Fostering Engagement and Understanding: The Impact of Kolb's Experiential Learning Theory on Teaching Theory of Machines

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***Abstract*— Despite being an essential subject in mechanical engineering education, the Theory of Machines (TOM) frequently presents substantial difficulties for students because of its mathematical rigor and abstract concepts. Learners are often not adequately engaged by traditional teaching approaches, which results in a superficial comprehension of basic concepts. This study investigates how to improve student engagement and comprehension in TOM courses by implementing Kolb's Experiential Learning Theory (KELT) as a teaching paradigm. This study intends to promote greater connections between theoretical knowledge and real-world application by incorporating experiential learning activities like practical projects, simulations, and group learning opportunities. The study assesses how experiential learning affects students' drive, critical thinking, and recall of TOM ideas using a mixed-methods methodology. According to the results, applying Kolb's ELT fosters a more dynamic and interesting learning environment in addition to enhancing comprehension of difficult subjects. This case report demonstrates how methods of hands-on education have the power to revolutionize Theory of Machines instruction and ultimately equip engineering students for problems they may face in the real world.**

***Keywords*— Kolb's Experiential Learning, Theory of Machines, Learning, Outcomes**

I. INTRODUCTION

The Theory of Machines (TOM) is a fundamental course in mechanical engineering that focuses on the study of mechanisms, kinematics, and dynamics of machinery. It plays a crucial role in equipping students with the analytical and conceptual skills needed to understand the motion and forces in mechanical systems.

Key topics covered in this course include kinematic analysis of mechanisms, gear and cam systems, balancing of rotating and reciprocating masses, and vibration analysis. Mastering these concepts is essential for designing efficient and reliable mechanical systems, making TOM a cornerstone of mechanical engineering education. However, teaching TOM effectively poses challenges, as students often struggle to visualize and comprehend complex mechanical interactions using traditional lecture-based methods. Theoretical explanations alone may not be sufficient to foster deep understanding, leading to disengagement and difficulties in grasping key concepts. To address these challenges, this study explores the application of Kolb's Experiential Learning Theory (ELT) in teaching TOM. ELT emphasizes learning through experience, which aligns well with the hands-on and application-driven nature of mechanical engineering. By incorporating experiential learning activities such as simulations, physical models, project-based learning, and real-world case studies, students can actively engage with TOM concepts, improving their conceptual clarity, problem-solving skills, and retention of knowledge. This research examines the impact of KELT-based teaching interventions on student engagement and learning outcomes in the TOM course. The study aims to demonstrate how experiential learning enhances students' ability to visualize, analyze, and apply mechanical principles more effectively than traditional instructional approaches, ultimately fostering deeper understanding and engagement in the subject.

A convincing framework for encouraging active learning through firsthand experience is provided by Kolb's theory of experiential learning (KELT). Kolb (1984) asserts that a cycle of being, reflecting, thinking, and doing is necessary for effective learning. By encouraging students to actively engage in the learning process, this experiential approach promotes greater retention and comprehension of the material(Devi & Thendral, 2023a). Students can become engaged parties in their own learning process rather than passive consumers of information if teachers fit the curriculum with Kolb's learning cycle(Chen et al., 2022). A popular method of instruction in a variety of educational contexts, including engineering education, is KELT (Healey & Jenkins, 2000). The theory emphasizes the importance of experiential learning through a cyclical process of concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984). This literature review examines the impact of Kolb's

ELT on student engagement and understanding, particularly in the context of teaching the Theory of Machines Numerous studies have highlighted the effectiveness of Kolb's ELT in enhancing student engagement and learning outcomes in engineering disciplines. For instance, Kavitha Devi and Thendral (2023) found that applying Kolb's experiential learning framework significantly improved student learning in theoretical courses, resulting in higher engagement and performance metrics(Devi & Thendral, 2023a). Similarly, Govender and Govender (2023) reported positive student experiences in learning computer programming through robotics, which leveraged the principles of experiential learning to foster deeper understanding and engagement(Govender & Govender, 2023). In the context of engineering education, the application of Kolb's ELT has facilitated active learning environments. Mahmoud and Nagy (2009) emphasized the importance of laboratory education in engineering, where hands-on experiences are pivotal for applying theoretical knowledge. They noted that students engaged in laboratory settings showed improved conceptual understanding and retention of engineering principles(Mahmood et al., 2024). Engagement is a critical factor influencing learning outcomes. Hung, Wang, and Yeh (2023) explored the effects of different stages of Kolb's experiential learning cycle on learning outcomes in marine debris education, finding that structured experiential activities enhanced student engagement and understanding(Hung et al., 2023). Their study underscored the need for educators to create opportunities for students to actively participate in their learning process, thus fostering a more profound comprehension of complex concepts. Bagweneza et al. (2021) analyzed clinical experiences in nursing education using Kolb's ELT and found that reflective practices significantly improved student understanding and engagement. This aligns with the notion that reflection plays a crucial role in the experiential learning cycle, allowing students to connect theory to practice and enhance their overall learning experience(Bagweneza et al., 2021). The importance of experiential learning in enhancing conceptual understanding is further supported by various studies. Sato and Laughlin (2018) integrated Kolb's ELT into a sport psychology classroom through a golf-putting activity, demonstrating that practical applications of theoretical concepts lead to improved student understanding and retention. This notion is particularly relevant in engineering education, where students must grasp complex concepts such as dynamics and mechanics in the Theory of Machines(Sato & Laughlin, 2018). Moreover, Liu et al. (2024) investigated the impact of augmented reality on learning processes in structural engineering education, indicating that innovative teaching methods grounded in experiential learning principles can significantly improve student engagement and understanding. Their findings highlight the necessity for educators to adopt diverse pedagogical strategies that incorporate experiential learning to cater to various learning styles(Liu et al., 2024). Despite the demonstrated benefits of Kolb's ELT, some challenges remain in its implementation. Meany et al. (2024) discussed communication barriers in virtual reality environments for medical education, suggesting that instructors must adapt their teaching approaches to accommodate emerging technologies while maintaining engagement. This is crucial for engineering educators who are increasingly integrating technology into their curricula(Meany et al., 2024).

Kolb's Experiential Learning Theory (ELT) has been widely applied to enhance engineering education by connecting theory with practical experience. (Haritha & Rao, 2024) emphasize a holistic approach to professional development, integrating ELT to improve students' soft skills, such as communication, teamwork, and adaptability.

(Devi & Thendral, 2023b) demonstrate the use of ELT to enhance learning in theory-based courses, showing that experiential activities promote deeper understanding, engagement, and retention of complex concepts.

(Mehta & Mehta, 2023)report that experiential learning positively impacts learning outcomes, based on a netnography study of engineering students, highlighting improved problem-solving abilities and applied knowledge.

This research aims to investigate the impact of implementing Kolb's Experiential Learning Theory in the teaching of TOM. By integrating experiential learning activities such as hands-on projects, simulations, and collaborative exercises, this study seeks to enhance student engagement and understanding of complex topics within TOM. The findings will provide insights into the effectiveness of experiential learning strategies in cultivating a more interactive and enriching educational experience, ultimately equipping engineering students with the skills and knowledge necessary to tackle real-world engineering challenges.

II. Methods

A. *Kolb's Experiential Learning Theory*

According to KELT, learning is a procedure in which experience is transformed into knowledge (Woodend et al., 2024). The theory, which originated by David A. Kolb in the 1970s, highlights the value of experiences in the process of learning and outlines four phases, as illustrated in figure 1:

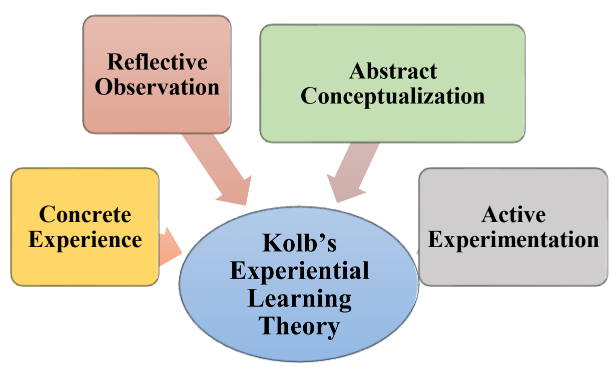


Fig. 1 KELT Concept

Traditional lecture-based teaching methods in TOM primarily focus on theoretical derivations and numerical problem-solving, which may not be sufficient for students to fully grasp the physical behaviour of mechanical systems. Many students struggle with visualizing motion, force interactions, and real-world applications, leading to lower engagement and conceptual difficulties. To bridge this gap, this study applies KELT, which emphasizes learning through experience. This model is particularly effective for engineering education as it integrates theory with hands-on learning, allowing students to actively engage with mechanical concepts rather than passively receiving information.

In the context of the TOM course, ELT can be implemented through:

- Concrete Experience: Using physical models, 3D simulations, and virtual reality tools to help students directly observe the motion of mechanisms(Morris, 2020).
- Reflective Observation: Encouraging students to analyze and discuss real-world machine components and failures(Pherson-Geyser et al., 2020).
- Abstract Conceptualization: Linking observations to theoretical principles and mathematical modeling(Hulaikah et al., 2020).
- Active Experimentation: Engaging students in project-based learning, laboratory experiments, and software-based simulations to test and validate their understanding(Helate et al., 2022).

By incorporating these experiential learning strategies, students can develop a deeper conceptual understanding, improved problem-solving skills, and stronger engagement with the subject matter. This study evaluates the impact of ELT-based instructional interventions on student performance, motivation, and comprehension in the TOM course, demonstrating how an experiential approach can enhance engineering education. Table I shows the Scheduling of KELT and timeline.

TABLE I
SCHEDULING OF KELT AND TIMELINE

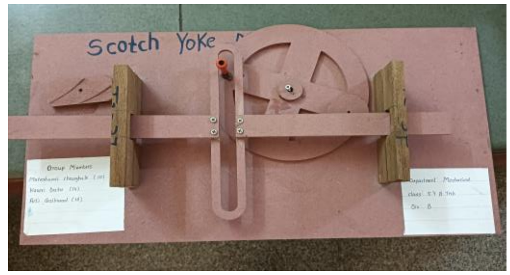
Unit	Topics Covered	Taught Using KELT	Experiential Learning Approach	KELT Hours
Unit I Fundamentals of Mechanisms (08 hrs)	- Introduction to Mechanisms & Machines - Kinematic Pairs & Chains - Degrees of Freedom (DOF) & Mobility	Yes	**Concrete Experience:** Hands-on model-making for Slider-Crank and Four-Bar mechanisms. **Reflective Observation:** Group discussions on real-world applications of linkages (e.g., robotic arms).	**3 hrs**
Unit II Kinematic Analysis of Planar Mechanisms (07 hrs)	- Grashoff's Law & Kinematic Inversions (Slider-Crank, Double Slider-Crank) - Kinematic analysis of Slider-Crank Mechanism (Analytical Method) - Velocity & Acceleration Analysis (Four-Bar & Slider-Crank) using Complex Algebra Method - Graphical Methods (Relative Velocity & ICR)	Yes	**Active Experimentation:** MATLAB/GeoGebra simulations for velocity & acceleration analysis. **Abstract Conceptualization:** Application of Newtonian mechanics & graphical methods.	**3 hrs**
Unit III Synthesis of Mechanisms (07 hrs)	- Type, Number & Dimensional Synthesis - Kinematic Synthesis Tasks: Path, Function & Motion Generation - Chebyshev Spacing, Mechanical & Structural Errors - Graphical (Relative Pole) & Analytical (Freudenstein's Equation) Synthesis	Yes	**Experiential Learning:** Design of motion-based mechanical systems (Green Gym Mechanism). **Simulation & Modeling:** Application of Freudenstein's equation for mechanism synthesis.	**3 hrs**
Unit IV Gears and Gear Trains (07 hrs)	- Classification & Terminology of Gears - Law of Gearing & Interference Avoidance - Simple, Compound, Reverted & Epicyclic Gear Trains	No	**Traditional Teaching Method Used:** Conceptual explanation with numerical problem-solving.	**0 hrs**
Unit V Cam and Follower (07 hrs)	- Types of Cams & Followers - Cam Displacement Diagrams: Uniform Velocity,	Yes	**Concrete Experience:** Cam profile design & 3D modeling exercises. **Active Experimentation:** Motion simulation of followers using MATLAB &	**3 hrs**

	SHM, UARM, Cycloid Motion	AutoCAD.	
	- Cam Profile Construction (Knife-Edge & Roller Follower) - Cam Jump Phenomenon		
Summary	**KELT was implemented in:** Units I, II, III, and V. **Traditional methods used in:** Unit IV.	**Impact:** Enhanced student engagement and understanding through hands-on learning, simulations, and real-world applications.	**Total: 12 hrs**

Since KELT activities require additional engagement time, their implementation must be strategically planned to balance experiential learning with syllabus completion. To ensure effective integration without exceeding the allocated course hours, KELT was incorporated into Units I, II, III, and V, while Unit IV followed a traditional lecture-based approach. The implementation was distributed across the semester in a phased manner. In Weeks 1-2, students engaged in hands-on model-making for Slider-Crank and Four-Bar mechanisms under Unit I, providing a concrete experience that helped them visualize kinematic motions. This activity replaced passive lectures and accounted for 3 hours of KELT. In Weeks 3-4, Unit II introduced MATLAB/GeoGebra simulations to analyze the velocity and acceleration of planar mechanisms. This phase emphasized active experimentation, allowing students to comprehend complex motion dynamics interactively within the allocated 3 hours. Weeks 5-6 focused on Unit III, where students applied experiential learning through a Green Gym Mechanism project, integrating motion-based mechanical system design. This hands-on approach enhanced students' synthesis skills, allocating 3 more KELT hours. Since Unit IV on gears and gear trains required rigorous numerical problem-solving, it was delivered using a traditional lecture-based method in Weeks 7-8, ensuring that theoretical understanding was not compromised. In Weeks 9-10, Unit V introduced cam profile design and motion simulation using MATLAB & AutoCAD, reinforcing concrete experience and active experimentation for another 3 KELT hours. The final Weeks 11-12 were dedicated to oral and written assessments, reinforcing KELT-based learning through reflection and exam preparedness. This structured approach allowed KELT to be implemented across four key units, totaling 12 hours, without exceeding course time. KELT was carefully integrated into lab hours and lecture sessions, replacing passive teaching with engaging activities. By doing so, students demonstrated improved scores in oral exams and end-sem assessments, as experiential learning strengthened their conceptual understanding, application skills, and problem-solving abilities. The blended KELT-traditional methodology ensured maximum PO attainment, making learning more effective and engaging.

1) Step 1: Concrete Experience

In the first stage of Kolb's cycle, students engage in concrete experiences. For teaching the Theory of Machines, this begins with hands-on projects that include building models of various mechanical mechanisms. For instance, students are tasked with designing and constructing models of different mechanisms such as the Oldham coupling, crank and slotted mechanism, Scotch yoke, Geneva drive, slider-crank mechanism, and crank-rocker mechanism. This variety allows students to explore fundamental concepts in machine design and operation.



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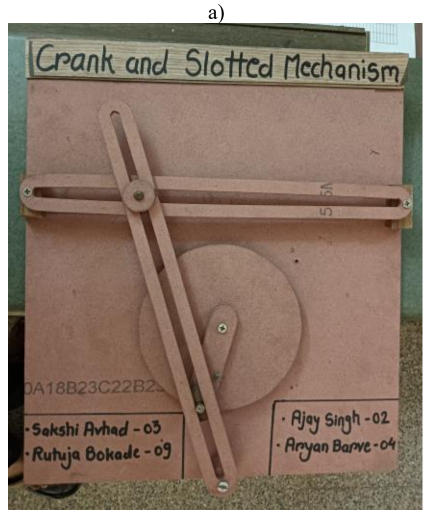

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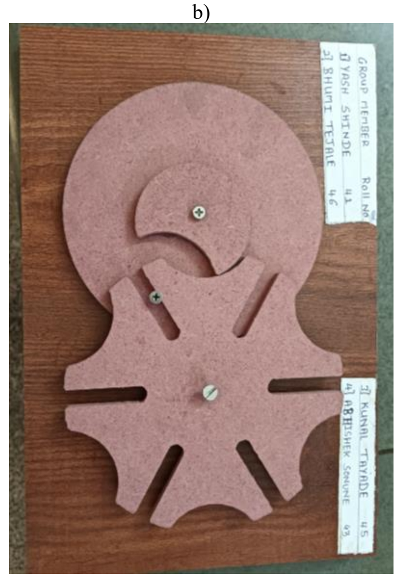

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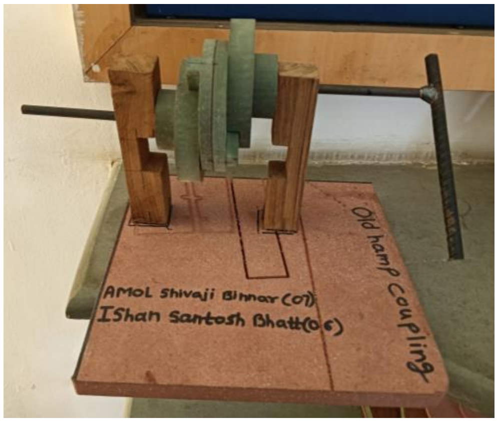

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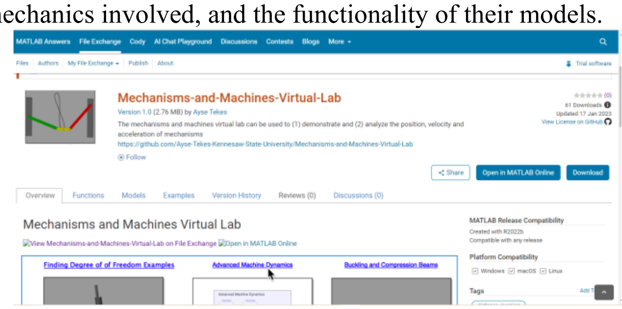
Fig. 2 Mechanisms prepared by students a) Scotch yoke, b) Crank and Slotted Mechanism, c) Geneva and d) Oldham coupling

Figure 2 presents the mechanisms prepared by the students, showcasing a variety of mechanical systems including a) Scotch Yoke, b) Crank and Slotted Mechanism, c) Geneva Mechanism, and d) Oldham Coupling. These mechanisms illustrate practical applications of theoretical concepts, providing hands-on experience in mechanical engineering principles. In addition, students are specifically asked to prepare a model of a green gym mechanism, an environmentally friendly exercise equipment system that incorporates some of these mechanical principles. This initial engagement not only encourages students to apply theoretical knowledge in practical scenarios but also promotes collaboration, as they work in groups of three. This group setting fosters teamwork and collective problem-solving, enabling students to learn from each other's insights and experiences while constructing their models.

2) Step 2: Reflective Observation

After constructing their models, students participate in reflective observation. This phase involves engaging in group discussions where they analyze their experiences, focusing on what worked well, what didn't, and the challenges they faced during the building process. Instructors play a crucial role in facilitating these discussions, guiding students to articulate their thoughts and feelings about the construction process, the mechanics involved, and the functionality of their models.



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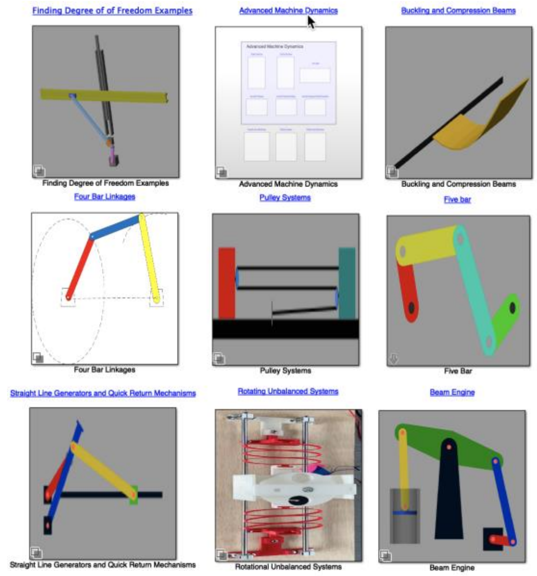

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Fig. 3 MATLAB simulation a) using web portal and b) using Math works website

Figure 3 shows the MATLAB simulation methods, illustrating a) using the web portal and b) using the MathWorks website.

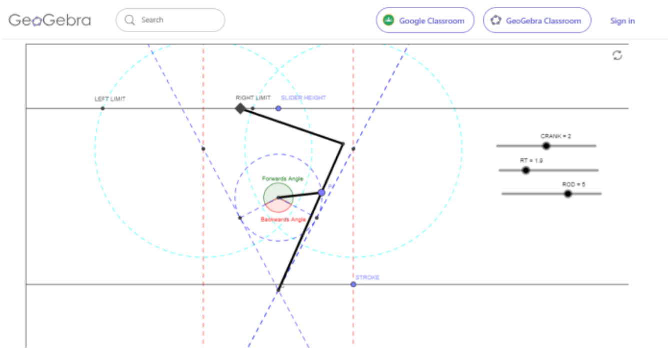
Using MATLAB simulation helped students in the Reflective Observation stage of KELT by allowing them to visualize and analyze how the Green Gym Mechanism works before building it. After designing the mechanism (Concrete Experience), they used MATLAB to simulate the movement of lever arms, force distribution, and resistance effects, helping them think critically about their design choices.

Through these kinematic and dynamic simulations, students understood how pivot points, counterweights, and friction affected the machine's function. They saw how changes in lever length, user weight, and applied force influenced exercises like chest presses and shoulder presses. This helped them spot issues, improve efficiency, and refine the design before making a physical model.

The simulation results gave them clear data to better understand torque, velocity, and force distribution in real-world conditions. This made their grasp of Theory of Machines (TOM) stronger by connecting theory with practical application. By testing and improving their design in MATLAB, students bridged the gap between learning and real-world engineering, enhancing their understanding of the Green Gym Mechanism.

Step 3: Abstract Conceptualization

Following the reflective observation phase, students move to the abstract conceptualization phase, where they integrate their hands-on experiences with theoretical knowledge. In this stage, they utilize GeoGebra software for simulation, allowing them to visualize and manipulate the mechanics of the mechanisms they've built. By simulating various parameters—such as force, torque, and angular velocity—students gain a deeper understanding of the theoretical concepts behind kinematics and dynamics.



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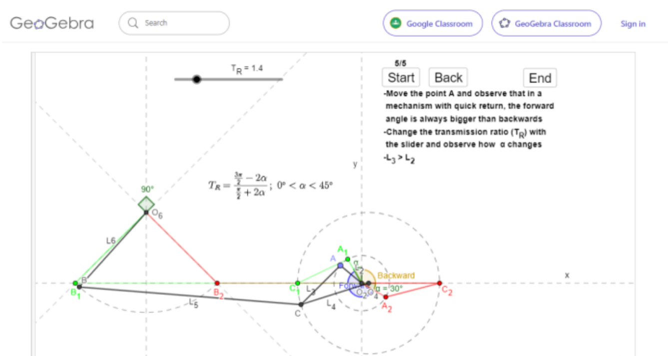


b)

Fig. 4 GeoGebra Simulations a) sample Mechanism prepared by students group A and b) a) sample Mechanism prepared by students group B

Figure 4 illustrates GeoGebra simulations, showcasing a) a sample mechanism prepared by students from group A and B) a sample mechanism prepared by students from group B.

To map PO9 (Individual and Team Work), students are divided into groups labeled A to Z, with each group consisting of a maximum of four students. Within these teams, students collaboratively design and develop the Mechanism, applying concepts from TOM while distributing tasks based on individual strengths. This approach fosters team coordination, problem-solving, and leadership skills, allowing students to experience both independent contributions and collective decision-making. By working in teams, students enhance their ability to function effectively in multidisciplinary environments, aligning with the PO9 outcome of developing teamwork and individual responsibility in engineering projects. In paper sample analysis of group A and B is shown as a case study

These simulations demonstrate the application of GeoGebra in modeling mechanical systems, providing a visual aid to enhance students' understanding of complex mechanisms. The interactive nature of GeoGebra enhances students' ability to experiment with different scenarios, encouraging them to hypothesize outcomes based on their adjustments. Additionally, the integration of virtual labs, animations, and instructional videos provides critical visual representations of complex concepts. These resources offer dynamic explanations of mechanical principles, helping students solidify their understanding and encouraging them to make connections between their practical work and the underlying theoretical frameworks. This phase fosters a richer learning experience, empowering students to conceptualize abstract ideas and apply them to real-world mechanical systems.

3) Step 4: Active Experimentation

In the final step, students engage in active experimentation, applying their newly acquired knowledge to solve real-life problems and refine their designs based on insights gained from simulations and discussions. This phase emphasizes the practical application of concepts learned throughout the course. To assess their understanding of the material, students participate in pre-tests and post-tests that evaluate their comprehension before and after the experiential learning activities. These assessments serve as benchmarks, enabling students to quantify their learning progress and reflect on their improvement.

a)

b)

Fig. 5 Mini Project a) Green gym model and b) Chest press Machine model for actual gym

Figure 5 presents mini projects created by students, depicting a) a Green Gym model and b) a Chest Press Machine model for an actual gym.

The Green Gym Mechanism for chest and shoulder workouts operates using a lever-based resistance system, incorporating pivoted arms, counterweights, and friction-controlled linkages to create a self-weight-driven workout. Designed for outdoor, energy-free fitness, the machine consists of a sturdy metal frame with adjustable levers that allow users to perform movements similar to bench presses, dips, shoulder presses, and lateral raises without external weights. The seated chest press mechanism uses a push-forward lever system, where the resistance is generated by the user's own body weight, simulating a bench press motion and engaging the pectoral, triceps, and shoulder muscles. For shoulder workouts, an overhead press system allows users to push against a pivoted handle that provides progressive resistance, mimicking the mechanics of a dumbbell shoulder press. Additionally, suspended lateral raise handles offer a smooth range of motion, utilizing friction-based resistance to engage the deltoids and trapezius muscles. The machine allows for adjustable resistance by modifying lever positions or user posture, ensuring suitability for different fitness levels. Built-in shock absorbers and controlled motion linkages enhance safety, preventing sudden jerks or strain. This innovative, self-powered gym system integrates engineering principles with experiential learning, enabling students to apply TOM concepts in designing a sustainable, interactive fitness solution.

These projects demonstrate the practical application of engineering concepts, showcasing the students' ability to design and prototype functional exercise equipment. Furthermore, students embark on group-wise mini-projects, where they are tasked with designing new green gym mechanisms. This encourages them to innovate and create designs with increased accuracy and functionality, building upon the principles they have learned. The prototype-building aspect allows students to iterate on their designs based on peer and instructor feedback, fostering a culture of continuous improvement. This hands-on approach not only reinforces their understanding of theoretical concepts but also empowers students to tackle real-world challenges, ultimately enhancing their skills in design, collaboration, and problem-solving.

III. Results and Discussion

A. Result Analysis

The comparative analysis of assessment scores between the previous batch (without Kolb's theory) and the current batch (with Kolb's theory) reveals a marked improvement in student performance across all evaluation metrics. In the pre-test phase, students in the current batch exhibited higher scores, with a 25th percentile of 9.00 compared to 7.00 for the previous batch, indicating a stronger foundational knowledge. The median pre-test score for the current batch was 12.0, surpassing the previous batch's median of 10.0, while the 75th percentile increased from 12.0 to 13.0. This trend of improvement becomes even more pronounced in the post-test results, where the current batch achieved a 25th percentile score of 15.00, significantly higher than the 9.00 of the previous batch.

Table II
Result analysis of Previous Batch

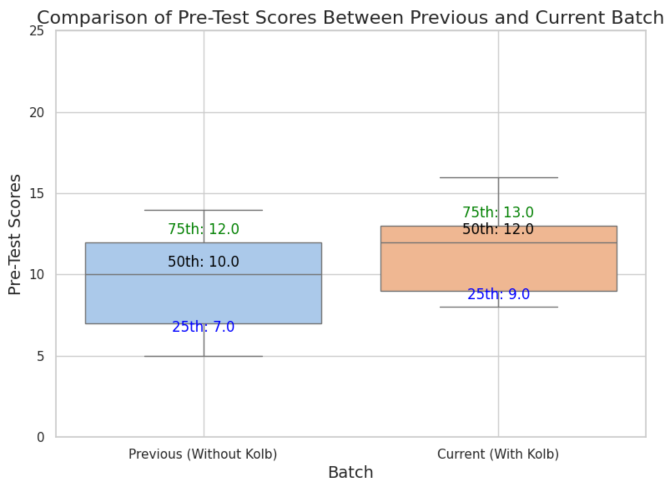
Parameter	Pre Test	Post Test	Oral Marks	End Semester Marks
Count	140.000	140.000	140.000	140.000
Mean	9.757	11.736	14.443	62.871
Std	2.831	3.034	2.927	12.132
Min	5.000	6.000	10.000	40.000
25%	7.000	9.000	12.000	51.750
50%	10.000	12.000	14.500	63.000
75%	12.000	14.000	17.000	74.000
Max	14.000	17.000	19.000	84.000

Table III
Result analysis of Current Batch

Parameter	Pre Test	Post Test	Oral Marks	End Semester Marks
Count	150.000	150.000	150.000	150.000
Mean	11.647	16.887	19.400	80.787
Std	2.573	2.518	2.795	11.749
Min	8.000	12.000	15.000	60.000
25%	9.000	15.000	17.000	70.000
50%	12.000	17.000	19.000	83.000
75%	13.000	19.000	22.000	90.000
Max	16.000	20.000	24.000	99.000

Tables II and III present the result analyses of the previous and current batches, respectively. Table II shows the performance metrics of the previous batch, including pre-test, post-test, oral marks, and end-semester marks, while Table III outlines the same parameters for the current batch.

The Current Batch has shown notable improvements compared to the Previous Batch across all stages of assessment. In the Pre-Test, the Current Batch achieved a 1.89-point higher mean score (11.647) than the Previous Batch (9.757). Moving to the Post-Test, the Current Batch showed a significant 5.15-point improvement (16.887) over the Previous Batch (11.736). In the Oral Marks, the Current Batch outperformed the Previous Batch by 4.96 points, with a mean score of 19.400 compared to 14.443. The most significant improvement was seen in the End Semester Marks, where the Current Batch scored 17.92 points higher, with a mean of 80.787 compared to 62.871 in the Previous Batch. Overall, the Current Batch demonstrated consistent and substantial improvements at each stage, reflecting better performance and progress throughout the course.



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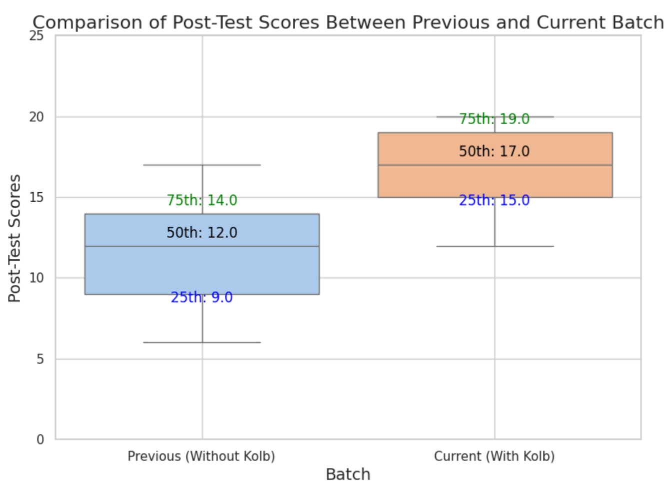

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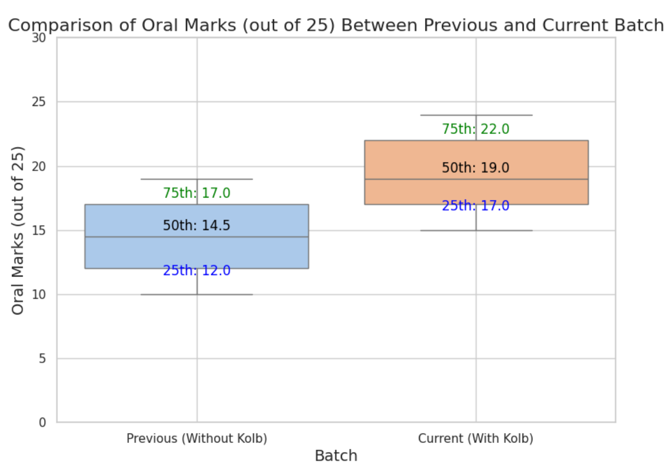

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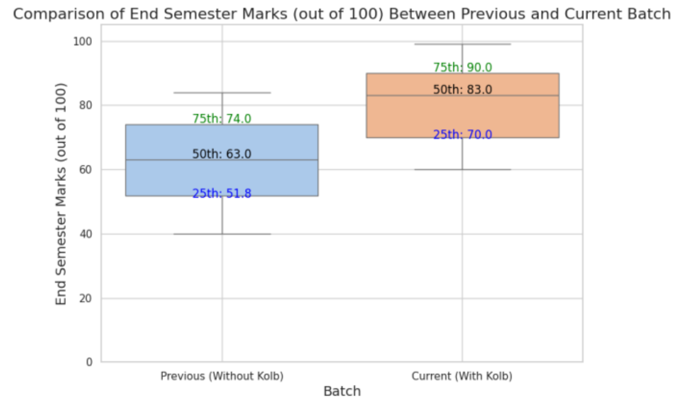

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Fig. 6 Comparison of a) Pre Test, b)Post Test, c) Oral Marks and d) End semester Marks of previous and current batch

Figure 6 illustrates the comparison of academic performance between the previous and current batches, detailing a) Pre-Test, b) Post-Test, c) Oral Marks, and d) End Semester Marks. The median post-test score for the current batch reached 17.0, up from 12.0, and the 75th percentile jumped from 14.0 to 19.0, suggesting that the implementation of Kolb's experiential learning approach effectively enhanced student understanding and retention of the material. Furthermore, oral assessment scores reflected similar advancements; the current batch's 25th percentile oral marks of 17.00 and median score of 19.0 contrasted sharply with the previous batch's 12.00 and 14.5, respectively. Finally, the end-semester examination results underscored these findings, with the current batch achieving a 25th percentile of 70.00, compared to 51.75 for the previous batch. The median score increased to 83.0 from 63.0, and the 75th percentile escalated to 90.0 from 74.0. Collectively, these results affirm the efficacy of Kolb's experiential learning theory in fostering deeper engagement, comprehension, and application of knowledge, ultimately leading to improved academic outcomes among students.

The current batch has shown a noticeable improvement in all areas (pre-test, post-test, oral marks, and end-semester marks) compared to the previous batch. The higher mean scores across all assessments suggest better preparedness, stronger learning outcomes, and possibly more effective teaching or curriculum delivery. Additionally, the narrower standard deviations in the current batch for most parameters suggest more consistent performance among students, indicating that fewer students are lagging behind. The significant improvements, particularly in the post-test and end-semester scores, reflect a positive trend in academic performance for the current batch.

B. Feedback Analysis

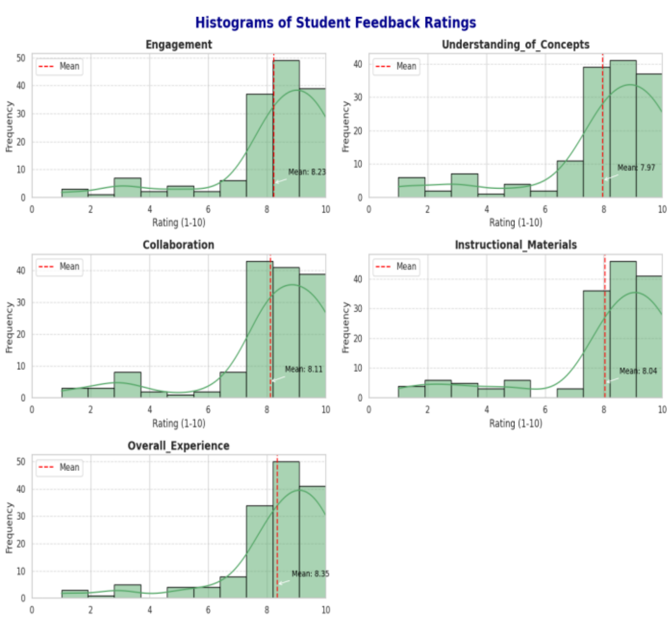
The feedback gathered from students provides valuable insights into their experiences across various categories, reflecting the overall effectiveness of the educational methodologies employed. The feedback for this study was collected digitally using a Google Form, which was distributed to the students at the end of the Theory of Machines (TOM) course. This digital method allowed easy access and convenience for all 149 students to participate in the feedback process.

The questionnaire focused on five main categories: Engagement, Understanding of Concepts, Collaboration, Instructional Materials, and Overall Experience. Each category was assessed using a 1 to 5 scale, where 1 represented Poor and 5 represented Excellent. This scale provided students with a straightforward way to rate their experiences and offer insights into different aspects of the course.

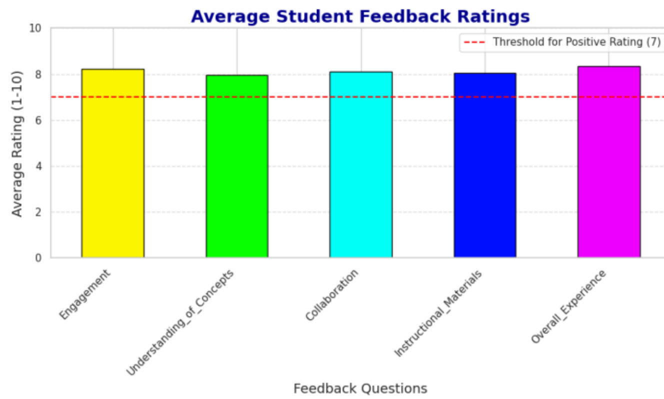
The mean scores across the different feedback categories suggest a generally positive perception among students. Notably, Engagement received a mean score of 8.23, indicating that students felt actively involved in the learning process. Similarly, the Overall Experience category, with a mean of 8.35, underscores a favorable reception towards the educational environment and instructional methods utilized. Table IV presents the feedback analysis, summarizing the responses gathered from 149 students regarding their experiences and perceptions of the course.

TABLE IV
FEEDBACK ANALYSIS

Feedback Category	Mean	Standard Deviation
Engagement	8.2333	2.0674
Understanding of Concepts	7.9667	2.3183
Collaboration	8.1133	2.1784
Instructional Materials	8.0400	2.3909
Overall Experience	8.3467	1.9455



a)



b)

Fig. 7 Feedback Analysis a) Question wise histogram distribution and b) Question wise Bar chart

Figure 7 illustrates the feedback analysis, showcasing a) the question-wise histogram distribution and b) the question-wise bar chart. The Understanding of Concepts category, while slightly lower at a mean of 7.97, still reflects a commendable level of comprehension among students, suggesting that the teaching strategies implemented successfully conveyed the necessary material. Collaboration and Instructional Materials also received positive ratings, with means of 8.11 and 8.04**,** respectively. This indicates that students valued collaborative opportunities and the resources provided to facilitate their learning.

Standard deviations across the categories reveal variability in student feedback, with Understanding of Concepts having the highest standard deviation (2.32), which may suggest differing levels of comprehension among students. In contrast, the Overall Experience had the lowest standard deviation **(**1.95**),** indicating a more consistent level of satisfaction. Overall, the data suggest that while students generally had a positive learning experience, there remains an opportunity for targeted improvements, particularly in enhancing conceptual understanding through refined instructional strategies.

TABLE V
PROGRAM OUTCOMES OF PREVIOUS AND CURRENT BATCH

PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
Previous Batch	1.5	1.5	1	1	0.5			1	1			0.48
Current Batch	2	2	1.3	1.3	0.7			1.3	1.3			0.67

The attainment levels for each Program Outcome (PO) in Table V were determined based on a structured assessment process defined in the Course Information Sheet (CIS). This process integrates Kolb's Experiential Learning Theory (KELT) to enhance student engagement, conceptual understanding, and application-oriented learning. The assessment framework consists of both internal and external evaluation methods. Internal assessments, such as tutorials, pre-semester exams, and oral examinations, help students develop a deeper understanding through structured reflection and active engagement, aligning with Kolb's Reflective Observation and Concrete Experience stages. Meanwhile, external assessments, including in-semester and end-semester exams, evaluate students' ability to synthesize and apply knowledge, corresponding to Kolb's Abstract Conceptualization and Active Experimentation stages.

To determine Course Outcome (CO) attainment, a weighted formula was applied: (0.8 × External Attainment) + (0.2 × Internal Attainment), ensuring a balance between theoretical knowledge and practical application. Once the CO attainments were computed, they were mapped to specific POs as per the predefined mappings in the CIS. The PO attainment was then calculated by averaging the CO attainment levels associated with each PO. For example, if a particular PO was linked to three COs with attainments of 2.0, 2.3, and 1.7, the PO attainment was determined as (2.0 + 2.3 + 1.7) / 3 = 2.

A comparison between the previous and current batch shows a significant improvement in PO attainment levels, indicating the positive impact of experiential learning. For instance, PO1 and PO2 increased from 1.5 to 2.0 (33.3% improvement), PO3 and PO4 improved by 30%, and PO5 saw a 40% increase. These improvements can be attributed to active learning strategies such as tutorials and oral examinations, structured reflection through pre-semester evaluations, and hands-on problem-solving in real-world contexts. The use of KELT in assessment design has facilitated better student engagement, deeper conceptual understanding, and enhanced application-based learning; ultimately leading to improved attainment levels across multiple POs. Table VI shows the Impact of KELT implementation.

TABLE VI
IMPACT OF KELT IMPLEMENTATION

Aspect	Before KELT Implementation	After KELT Implementation	Impact on Student Scores
Conceptual Understanding	Students relied on rote learning and struggled with visualization of mechanisms.	Hands-on model-making, simulations, and real-world applications helped students develop deep conceptual clarity.	Better written explanations and structured answers in exams led to higher scores.
Numerical Problem Solving	Students found velocity & acceleration analysis difficult due to a lack of visualization.	Graphical methods & MATLAB simulations allowed students to see real-time changes in velocity & acceleration.	Improved accuracy & speed in solving numerical problems, increasing overall marks.
Oral Exams (Viva Performance)	Lack of confidence in verbal explanation and difficulty in justifying answers.	Hands-on learning & practical exposure to mechanisms enhanced their ability to describe concepts logically.	Higher scores in viva due to improved articulation & confidence.
Application-Based Questions	Struggled to relate theoretical knowledge to real-world applications.	Exposure to gear systems, cam motion, and real-world examples (bicycles, industrial machines, automotive mechanisms, etc.) improved their ability to apply concepts.	Improved scores in design and synthesis-related questions.
Diagram & Graphical Representation	Poor sketching skills and lack of clarity in cam profile construction, velocity diagrams, etc.	Cam profile design using MATLAB & AutoCAD enhanced precision in sketching.	Better scores in descriptive & graphical questions.

C. Limitations and future scope

Using Kolb's Experiential Learning Theory to teach the Theory of Machines has some limitations. These include having a small and varied group of students, relying mostly on numbers for assessment, differences in how teachers apply the methods, and time restrictions in traditional classes. For future research, it's important to conduct long-term studies to see how effective this approach is over time, several strategies can be implemented. Diverse student enrollment can be encouraged through collaborations with universities, technical colleges, and online platforms. Flexible teaching methods should cater to different learning styles using videos, simulations, and hands-on experiments. Simulation based learning enhance accessibility, allowing students from various locations to participate. Interdisciplinary exposure through industry collaborations and open elective courses can further enrich learning. Hybrid models combining online and in-person activities ensure inclusivity, while group projects and mentoring programs help integrate students from varied social and academic backgrounds. These approaches make KELT more effective and adaptable for diverse learners.

CONCLUSION

In conclusion, the integration of Kolb's Experiential Learning Theory (KELT) in teaching the Theory of Machines has led to a significant improvement in student performance and engagement. The current batch outperformed the previous one across all assessment metrics, demonstrating higher scores in pre-tests, post-tests, oral exams, and end-semester evaluations. This underscores the effectiveness of experiential learning in strengthening conceptual understanding, problem-solving abilities, and knowledge retention.

Student feedback reflects high engagement levels and a positive learning experience, reinforcing the impact of hands-on activities, simulations, and real-world applications. However, further refinement is needed to enhance conceptual clarity and cater to diverse learning styles. Future research should focus on integrating technology, personalizing learning strategies, and addressing varied student backgrounds to maximize the benefits of experiential learning and better equip students for their engineering careers.

References

Bagweneza, V., Anita, C., Nsanzamahoro, I., Mukanoheli, V., Bahaya, F., Niyitegeka, P., Kabanyana, P., Mwiseneza, M. J., Gaterega, T., Kura, A., Twahirwa, C., & Munezero, M. (2021). Analysis of Clinical Experience Using Kolb's Experiential Learning Theory: Postgraduate Medical Surgical Nursing Track Students in Selected Sub-Specialties at the University Teaching Hospital of Kigali, Rwanda. *Rwanda Journal of Medicine and Health Sciences*, *4*(3). https://doi.org/10.4314/rjmhs.v4i3.13

Chen, L., Jiang, W. J., & Zhao, R. P. (2022). Application effect of Kolb's experiential learning theory in clinical nursing teaching of traditional Chinese medicine. *Digital Health*, *8*. https://doi.org/10.1177/20552076221138313

Devi, M. K. K., & Thendral, M. S. (2023a). Using Kolb's Experiential Learning Theory to Improve Student Learning in Theory Course. *Journal of Engineering Education Transformations*, *37*(1). https://doi.org/10.16920/jeet/2023/v37i1/23133

Devi, M. K. K., & Thendral, M. S. (2023b). Using Kolb's Experiential Learning Theory to Improve Student Learning in Theory Course. *Journal of Engineering Education Transformations*, *37*(1), 70–81. https://doi.org/10.16920/jeet/2023/v37i1/23133

Govender, R. G., & Govender, D. W. (2023). Using Robotics in the Learning of Computer Programming: Student Experiences Based on Experiential Learning Cycles. *Education Sciences*, *13*(3). https://doi.org/10.3390/educsci13030322

Haritha, D. G., & Rao, D. R. (2024). A Holistic Approach to Professional Development: Integrating Kolb's Experiential Learning Theory for Soft Skills Mastery. *Journal of Engineering Education Transformations*, *37*(IS2), 415–424. https://doi.org/10.16920/jeet/2024/v37is2/24069

Healey, M., & Jenkins, A. (2000). Kolb's experiential learning theory and its application in geography in higher education. *Journal of Geography*, *99*(5). https://doi.org/10.1080/00221340008978967

Helate, T. H., Metaferia, T. F., & Gezahegn, T. H. (2022). English language teachers' engagement in and preference for experiential learning for professional development. *Heliyon*, *8*(10). https://doi.org/10.1016/j.heliyon.2022.e10900

Hulaikah, M., Degeng, I. N. S., Sulton, & Murwani, F. D. (2020). The effect of experiential learning and adversity quotient on problem solving ability. *International Journal of Instruction*, *13*(1). https://doi.org/10.29333/iji.2020.13156a

Hung, L. Y., Wang, S. M., & Yeh, T. K. (2023). Kolb's experiential learning theory and marine debris education: Effects of different stages on learning. *Marine Pollution Bulletin*, *191*. https://doi.org/10.1016/j.marpolbul.2023.114933

Liu, P., Yang, Z., Huang, J., & Wang, T. K. (2024). The effect of augmented reality applied to learning process with different learning styles in structural engineering education. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-06-2023-0596

Mahmood, A., Hashim, H. N. M., & Zakuan, Z. Z. A. (2024). Utilizing Experiential Learning Methods to Teach Substantive Law Courses to Undergraduate Students. *Asian Journal of Legal Education*, *11*(1). https://doi.org/10.1177/23220058231175984

Meany, B., Fenn, J., Rescober, S., Narang, K., & Dhanda, J. (2024). Communication in virtual reality as applied to medical education. *Arts & Humanities Open Access Journal*, *6*(1). https://doi.org/10.15406/ahoaj.2024.06.00222

Mehta, D. M., & Mehta, N. (2023). Impact of Experiential Learning on Learning Outcomes Among Engineering Students Based on Kolb's Model: A Netnography Study. *Journal of Engineering Education Transformations*, *37*(2), 51–59. https://doi.org/10.16920/jeet/2023/v37i2/23149

Morris, T. H. (2020). Experiential learning–a systematic review and revision of Kolb's model. In *Interactive Learning Environments* (Vol. 28, Issue 8). https://doi.org/10.1080/10494820.2019.1570279

Pherson-Geyser, G. M., Villiers, R. de, & Kavai, P. (2020). The use of experiential learning as a teaching strategy in life sciences. *International Journal of Instruction*, *13*(3). https://doi.org/10.29333/iji.2020.13358a

Sato, T., & Laughlin, D. D. (2018). Integrating Kolb's Experiential Learning Theory into a sport psychology classroom using a golf-putting activity. *Journal of Sport Psychology in Action*, *9*(1). https://doi.org/10.1080/21520704.2017.1325807