedback Questionnaire	**Response/Score**
Did the hackathon enhance your understanding of engineering principles and their practical applications? (PO1)	93.2
Did the hackathon help you improve your ability to analyse complex problems and identify key issues disassembly and brainstorming phases? (PO2)	91.7
Did you effectively design and develop solutions for this hackathon, and do you feel confident in your ability to continue designing and developing solutions for future challenges? (PO3)	90.4
Did the hackathon encourage you to investigate and understand the inner workings of engineering and everyday products? (PO4)	95.7
Were you able to utilize modern engineering tools effectively in crafting your design solutions? (PO5)	94
Did the hackathon promote awareness of the societal impact of engineering solutions? (PO6)	90.7
Did the hackathon enhance your ability to work and contribute effectively to a team? (PO8)	96.2
Did the hackathon improve your ability to present technical information effectively? (PO9)	95.1
Did the hackathon inspire you to continue exploring and learning about innovative engineering solutions?	96.5

Feedback on the impact of the hackathon on the program outcomes was collected apart from the descriptive feedback collected as shown in Table IX. These responses were collected using a 5-point scale and were subsequently converted into percentage-based data for analysis The responses from the students clearly indicate that program outcomes such as Problem analysis, Design and development of solutions, investigation of complex problems, and lifelong learning which can be challenging to fully achieve through traditional classroom instruction, were successfully attained through this hands-on activity.

The detailed implementation strategies and outcomes of this approach demonstrate its efficacy as a model for integrating experiential learning into engineering curricula, thereby equipping students with the requisite skills and knowledge to thrive in a dynamic engineering landscape.

CONCLUSION

The rise of AI and ML courses has shifted the landscape of technological education, challenging traditional fields like mechanical engineering to stay relevant. The survey results clearly indicate a strong student interest in hackathon-based learning as a method to bridge the gap between theoretical knowledge and practical application. Our detailed analysis highlighted the areas where the traditional method of education is lacking, leading to the development of four new approaches for hackathons: Industry-Based Hackathon, Product Development Hackathon, Innovation through Reverse Engineering, and a 1-credit Hackathon Course for Societal Solutions. The successful implementation of the "Innovation through Reverse Engineering" approach provided concrete evidence of the benefits, including enhanced problem-solving skills, increased industry readiness, and improved collaborative learning. The outcomes validated the effectiveness of hackathon-based learning, highlighting its potential to transform mechanical engineering education.

Incorporating these methods into the curriculum will require careful planning. Initially, hackathons can be conducted as standalone events to familiarize students with the concept and assess their engagement. Over time, these events can be transitioned into a 1-credit course that spans the semester. Students can progress their hackathon activities during their free time, under the mentorship of faculty, ensuring flexibility and minimal disruption to their regular coursework. This approach allows for integration without removing any existing courses. To further ensure feasibility and scalability, pilot programs will be conducted to evaluate their effectiveness and identify best practices for full-scale integration.

Hackathons can also be designed to foster interdisciplinary collaboration by involving students from other branches. Themes like building a small autonomous car, which require inputs from mechanical, electrical, and software engineering, can enrich learning outcomes and drive innovation. The effectiveness of these approaches will be evaluated using metrics such as participation rates, skill improvement assessments, and feedback from students and faculty. Long-term impact will be assessed through improvements in capstone projects, job readiness, and industry feedback on graduate performance.

This study emphasizes the transformative potential of hackathon-based learning in core engineering branches like mechanical engineering. It provides a roadmap for integrating these methods into the curriculum while highlighting the importance of stakeholder engagement and industry-academia collaboration. The findings set the stage for broader adoption, interdisciplinary exploration, and future research into hackathon-based learning as an effective pedagogical tool.

REFERENCES

Afshar, Y., Bahrehvar, M., Moshirpour, M., & Behjat, L. (2022). Hackathon as an Effective Learning and Assessment Tool: An Analysis of Student Proficiency against Bloom’s Taxonomy. Proceedings of the Canadian Engineering Education Association (CEEA). https://doi.org/10.24908/pceea.vi.15925

Dixit, A. C., Achutha, M. V., & Sridhara, B. K. (2020). Elastic properties of aluminum boron carbide metal matrix composites. Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2020.08.766

Dixit, A. C., Sridhara, B. K., & Achutha, M. V. (2019). Evaluation of Critical Speed for Aluminum–Boron Carbide Metal Matrix Composite Shaft. In U. Chandrasekhar, L.-J. Yang, & S. Gowthaman (Eds.), Innovative Design, Analysis and Development Practices in Aerospace and Automotive Engineering (I-DAD 2018) (pp. 527–534). Springer. https://doi.org/10.1007/978-981-13-2718-6_51

Dixit, Arun C, B, Harshavardhan, B C, Ashok, K N, Prakasha, M A, S., & K N, P. (2024). Innovative Pedagogical Approaches for Diverse Learning Styles and Student-Centric Learning. Journal of Engineering Education Transformations, 37(IS2), 178–188. https://doi.org/10.16920/jeet/2024/v37is2/24039

Flus, M., & Hurst, A. (2021). Design at hackathons: New opportunities for design research. Design Science, 7, e4. https://doi.org/10.1017/dsj.2021.1

Gama, K., Alencar Gonçalves, B., & Alessio, P. (2018). Hackathons in the formal learning process. Proceedings of the 23rd Annual ACM Conference on Innovation and Technology in Computer Science Education, 248–253. https://doi.org/ 10.1145/ 31970 91.3197138

Garcia, M. B. (2022). Hackathons as extracurricular activities: Unraveling the motivational orientation behind student participation. Computer Applications in Engineering Education, 30(6), 1903–1918. https:// doi.org/10.1002/cae.22564

Garcia, M. B. (2023). Fostering an Innovation Culture in the Education Sector: A Scoping Review and Bibliometric Analysis of Hackathon Research. Innovative Higher Education, 48(4), 739–762. https://doi.org/10.1007/ s10755-023-09651-y

García-Castanedo, J., Corrales-Garay, D., Rodríguez-Sánchez, J.-L., & González-Torres, T. (2024). The ideathon as an instrument for entrepreneurial education in university contexts. The International Journal of Management Education, 22(1), 100926. https:// doi.org/10.1016/j.ijme.2023.100926

Happonen, A., Nolte, A., Bystriakova, N., Santti, U., & Kärhä, K. (2022). Study on Hackathons for New Innovation Seed and Business Model Development Needs in Digitalization Driven Sustainability, Circularity and Environmentally Friendly Solutions Demanding Digitalizing Societies. In Dr. C.-C. Kuo (Ed.), New Innovations in Economics, Business and Management Vol. 4 (pp. 1–29). https://doi.org/10.9734/bpi/ niebm/ v4/14443D

Hogan, M. (2020, March 31). From Times Square to Eyre Square: Hackathons as Authentic Learning for Information Systems Students. Sixth International Conference on Higher Education Advances. Sixth International Conference on Higher Education Advances. http://ocs.editorial.upv.es /index.php/ HEA D/HEAd20/paper/view/11046

Kelly, S., Kaye, S.-A., & Oviedo-Trespalacios, O. (2023). What factors contribute to the acceptance of artificial intelligence? A systematic review. Telematics and Informatics, 77, 101925. https://doi.org/10.1016/ j.tele.2022.101925

Kumalakov, B., Kim, A., Mukhtarova, S., Shukurova, A., & Khon, N. (2018). Hackathon as a Project Based Teaching Tool: Employing Programming Challenge in the Class. 2018 IEEE 12th International Conference on Application of Information and Communication Technologies (AICT), 1–5. https://doi.org/10.1109/ ICAICT.2018.8747149

Medina Angarita, M. A., & Nolte, A. (2020). What Do We Know About Hackathon Outcomes and How to Support Them? – A Systematic Literature Review. In A. Nolte, C. Alvarez, R. Hishiyama, I.-A. Chounta, M. J. Rodríguez-Triana, & T. Inoue (Eds.), Collaboration Technologies and Social Computing (Vol. 12324, pp. 50–64). Springer International Publishing. https://doi.org/10.1007/978-3-030-58157-2_4

Milićević, A., Despotović-Zrakić, M., Stojanović, D., Suvajžić, M., & Labus, A. (2024). Academic performance indicators for the hackathon learning approach – The case of the blockchain hackathon. Journal of Innovation & Knowledge, 9(3), 100501. https:// doi.org/10.1016/j.jik.2024.100501

Nolte, A., Chounta, I.-A., & Herbsleb, J. D. (2020). What Happens to All These Hackathon Projects?: Identifying Factors to Promote Hackathon Project Continuation. Proceedings of the ACM on Human-Computer Interaction, 4(CSCW2), 1–26. https:// doi.org/10.1145/3415216

Panth, B., & Maclean, R. (Eds.). (2020). Anticipating and Preparing for Emerging Skills and Jobs: Key Issues, Concerns, and Prospects (Vol. 55). Springer Singapore. https://doi.org/10.1007/978-981-15-7018-6

Rennick, C., Litster, G., Hulls, C. C. W., & Hurst, A. (2023). Curricular Hackathons for Engineering Design Learning: The Case of Engineering Design Days. IEEE Transactions on Education, 66(6), 654–664. https://doi.org/10.1109/TE.2023.3295754

Sharma, A., Hemanth, P. B., Bhavani, A., & Dixit, A. C. (2023). Green Hydrogen for a Sustainable Future: Prospects and Challenges for Energy-Based Applications in Major Indian States by 2030. E3S Web of Conferences, 405, 02027. https://doi.org/10.1051/ e3sconf/ 202340 502027

Steglich, C., Salerno, L., Fernandes, T., Marczak, S., Dutra, A., Bacelo, A. P., & Trindade, C. (2020). Hackathons as a Pedagogical Strategy to Engage Students to Learn and to Adopt Software Engineering Practices. Proceedings of the XXXIV Brazilian Symposium on Software Engineering, 670–679. https://doi.org/10.1145/ 3422392.3422479