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Personalized and Collaborative Learning Approach for Enhanced Student Engagement

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***Abstract*—This paper examines the implementation of personalized learning strategies in the "Theory of Machines" course for mechanical engineering students, aimed at addressing diverse learning preferences often overlooked in traditional teaching methods. A survey conducted at the beginning of the semester identified students' preferred learning styles, including Visual, Aural, Kinesthetic, and Read/Write. Tailored activities, designed using freely available online tools, were introduced to align with these preferences, ensuring students engaged with the content in a manner that best supported their individual learning styles. Engagement metrics and pre- and post-activity surveys indicated improved participation and self-assessed understanding across all learner types. To further extend learning beyond individual preferences, a collaborative hackathon was organized at the end of the course. Diverse teams, composed of students with different learning styles, worked together to simulate real-world engineering collaboration. This interdisciplinary teamwork allowed students to contribute based on their strengths while learning new approaches from their peers. The hackathon results demonstrated that peer learning significantly enhanced students' problem-solving abilities and communication skills. This study underscores the effectiveness of combining personalized learning with collaborative projects in engineering education. By addressing individual learning needs and fostering teamwork, students were better prepared for the demands of professional engineering environments. The findings suggest that this model is scalable to other technical courses and has the potential to reshape engineering curricula to be more inclusive and dynamic. Future research should explore the long-term impacts on student outcomes and the integration of emerging technologies, such as virtual reality, to further enrich the learning experience.**

***Keywords*—Personalized Learning, Engineering Education, Collaborative Learning, Learning Styles, Hackathon.**

***JEET Category*—Practice**

I. INTRODUCTION

Engineering education has traditionally relied heavily on lecture-based methods, which typically cater to a limited range of learning styles. This uniform approach can leave many students disengaged or struggling to link theoretical concepts with practical applications. In courses like "Theory of Machines," where students must master abstract concepts and spatial reasoning to address real-world engineering challenges, such an approach often falls short (Bondie et al., 2019; Patil & Kamerikar, 2020; Tulsi et al., 2016).

While it is well-recognized that students differ in their learning preferences—visual, auditory (aural), kinesthetic, and reading/writing-oriented (VARK model)—these insights have been underutilized in actual instructional practice. Conventional teaching predominantly addresses logical and verbal learners, leaving visual or kinesthetic learners inadequately supported (Dixit, Arun C et al., 2024; Yotta, 2023).

To bridge this gap, this study introduces a practical implementation framework designed to accommodate individual learning styles, thereby enhancing student engagement and comprehension(Kabilan, 2023; Mehta & Mehta, 2023).

The aim of this research is to evaluate personalized learning strategies within the "Theory of Machines" course, explicitly identifying student learning preferences through a structured survey administered at the start of the semester. Results informed the design of customized learning activities utilizing freely accessible digital tools (e.g., simulations, virtual labs, interactive resources). Furthermore, recognizing the collaborative nature of engineering practice, the approach was extended through a collaborative hackathon, grouping students from diverse learning styles to address complex mechanical problems collectively.

This study does not propose a new theoretical framework but provides a detailed classroom-tested implementation of personalized and collaborative learning strategies, addressing a notable practical gap in engineering education literature. The outcomes suggest meaningful improvements in student engagement, conceptual understanding, and teamwork skills. The resulting scalable and easily adaptable instructional model offers practical insights for educators aiming to enrich their courses with personalized and collaborative elements, thus aligning closely with real-world engineering environments(Gaur et al., 2024; Haleem et al., 2022; Marougkas et al., 2024; Parvathi, 2021).

This study therefore addresses the following research question: How does integrating personalized learning activities with collaborative projects affect student engagement, understanding, and teamwork skills in the context of mechanical engineering education? (Kozlowski & Ilgen, 2006; Sharma et al., 2023; Villegas-Ch & García-Ortiz, 2023).

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II. LITERATURE REVIEW

Research over the past few decades has highlighted the importance of aligning teaching strategies with students' individual learning preferences. This section reviews the literature on learning styles, personalized learning, collaborative learning, and active learning in engineering education, providing the context for the approach taken in this study (Børte & Lillejord, 2024).

Learning Styles and Personalized Learning in Engineering Education: The recognition of diverse learning styles, notably through models like VARK, has influenced approaches to teaching. Studies indicate that aligning teaching methods with student preferences improves engagement and retention. Despite this, engineering education has been slow to fully integrate these approaches, often focusing on logical and verbal learners while overlooking Visual and Kinesthetic learners, who benefit from simulations and hands-on tasks. Emerging technologies, such as PhET simulations and Tinkercad, offer new opportunities to support these learning preferences, but research on effectively integrating these tools into a comprehensive personalized learning model is limited (Cuevas, 2015; Dixit, Prakasha, et al., 2025; Lyle et al., 2023; Walkington & Bernacki, 2020).

Collaborative Learning and Peer Interaction: Collaborative learning has long been recognized as essential in engineering education, fostering both technical and soft skills like communication and problem-solving. Team-based approaches, including problem-based learning (PBL) and flipped classrooms, enhance student engagement and help mirror real-world interdisciplinary collaboration. However, few studies have explored how to effectively combine personalized learning with collaborative teamwork. The hackathon model, which involves students working in diverse teams to solve real-world problems, has shown promise in promoting peer learning and applying theoretical knowledge (Dixit, K N, et al., 2025; Rajalingam et al., 2021; Sukackė et al., 2022; Zhang et al., 2024).

Active Learning in Engineering Education: Active learning strategies, such as PBL and case studies, have proven effective in engineering education by fostering deeper engagement with content. These approaches encourage students to take ownership of their learning and apply theoretical knowledge to practical problems. While these methods have demonstrated success, they often assume a uniform approach to content engagement, failing to address individual learning preferences. This study bridges this gap by combining personalized learning with active learning and collaborative activities, offering a more holistic approach to engineering education (Ang et al., 2021; Harshavardhan et al., 2020; Reddy et al., 2024; Upadhye et al., 2022).

Theoretical and Practical Integration: Traditional assessments tend to emphasize theoretical understanding, which may not fully capture students' practical abilities. The hackathon model offers a way to integrate theoretical knowledge with hands-on, team-based problem-solving, providing students with a more comprehensive learning experience. By combining personalized learning activities with collaborative projects, this study aligns with the broader educational shift towards more inclusive and practical engineering curricula (Dixit et al., 2019; Raravi & Madhusudan, 2017; Rennick et al., 2023).

Gaps in Literature: While the benefits of personalized and collaborative learning are well-documented, few studies have combined these approaches into a cohesive model for engineering education. This research addresses that gap by integrating personalized activities with a team-based hackathon, providing a scalable and effective method for improving both individual engagement and collaborative skills.

III. METHODOLOGY

This study employed a multi-layered mixed-methods research design to evaluate the effectiveness of personalized learning strategies in the "Theory of Machines" course. The methodology consisted of identifying student learning preferences, implementing tailored activities, and culminating in a collaborative hackathon to integrate diverse learning styles as shown in Figure 1. This approach ensured that students not only learned in a way that aligned with their individual preferences but also engaged in interdisciplinary teamwork that mirrors real-world engineering scenarios (Dixit et al., 2021; Liu et al., 2021).

Phase 1: Identifying Learning Preferences - In the first week of the semester, a structured self-report survey was conducted using Google Forms. The instrument was adapted from the VARK model (Visual, Aural, Read/Write, Kinesthetic) and extended to include Logical/Mathematical, Social (Interpersonal), Solitary (Intrapersonal), and Verbal (Linguistic) categories. Students responded to multiple-choice items that indicated their preferred way of understanding new content (e.g., "I learn best when I..."), and additional items gauged their familiarity with digital learning tools like simulations, CAD software, and collaborative platforms. This classification helped segment the cohort for tailored instructional design. Though the survey was not statistically validated for reliability, it served as an exploratory tool to inform instructional planning. This limitation has been acknowledged in the Discussion section (Dixit et al., 2020; Othman & Amiruddin, 2010).

Phase 2: Implementing Tailored Activities - Based on survey responses, students were assigned personalized activities and assignments that matched their dominant learning style. The activities were designed using a blend of traditional and modern methods, with emphasis on free, accessible online tools such as PhET, Tinkercad, YouTube tutorials, and Google Docs. Activity planning was based on the course instructor's teaching experience and informal consultations with departmental faculty. Feedback from alumni working in mechanical design and product development also influenced the skill-focus areas (e.g., CAD skills for visual learners, collaborative documentation for read/write learners). Each learning category received activities with clear objectives, appropriate tools, and customized assessments. These activities were conducted within scheduled class hours, ensuring the traditional lecture content was not compromised(Dixit et al., 2021).

Phase 3: Collaborative Hackathon for Interlearning Across Diverse Learning Styles - To simulate professional teamwork, a collaborative hackathon was conducted in the final two weeks. Students were grouped into interlearning teams comprising a balanced mix of learning types. Each team was tasked with designing and simulating a mechanical system (e.g., a camshaft or gearbox) using the tools and skills they developed earlier. Roles were distributed based on learning strengths - for instance:

- Visual learners handled CAD design and visualization.
- Kinesthetic learners executed physical prototyping or simulation testing.
- Logical learners developed calculations and algorithmic logic.
- Read/Write learners-maintained documentation and reports.

The hackathon promoted peer learning and enabled students to observe and appreciate alternate learning styles in action—an essential skill for real-world engineering collaboration.

Phase 4: Evaluating Engagement, Performance, and Collaboration - To assess the impact of the intervention, both quantitative and qualitative metrics were used:

- Engagement was measured by tracking completion rates of assigned activities, frequency of tool usage, and in-class participation.
- Performance was evaluated through weekly assignments and team project outputs.
- Peer evaluations during the hackathon gauged individual contribution and collaboration quality.
- Student reflections and feedback were collected through open-ended surveys and semi-structured interviews post-hackathon.

Although no control group was used, internal comparisons were drawn from early-semester and post-intervention engagement patterns. The analysis was primarily descriptive due to the practical nature of the classroom context.

IV. RESULTS

A. *Learning Preferences and Grouping:*

The first step of the study involved identifying the learning preferences of students enrolled in the "Theory of Machines" course. A total of 120 third-year mechanical engineering students participated in a comprehensive survey that captured their dominant learning styles. The survey was based on an expanded VARK model, including additional categories such as Logical/Mathematical, Social, Solitary, and Verbal learners. Before administration, the instrument was piloted with a small batch of 15 students to ensure reliability and clarity, achieving a Cronbach’s alpha of 0.82.

Students were asked to rate their preferences through multiple-choice questions and Likert-scale items related to how they processed information and their comfort with tools like simulations, group work, and independent research. Based on their responses, students were grouped according to their highest scoring category. Table I summarizes this distribution, showing that while Visual and Aural learners formed the majority, every learning type was represented, underlining the diversity of the classroom and the need for differentiated instruction.

TABLE I
DISTRIBUTION OF LEARNING PREFERENCES AMONG STUDENTS

Learner Type	Number of Responses	Percentage of Students (%)
Visual Learners	26	22
Aural Learners	22	18
Read/Write Learners	17	14
Kinesthetic Learners	19	16
Logical/Mathematical Learners	12	10
Social (Interpersonal) Learners	10	8
Solitary (Intrapersonal) Learners	7	6
Verbal (Linguistic) Learners	7	6

B. *Designing and Delivering Personalized Activities*

Once students were grouped, specific learning activities were designed for each group using low-cost or free online tools. These activities were carefully integrated into the course without disrupting the regular lecture schedule. After each lecture, time was allocated within the same class period for students to engage in tasks aligned with their learning preferences. For instance, Visual learners used simulations, Kinesthetic learners engaged in model-building, and Logical learners worked with mathematical software.

The activities were designed not only to align with individual learning styles but also to reinforce key course outcomes. Assignments were chosen to blend theoretical understanding with practical application. These were reviewed regularly and refined based on student performance and feedback. Table II lists the activities designed for each learning type, along with the tools and learning objectives. This structure allowed for a balanced approach—ensuring every student interacted with the content in a way that felt intuitive and meaningful.

C. *Engagement and Performance Improvements*

To measure the effectiveness of the personalized learning strategy, engagement and performance data were tracked throughout the semester. Engagement was recorded through LMS logs, task submissions, and classroom interactions, while performance was measured through assignment scores evaluated on a uniform rubric.

Initial data showed that learners like Kinesthetic and Aural types had lower engagement in the first few weeks due to a mismatch between teaching methods and their preferred learning modes. For example, Kinesthetic learners struggled with text-heavy tasks, while Aural learners had difficulty following simulations that lacked narration. Upon integrating more interactive tools—like virtual labs and podcasts—these groups showed marked improvement in both participation and performance.

As shown in Table III, the completion rates and average assignment scores increased across most learner types. Read/Write and Logical learners remained consistent

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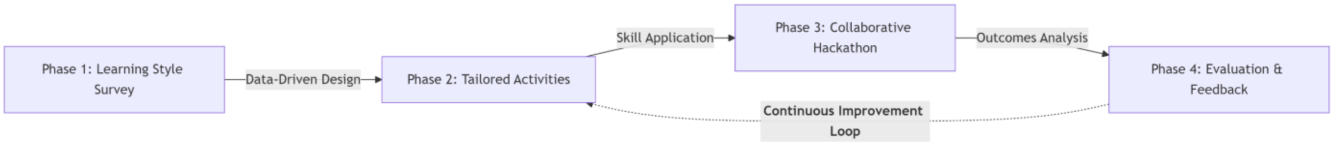

Fig. 1. Instructional Model for Personalized and Collaborative Learning in Engineering Education

TABLE II
PERSONALIZED LEARNING ACTIVITIES FOR DIFFERENT LEARNER TYPES

Learner Type	Activity	Description	Tools Used	Objective	Assignment
Visual Learners	Interactive Simulations and Animations	Engage with detailed visual simulations of mechanical systems.	PhET, Tinkercad, Algodoo	Enhance spatial understanding and visualization of mechanical systems.	Create annotated diagrams of mechanisms, explaining their function visually.
Aural Learners	Podcasts, Webinars, and Group Discussions	Participate in auditory activities, such as webinars, group discussions, and podcasts.	Zoom, Anchor, Google Meet	Reinforce learning through listening and speaking activities.	Prepare and present a podcast or oral explanation of a mechanical concept.
Read/Write Learners	Technical Readings and Detailed Notes	Engage with written materials such as technical documents, research papers, and detailed notes.	Khan Academy, Google Docs, MIT OpenCourseWare	Deepen understanding through reading and writing tasks.	Write a technical report on a specific mechanism, with detailed research and analysis.
Kinesthetic Learners	Virtual Labs and Physical Model Construction	Hands-on interaction with models using virtual labs and 3D modeling tools.	Tinkercad, Virtual Lab simulators, Linkagae Mechanism simulator	Facilitate hands-on learning by building and manipulating models.	Construct a mechanical model and document the process, explaining the function of each part.
Logical/ Mathematical Learners	Problem-Solving and Algorithmic Tasks	Engage in mathematical modeling and problem-solving activities related to mechanical systems.	MATLAB, Wolfram Alpha, Excel	Strengthen problem-solving skills through mathematical analysis.	Model and solve equations related to the performance of a machine, analyzing the results.
Social Learners	Group Projects and Peer Teaching	Collaborate on group projects and engage in peer teaching activities.	Google Docs, Slack, Zoom	Foster collaboration and team-based problem-solving tasks.	Work in teams to solve a complex mechanical problem and present the solution collaboratively.
Solitary Learners	Independent Research Projects	Conduct independent research on mechanical topics, using self-paced resources.	MIT OpenCourseWare, Khan Academy, Google Scholar	Encourage self-paced learning and reflective analysis.	Research a complex mechanical system and write a comprehensive report supported by independent research.
Verbal Learners	Storytelling and Oral Explanations	Participate in storytelling and verbal explanation exercises, using narrative techniques to explain concepts.	Audacity, Google Meet	Enhance conceptual understanding by verbalizing complex topics.	Deliver an oral presentation or debate on a mechanical concept, explaining its operation through storytelling.

throughout, while the highest improvement was seen among Kinesthetic learners, whose completion rate jumped from 75% to 91%. Aural learners also showed a strong increase after auditory-rich content was introduced, with scores rising from 72% to 80%. These results confirm that when learning materials align with students' preferences, their motivation and understanding improve noticeably.

TABLE III
ENGAGEMENT AND PERFORMANCE BY LEARNER TYPE

Learner Type	Initial Completion (%)	Final Completion (%)	Initial Score (%)	Final Score (%)
Visual	90	92	80	84
Aural	78	85	72	80
Read/Write	98	98	89	89
Kinesthetic	75	91	75	82
Logical/ Mathematical	95	95	91	91
Social	78	89	78	83
Solitary	87	87	87	87
Verbal	81	86	72	81

D. *Student Reflections and Feedback*

In addition to quantitative data, student feedback was collected through reflection forms and anonymous course evaluations. This feedback provided deeper insight into how students perceived the effectiveness of the personalized learning approach.

Students often described feeling "seen" and "understood" when activities resonated with their natural learning methods. Visual learners appreciated detailed CAD animations; Kinesthetic learners reported breakthroughs when manipulating models; and Social learners felt energized through collaborative assignments. These sentiments are reflected in Table IV, which presents a sample of student quotes that directly relate to the personalized tasks they were assigned.

Interestingly, some students mentioned that while they preferred one learning style, exposure to other modes also helped broaden their understanding. For example, a Kinesthetic learner mentioned that writing reflections helped them retain what they had built, while a Read/Write learner found value in group discussions. This highlights the subtle benefit of adaptive engagement, where students begin to explore beyond their comfort zones.

A. *Collaborative Hackathon: Bringing Learning Styles Together*

To simulate real-world engineering teamwork and test the collective impact of diverse learning styles, a mini hackathon was conducted at the end of the semester. Students were reorganized into heterogeneous teams that included representatives from all learning types. The task was to collaboratively design, simulate, and present a mechanical system over two days.

TABLE IV
SAMPLE STUDENT FEEDBACK BY LEARNER TYPE

Learner Type	Student Feedback
Visual	"The CAD tools made it easier to understand mechanisms than textbook diagrams."
Aural	"The recorded webinars and discussions helped me stay focused and understand better."
Kinesthetic	"I finally grasped the cam movement after building the model myself."
Read/Write	"Reading technical articles and summarizing them made the concepts stick."
Social	"Group activities helped me stay motivated and learn faster from others."

Each student contributed to the project based on their strengths - Visual learners handled design visuals, Logical learners tackled technical calculations, and Verbal learners led the presentations. Importantly, students also learned from each other. Read/Write learners coached others on technical documentation, while Kinesthetic learners taught team members how to model mechanisms interactively.

The hackathon was evaluated using faculty rubrics, peer ratings, and post-event reflections. As shown in Table V, peer evaluations averaged 8.7/10, and 92% of students reported gaining new skills from teammates with different learning styles. These findings confirm that interdisciplinary collaboration, when properly structured, promotes not only task completion but also mutual growth and respect for different learning approaches.

TABLE V
HACKATHON EVALUATION SUMMARY

Evaluation Metric	Score
Average Peer Rating (out of 10)	8.7
Faculty Panel Score (out of 10)	8.4
Collaboration Index (Peer-rated)	8.6
Self-reported Skill Gain (%)	92

B. *Summary of Results*

The data from this study reveals three key outcomes:

- Personalized learning activities significantly improved student engagement and performance across all learner types.
- Feedback from students showed high satisfaction, with many expressing that their learning preferences were respected and supported.
- The collaborative hackathon provided a meaningful extension to the personalized activities, demonstrating how peer learning and role diversity can enrich the engineering learning experience.

These results establish that integrating personalized learning within traditional teaching, and extending it through real-world collaboration, can make engineering education more inclusive, effective, and professionally relevant.

The next section will explore the broader implications of these findings, including how they align with current literature and what they suggest for the future of instructional design in engineering classrooms.

V. DISCUSSIONS

This study shows that a structured combination of personalized and collaborative learning strategies can significantly enrich engineering education when thoughtfully integrated into a traditional classroom. In the "Theory of Machines" course, the blended model preserved core lecture-based instruction while enhancing it through student-specific activities and peer-driven problem solving.

Effectiveness of Personalized Learning: Survey-based personalization enabled targeted engagement. Students who initially struggled with abstract content—especially kinesthetic and visual learners—showed noticeable improvements once matched with activities suited to their learning styles. For example, kinesthetic learners improved task completion by over 20% after hands-on tasks were introduced. Aural and verbal learners also responded well once podcasts and oral explanations were added. These results, measured through completion rates and self-reflections, highlight how adapting instruction to learning preferences improves both motivation and academic progress.

While each learner type benefited differently, many students gravitated toward hybrid modes—e.g., combining discussion with hands-on exploration—suggesting that flexibility is key. This underscores the need for adaptable environments rather than rigid categories. Additionally, tools like Tinkercad, Google Docs, and Khan Academy ensured equitable access and practical skill-building, as emphasized in student feedback.

Collaborative Hackathon: The collaborative hackathon served as a bridge between individual learning and interdisciplinary teamwork. Students worked in mixed-style teams to design and simulate mechanical systems, applying their respective strengths. Logical learners handled calculations, kinesthetic learners built models, and read/write learners managed documentation. More importantly, peer learning allowed less confident learners to observe and adopt new strategies. Verbal learners, for instance, deepened their understanding by explaining concepts to others.

This peer interaction mirrored real-world engineering scenarios, where diverse team members contribute unique skills. Students reported that the hackathon boosted their communication, problem-solving, and time-management abilities—key attributes in engineering practice. Peer evaluations also revealed improved collaboration dynamics over time.

Maintaining Academic Structure: Importantly, personalized learning was not introduced at the cost of academic content. Core lectures continued throughout the semester. Time was strategically allotted for tailored activities within scheduled hours, reinforcing lecture material rather than replacing it. This balance made the model realistic and feasible within curriculum constraints.

Implications for Engineering Education: The study provides a scalable framework that educators can implement without major curriculum overhauls. By using free, accessible tools and building on existing course structures, institutions can support diverse learners while enhancing teamwork readiness. The approach also prepares students for industry-like settings, where collaboration and adaptability are essential.

Study Limitations: While the findings are promising, the study did not include a control group or validated survey instrument, which limits generalizability. However, these have been clearly stated as limitations in the paper. Future iterations should incorporate validated tools and include performance comparisons across cohorts. Furthermore, engagement was tracked through completion metrics and student feedback, rather than formal hypothesis testing. Despite this, the descriptive analysis provides actionable insight into instructional design.

Future Work: Future studies can expand this framework to other engineering courses, explore the use of immersive technologies (e.g., VR/AR), and evaluate long-term outcomes on retention and problem-solving. Investigating cross-institutional implementations can also add to the robustness of this approach.

Overall, this study offers a practical model that responds to the diversity in engineering classrooms. By blending personalization with collaboration, students not only improve academically but also gain professional competencies that extend beyond the classroom.

CONCLUSION

This study highlights how integrating personalized learning activities into a traditional engineering course can improve student engagement and learning outcomes. By identifying students' learning preferences and offering activities that matched their styles, the "Theory of Machines" course became more inclusive and responsive to individual needs. This approach allowed students to understand complex mechanical concepts more effectively and encouraged deeper participation in class.

Importantly, the use of personalized learning did not replace traditional lectures but complemented them. Core concepts were taught through lectures, while time was given during class hours for students to engage with personalized tasks. This balanced structure ensured academic depth while making space for individual exploration.

The collaborative hackathon further enhanced the experience by enabling students from different learning backgrounds to work together. This activity not only promoted peer learning but also simulated real-world teamwork, a key requirement in engineering practice. Students reported gaining new perspectives and soft skills such as communication, coordination, and problem-solving.

While the findings are promising, the study had some limitations. It involved a single course and relied on descriptive data and self-assessments. Future studies should include control groups, validated instruments, and long-term tracking of student outcomes.

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