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Integrating Real-World Applications into the Machine Design Course through an Open-Ended Assignment – A Case Study

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***Abstract*—This paper presents a case study in engineering education, focusing on enhancing conceptual understanding, real-world application, comprehension, teamwork, self-directed learning, and familiarity with design codes and standards. The study involves student analysis of artifact safety and optimization, engaging them in practical problem-solving. The outlined methodology covers artifact selection, analysis, and assessment of the assignment's impact. The findings exhibit improvements in knowledge acquisition, real-world relevance, teamwork, and self-learning. Moreover, the study highlights the assignment's enhanced appeal and challenge compared to conventional assignments. Students express a preference for more such assignments over routine ones. The paper underscores experiential learning's significance in cultivating critical skills for modern engineering and advocates integrating practical applications into curricula for holistic skill development.**

***Keywords*—Conceptual Understanding; Experiential Learning; Engineering Education; Real-World Applications; Open-Ended Assignments; Assignment Impact.**

***JEET Category*—Research Paper.**

I. INTRODUCTION

Engineering education has undergone a paradigm shift, moving beyond traditional classroom instruction to embrace experiential learning as a cornerstone of pedagogy. Experiential learning, rooted in the philosophy that practical application enhances understanding, equips students with the skills needed for modern engineering practice. By immersing students in real-world scenarios, experiential learning bridges the gap between theory and practice, fostering critical thinking, problem-solving, and a deeper comprehension of engineering concepts. An example of this is the EPICS program, which stands for "Engineering Projects in Community Service,". This is a widely recognized and respected initiative in engineering education. As demonstrated in the EPICS program, to the broader topic of this paper, which focuses on real-world applications in engineering education, emphasizes the tangible benefits that students gain when applying their knowledge and skills to address real-world challenges. Furthermore, universities can leverage such experiential learning opportunities to engage students with diverse problem-solving approaches in the context of practical, real-world applications (Benning et al., 2022). Austin & Rust (2015) offers valuable theoretical evidence regarding the significance of experiential learning, benefiting both students and faculty. Moreover, it outlines a systematic process for establishing a comprehensive experiential learning program on a university campus. The literature review in this paper by Austin & Rust (2015) provides crucial support for the pedagogical technique of experiential learning. It not only underscores the educational advantages but also contributes insights into the evolution of the definition and conceptualization of experiential learning over time.

Integrating real-world applications into engineering curricula offers students the opportunity to bridge the gap between theoretical knowledge and its practical implications (Hanh &

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Hop, 2017). This approach aligns with the broader goals of modern engineering education, which seeks to prepare students for the challenges of real-world engineering practice. The notion of safety and optimization in engineering design is a pivotal consideration in engineering education. Gunasekera et al. (2019) emphasizes the significance of incorporating safety engineering design courses to instill an awareness of safety regulations and principles. This integration empowers students to make informed design decisions that prioritize user safety. Gelder et al., (2021) further underscore the importance of integrating safety considerations into engineering design for more responsible solutions.

The paper by Rahim et al. (2020) highlights the importance of materials selection in engineering design, shedding light on how materials impact performance, manufacturability, and overall design feasibility. Henriksson (2021) extends this discussion by exploring the role of design projects in manufacturing, illustrating the practical implications of materials selection and manufacturing methods on product outcomes.

Design analysis and evaluation play a critical role in engineering practice. Newton et al., (2018) presents a new mode of teaching engineering graphics that integrated industrial design principles into the Mechanical Engineering curriculum. Chehade and Smaili (2021) present the integration of project-based learning model in incorporating mechatronics into the mechanical engineering curriculum, underscoring the value of hands-on projects in enhancing design analysis skills. Furthermore, considerations related to installation and maintenance are critical in ensuring the usability and longevity of engineering artifacts. Gadola and Chindamo (2019) present the benefits of experiential learning in engineering, particularly through student design competitions such as Motostudent. These competitions encapsulate the core elements of experiential learning, making them an ideal platform for applying innovative teaching methods in engineering education. In this context, the current paper gains significance. It addresses the need to further explore and understand the pedagogical advantages of experiential learning, especially when integrated into engineering education. By examining real-world applications and open-ended assignments, the current paper seeks to enhance the learning outcomes of students in the machine design course. This study is expected to lead towards a structured approach for educators to harness the potential of experiential learning in engineering curricula, allowing students to benefit from hands-on, emotionally engaging, and reflective learning experiences.

The primary objective of this study is to present a case study where students delve into the intricacies of engineering design through hands-on experience. The study centers on the analysis of existing engineering artifacts, culminating in recommendations for enhancing safety, optimizing design parameters, and ensuring practical viability. Beyond this, the study seeks to investigate the broader impacts of experiential learning. Specifically, it aims to evaluate how this pedagogical approach enhances conceptual knowledge, deepens understanding of real-world applications, fosters teamwork skills, encourages self-directed learning, and cultivates familiarity with design codes and standards. Feedback from the participants serves as a valuable compass in this study. By soliciting responses to specific criteria, such as increased conceptual knowledge, improved teamwork skills, and better understanding of design codes and standards, this study aims to quantitatively measure the efficacy of experiential learning and its resonance with students. The feedback will further illuminate whether experiential learning through the analysis of engineering artifacts surpasses traditional methods in terms of engagement, learning outcomes, and skill development.

Incorporating these findings, the present study presents a comprehensive case study where students engage in experiential learning through analyzing real-world artifacts for safety, optimization, and practical considerations. This approach aims to equip students with a holistic understanding of engineering design principles and their application, while also fostering teamwork, self-directed learning, and familiarity with industry standards.

II. Research questions and hypotheses

Incorporating experiential learning into engineering education has become a cornerstone in fostering a dynamic and practical approach to skill development and knowledge acquisition. In light of this pedagogical landscape, the present study aims to investigate the synergistic impact of experiential learning and open-ended assignments on students' understanding, skill development, and engagement in the realm of engineering education. Therefore, the research questions developed for this study are listed below.

1. Does combining experiential learning through open-ended tasks with the analysis of real-world artifacts boost students' grasp of engineering principles and their real-world relevance?
2. To what degree does experiential learning via open-ended assignments enhance students' teamwork, self-directed learning, and knowledge of engineering design standards?
3. How do students perceive variations in engagement, learning outcomes, and skill development between open-ended assignments centered on real-world artifacts and traditional classroom tasks?

As education adapts to meet the demands of a rapidly evolving world, the integration of experiential learning and open-ended assignments has gained prominence as a transformative approach in engineering education. These pedagogical strategies transcend conventional classroom boundaries, fostering a deep understanding of theoretical concepts and practical applications. In the specific context of this study, we delve into the dynamics of experiential learning through open-ended assignments and its potential impact on students' conceptual understanding, skills enhancement, and engagement within the realm of engineering education. Building upon this exploration, the study proposes hypotheses that illuminate the anticipated outcomes of this integrative approach. The three hypotheses' statements are listed below.

1. Experiential learning involving open-ended assignments and the analysis of real-world artifacts will lead to a

significant improvement in students' conceptual understanding of engineering principles compared to traditional classroom instruction.

2. Participation in experiential learning assignments, particularly open-ended ones, will result in a measurable enhancement in students' teamwork skills, self-directed learning capabilities, and familiarity with engineering design codes and standards.
3. Students' perceptions of interest, challenge, and overall learning outcomes will be significantly more favorable for open-ended assignments centered on real-world artifact analysis than for conventional classroom-based assignments.

III. Details of the Open-Ended Assignment

In this section, the practical implementation of experiential learning through an Open-Ended Assignment will be explored. This assignment was designed to address Course Outcomes (COs) for the Machine Design course offered in the Fifth Semester of the Mechanical Engineering program.

A. Course Outcomes

The following Course Outcomes were considered for the assignment.

1. CO1: Evaluate an existing loaded machine element for stresses and deformations to identify the factor of safety and suggest minimum dimensions that could further reduce the cost.
2. CO2: Justify the selection of certain machine elements in existing machine designs and suggest possible alternatives based on the principles of machine design.
3. CO3: Demonstrate teamwork skills in projects related to evaluating designs of machine elements.
4. CO4: Develop design analysis reports for effective communication of the evaluations.

The Topic Level Outcome (TLO) associated with the above Course Outcomes deals with the students working on the open-ended assignments in teams and evaluate designs of machine elements.

B. Assignment Overview

The assignment emphasizes the application of theoretical knowledge in real-world contexts. The assignment tasks students with the analysis of an existing engineering design, mirroring the responsibilities of consultants engaged in assessing design safety and optimizing parameters to reduce costs.

C. Assignment Objectives

1) Team Formation

To facilitate collaboration and encourage diverse perspectives, students were tasked with creating teams, each comprising six members. Before forming teams, the process began with the nomination of Team Leaders by the students themselves. Six students volunteered to take on leadership roles, and their nominations received endorsements from a minimum of two students during an open forum discussion. This participatory approach ensured that team leaders were chosen through a collaborative and consensus-driven process.

2) Real-World Artifact Selection

Teams were asked to choose a tangible engineering artifact, preferably a machine component that is exposed to constant and fluctuating loads. This selection process encourages creativity and practicality, mirroring real-world engineering decisions. Photographs of structures and machine components inside the college campus were used as examples in classroom discussions to help the students understand the selection criteria. One such photograph is presented below, as Figure 1, of a supporting beam. The beam analyzed in this study constitutes an integral component of a larger supporting structure designed to provide stability for an extensive roofing system. Classroom sessions dedicated to studying this structure played a pivotal role in reinforcing students' comprehension of fundamental engineering concepts, including loads, stresses, deformations, factor of safety, material selection, and joints. This focused discussion had a dual purpose. Firstly, it aimed to deepen students' understanding of these key engineering principles by applying them to a real-world scenario, thus bridging the gap between theory and practice. Secondly, it encouraged students to identify and critically assess other real-world structures that could undergo similar analytical scrutiny, as a part of the open-ended assignment.

Fig. 1. a) Cantilever beams for structural support of an extended ceiling in the College Campus b) Joint mechanism.

3) Comprehensive Design Analysis

This assignment empowers students to conduct a thorough design analysis that encompasses critical elements. This comprehensive analysis involves evaluating loads, analyzing fluctuation patterns, pinpointing critical sections, conducting stress assessments, interpreting Mohr's Circle, and determining

TABLE I
OPEN ENDED ASSIGNMENT – 1

Course Outcomes (COs) Addressed	18ME52.1, 18ME52.2, 18ME52.5, 18ME52.6
Topic Level Outcome (TLO)	6.1
Assignment Statement	In this Assignment, your team will be responsible for analyzing an existing engineering artifact (design). Imagine you are working for a consulting company that has been hired to determine how safe a particular design is. Your study will determine the factors of safety in the designs and suggest what the minimum values for the design parameters could be to reduce the cost. Design parameters could be: 1. Dimensions of components 2. Materials chosen 3. Ease of Manufacturing 4. Ease of installation and maintenance
Steps involved in completing the Assignment	
Team Formation	Form a team of 6 members. Team Leaders will be chosen in an open-forum in class.
Artifact Selection	Find an engineering artifact (structures, consumer product, fixtures, etc.), in the campus or outside, that is subject to constant and fluctuating loads. Some examples are the awning (canopy, portico) at your apartment, the pedal crank on your bicycle, or the chair you're sitting in. Brainstorm ideas with your teammates. Your idea needs to be approved by the faculty.
Analysis	a. What are the loads? b. How do they fluctuate? c. What are the locations of concern (Critical sections) (pick at least 2)? d. What are the stresses at these locations? e. What does Mohr's Circle look like for at least one of these locations? f. What is the Safety Factor at these locations? Is it being overloaded? g. How small could the artifact be if a Safety Factor of 1 was used? h. Justify the materials used and suggest alternatives? i. What are your opinions on the manufacturing methods used during the fabrication? Could the design be changed for easier manufacturing? j. What modifications will you make in the designs for easier installation and maintenance of the artifact?

safety factors. It serves as an extension of the theoretical groundwork laid in the classroom, providing students with the opportunity to apply their knowledge to real-world engineering applications.

4) Optimization and Cost Reduction

This facet of the assignment compels students to apply their theoretical knowledge in practical scenarios. By dissecting the artifact's design, they are encouraged to critically assess every dimension, material choice, and manufacturing aspect. The aim is not just to propose cost-saving alterations but to do so with a profound understanding of how these modifications might impact the overall safety and performance of the artifact. In essence, this portion of the assignment challenges students to think like engineering consultants tasked with optimizing real-world structures. It bridges the gap between classroom theory and hands-on application, fostering a holistic understanding of how engineering decisions influence both safety and cost in practice.

5) Materials Evaluation

In this section, students are not only prompted to justify the materials employed in the selected artifact but are also encouraged to propose alternative materials. Students are tasked with a dual challenge: firstly, to comprehensively assess why specific materials were chosen for the artifact's construction. This involves understanding the mechanical, thermal, and chemical properties of the materials in relation to the artifact's intended function and environment. Secondly, they are encouraged to critically analyze whether these choices are optimal or if alternative materials could offer advantages in terms of cost, performance, or sustainability.

6) Manufacturing considerations

In this section, students are encouraged to delve into the practical realm of engineering by reflecting on how the chosen artifact is manufactured. Their mission is to not only understand the fabrication methods used but also to explore potential design modifications that could optimize and streamline the manufacturing process. This phase of the assignment challenges students to think like engineers on the shop floor. They must critically assess the current manufacturing methods and identify areas where improvements can be made. This could involve simplifying complex components, reducing the number of intricate machining steps, or rethinking assembly processes for greater efficiency.

7) Installation and Maintenance Enhancement

In this section the teams are entrusted with the responsibility of suggesting design improvements that go beyond initial construction, focusing on making artifact installation and future maintenance more efficient and user-friendly. In this phase, students are challenged to consider the entire lifecycle of the artifact. They must contemplate how ease of installation can impact not only the initial setup but also any future reinstallation or adjustments. Additionally, they are tasked with proposing modifications that simplify maintenance, reducing downtime and long-term operational costs.

D. Communique of the Open-Ended Assignment

The assignment was communicated to the students through the Google Classroom created for the course. The assignment as viewed by the students is presented as Table – 1. The submissions from the students were sought in two stages. In the first submission, students were asked to work and submit the following details.

1. Team Name with names and USNs of students.
2. Name of the machine element identified for the analysis?
3. Provide a simple hand sketch of the machine element?
4. Where is this machine element applied? Describe in detail the function of the machine element?
5. What is the material used to make the machine element?
6. What are the types of loads and their magnitudes acting on the machine element? Justify your answer.
7. What are the minimum and maximum loads acting on the machine element? Justify your answer.

8. Model the machine element in Solidworks and add the different views in the report?

In the second submission, the complete analysis as listed in the Table – 1 was sought. A total duration of 30 days was provided to the students to complete and submit the assignment.

IV. Results and Discussions

The students collaborated in teams for a 30-day period, and made their submissions for the assignments within this timeframe. In this section, the outcomes of their collective efforts are summarized, providing a brief overview of the results achieved. Furthermore, a comprehensive discussion concerning the feedback received from the students as a crucial element of the assignment's evaluation process is presented.

TABLE II
Rubric – I: Initial assessment of the artifact selected for the analysis

Parameter	Description	(10)	(8)	(6)	(4)	(2)
Figure of the Machine Element	Evaluation of the quality and accuracy of the machine element's depiction					
Applications of Machine Element	Assessment of the appropriateness and clarity of the machine element's intended applications					
Identification of the Material used for the machine element	Review of the identification and justification of the materials used					
Identification of Loads and their magnitudes	Evaluation of the identification of applied loads and their magnitudes					
Identification of variation in the load (range)	Assessment of the recognition of load variations, considering both direction and magnitude					
Modeling of the Machine Element	Evaluation of the quality and precision of the modeling of the machine element.					

A. Artifacts Selected

Below, a listing of the artifacts selected for analysis by the six teams is provided:

1) Analysis of a Motorcycle Chain
2) Analysis of a Commercial Vehicle Steering Knuckle
3) Analysis of a L-Clamp
4) Analysis of a Side Stand of a Motorcycle
5) Analysis of an automobile Brake Pedal
6) Analysis of a loaded hook

B. First Submission

Rubrics were developed and used to evaluate the submissions. The rubric used for evaluating the initial submissions along with the parameters being assessed is presented below as Table– II. The average evaluation of the class stood at 47.78 out of the total score of 60. This translates to 79.63% overall score. The summary of the assessment is presented in Figure 2.

For rubric shown in Table-II, the descriptions for the parameters are not included due to space constraints. Each parameter was provided with clear statements corresponding to scores 10 to 2. A sample marks distribution for the first parameter – *Figure of the Machine Element* is given below.

- **10**: A highly detailed and accurate depiction of the machine element. The figure is comprehensive, providing all necessary details with precision and accuracy.
- **8**: A good-quality depiction with minor inaccuracies. The figure is mostly accurate, but there may be some details lacking or imprecise.
- **6**: An adequate depiction but may be incomplete or somewhat inaccurate. The figure may lack certain details or have noticeable inaccuracies.
- **4**: Limited information in the depiction, with several inaccuracies or omissions. The figure does not accurately represent the machine element.
- **2**: Minimal or no information provided in the depiction. The figure lacks the necessary details and does not accurately represent the machine element.

It is observed from the summary that the students find identification of materials, estimating the loads, and determining the variation in loads to be challenging. This challenge likely stemmed from the need to consider various material properties, such as mechanical strength, durability, and cost-effectiveness, and to align them with the specific requirements of the machine element's intended function. Selecting the most suitable material requires a deep understanding of materials science and engineering, making it a complex aspect of the assignment. Another noteworthy challenge encountered by students was the estimation of loads and their magnitudes acting on the machine element. This aspect necessitates a comprehensive understanding of engineering mechanics and the ability to assess the real-world conditions that subject the machine element to varying loads. The task of identifying the variation in loads, considering both their direction and magnitude, also proved to be demanding for students. In lieu of these findings, the teams were supported further in their efforts to perform the analysis.

C. Final Submission

Taking into account the feedback received from the assessment of the first submission, the teams completed the analysis of the artifact and submitted their findings in the form of Submission – 2. The overall submission was evaluated using the rubric presented in Table – III. Each of the parameters are assessed on a scale of 10 as it was used in the Rubric – I. Due to space constraints, the ratings are not shown in Table– III and only the parameters and their descriptions are presented. Each parameter is evaluated on a weighted scale ranging from 10 marks to 2 marks. Similar descriptive statements as illustrated for Initial Assessment Rubric in Table -II, are provided for each parameters of rubric presented in Table – III. The assessment outcomes have unearthed specific areas where students have encountered challenges and would benefit from additional learning interventions. These intricate concepts, which have posed particular difficulties for the students, are thoughtfully identified below:

1. Mohr’s Circle: It becomes evident from the assessment that students achieved an average rating of only 47% in comprehending and applying Mohr's Circle, a fundamental concept in stress analysis. This underscores the need for focused attention and targeted educational support in this area to enhance students' proficiency.
2. Factor of Safety: The assessment also highlights challenges in grasping the concept of Factor of Safety, with students securing ratings of 53% and 40%. Factor of Safety is a pivotal element in engineering design, emphasizing the importance of safety margins. Addressing this concept comprehensively is crucial for students' competence in engineering analysis.
3. Maintenance Aspects: Another area of concern revealed by the assessment is the students' understanding of maintenance aspects, where they secured an average rating of 52%. Given the significance of maintenance considerations in engineering design, addressing this knowledge gap is imperative.

Despite these challenges, the class as a whole achieved an impressive average score of 71.42% in the assessment as shown in Figure 3. This collective achievement demonstrates the potential and dedication of the students. However, recognizing and addressing these specific areas of difficulty will be instrumental in further enhancing their proficiency and ensuring a holistic understanding of machine design principles. A five-point strategy to address the challenges identified in comprehending and applying Mohr's Circle, understanding the Factor of Safety, and grasping maintenance aspects:

TABLE III
RUBRIC – II: FINAL ASSESSMENT OF THE ARTIFACT SELECTED FOR THE ANALYSIS

Parameter	Description
Loads	List the loads that act on the machine element and its maximum values
Variation of Loads	How does the load vary? Consider direction and magnitude
Critical Sections	Identify the critical sections on the machine element. Select at least two sections
Stresses	List and calculate the stresses at these critical locations
Maximum Stresses	Specify the maximum stresses at these locations
Mohr's Circle	For any one of the critical sections, draw the Mohr’s Circle and interpret it
FOS (Factor of Safety)	Calculate the factor of safeties at these two critical locations. Is the design safe?
FOS - 2 (Factor of Safety)	If the Factor of Safety was One, what would have been the dimensions at the critical section?
Materials	Justify the materials used and suggest alternatives
Manufacturing	What are your opinions on the manufacturing methods used during the fabrication? Could the design be changed for easier manufacturing?
Maintenance	What modifications will you make in the designs for easier installation and maintenance of the artifact?

1. Interactive Workshops and Tutorials:

Conduct interactive workshops specifically focusing on Mohr's Circle and Factor of Safety. Utilize visual aids, practical examples, and hands-on exercises to enhance students' comprehension. Implement tutorials that break down complex concepts into step-by-step processes. Provide ample opportunities for students to practice calculations and applications of Mohr's Circle and Factor of Safety in a guided environment.

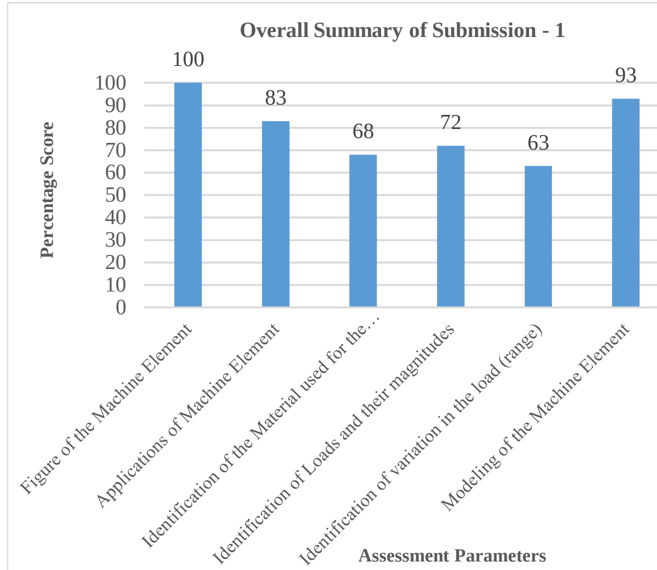

Fig. 2. Summary of assessment for Submission - 1.

2. Simulation Software Integration:

Integrate simulation software tools that allow students to visualize stress analysis concepts, including Mohr's Circle. This hands-on approach can enhance understanding by providing a dynamic, interactive learning experience. Utilize virtual labs and simulation exercises to reinforce the application of the Factor of Safety in various engineering scenarios. Real-world simulations can bridge the gap between theoretical knowledge and practical application.

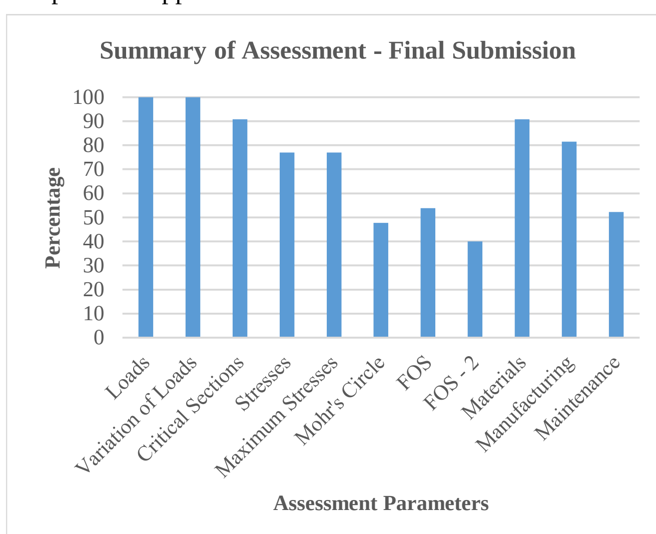

Fig. 3. Summary of Assessment of Final Submission.

3. Case Studies and Practical Examples:

Develop case studies that involve real-world applications of Mohr's Circle and the Factor of Safety. Analyze historical engineering failures and successes to illustrate the practical implications of these concepts. Incorporate maintenance-related case studies to underscore the importance of considering maintenance aspects in the design process. Showcase examples where neglecting maintenance considerations led to engineering challenges.

4. Peer-Assisted Learning:

Facilitate peer-assisted learning sessions where students can collaborate in understanding and solving problems related to Mohr's Circle, Factor of Safety, and maintenance aspects. Assign group projects that require students to collectively apply these concepts to practical engineering challenges. Encouraging peer discussions can enhance comprehension and problem-solving skills.

5. One-on-One Consultations and Support:

Offer one-on-one consultations with instructors to address individual concerns and challenges related to Mohr's Circle, Factor of Safety, and maintenance aspects. Provide additional learning resources, such as tutorial videos, supplementary reading materials, and online forums, to support students in self-directed learning and addressing specific areas of difficulty.

D. Students Feedback on the Open-Ended Assignment

The impact of the Open-Ended Assignment from the students' perspectives was studied through a feedback survey conducted on completion of the assignment. The feedback was conducted after the results were returned to the students and adequate discussions on the performance of each team was carried out in the classroom. The feedback assessed the following statements on a Likert scale of 1 to 5, were 5 refers to strongly agree and 1 refers to strongly disagree. The summary of the results from the survey are presented in Figure 4.

The feedback survey conducted to assess the impact of the open-ended assignment has yielded valuable insights into its effectiveness and the overall learning experience of the students. The survey encompassed several key parameters, each of which is detailed below along with the corresponding percentage scores:

1. Increased Conceptual Knowledge: An overwhelming 96.52% of students acknowledged that the open-ended assignment significantly contributed to enhancing their conceptual knowledge in the subject matter. This high score underscores the assignment's effectiveness in deepening students' understanding of core engineering principles.
2. Understanding Real-World Applications: Approximately 92.17% of respondents reported a heightened understanding of the real-world applications of the topics covered. This outcome reflects the assignment's success in bridging the gap between theoretical knowledge and practical relevance.
3. Improved Teamwork Skills: A substantial 93.04% of students recognized notable improvements in their teamwork skills. This finding highlights the assignment's role in fostering collaboration, communication, and cooperation among team members, crucial attributes for future engineers.
4. Experiencing Self-Learning: Nearly 94.78% of students expressed that the assignment facilitated a valuable experience of self-directed learning. This outcome demonstrates the assignment's capacity to empower students to take ownership of their learning journey.

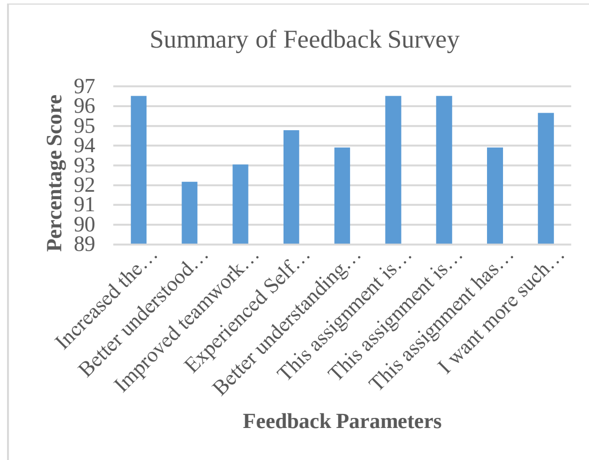

Fig. 4. Summary of Feedback Survey.
The parameters are: 1) Increased the conceptual knowledge on subject 2) Better understood the real-world applications of the topics 3) Improved teamwork skills 4) Experienced Self Learning 5) Better understanding of Design Codes and Standards 6) This assignment is more interesting than regular assignment 7) This assignment is more challenging than regular assignments 8) This assignment has helped me learn better than regular assignments 9) I want more such assignments in comparison to regular assignments

5. Enhanced Understanding of Design Codes and Standards: A significant 93.91% of respondents indicated an improved understanding of design codes and standards. This suggests that the assignment effectively integrated these critical aspects into the learning process.

Furthermore, the students provided feedback regarding their perception of the assignment in comparison to regular assignments:

1. Interest Level: An impressive 96.52% of students found the open-ended assignment more interesting than regular assignments. This indicates that the assignment succeeded in engaging and capturing students' interest.
2. Challenging Nature: Similarly, 96.52% of respondents perceived the open-ended assignment as more challenging than regular assignments, implying that it stimulated critical thinking and problem-solving skills.
3. Enhanced Learning: Approximately 93.91% of students reported that the open-ended assignment contributed to their learning experience more effectively than regular assignments.
4. Preference for Such Assignments: An overwhelming 95.65% of students expressed a preference for more open-ended assignments in comparison to regular assignments.

Key Observations:

1. The open-ended assignment has proven to be highly effective in increasing students' conceptual knowledge, promoting real-world applications, improving teamwork skills, fostering self-directed learning, and enhancing understanding of design codes and standards.

2. Students perceive the open-ended assignment as more interesting, challenging, and conducive to better learning compared to traditional assignments.
3. There is a clear preference among students for more open-ended assignments, indicating their recognition of the assignment's value in their education.

In summary, the feedback survey underscores the positive impact of the open-ended assignment on students' learning outcomes and their overall educational experience. It highlights the assignment's potential as a transformative tool in engineering education, enriching students' knowledge and skill sets while making learning more engaging and relevant.

V. Conclusions

In conclusion, the assessment of the open-ended assignment and the feedback survey have provided valuable insights into its impact on students' learning experiences and outcomes. The assignment has effectively enhanced students' conceptual knowledge, improved their understanding of real-world applications, honed their teamwork skills, promoted self-directed learning, and deepened their understanding of design codes and standards. Students have not only found the assignment more interesting and challenging than traditional assignments but have also expressed a strong preference for such experiential learning opportunities.

However, challenges identified in the assessment, such as difficulties with Mohr's Circle, the Factor of Safety concept, and maintenance aspects, indicate areas where targeted educational support can further enhance students' proficiency. Future studies could focus on developing tailored interventions to address these specific challenges.

The open-ended assignment has demonstrated its potential to bridge the gap between theoretical knowledge and practical application, preparing students for the complexities of real-world engineering challenges. Its success underscores the value of experiential learning in engineering education, offering a pathway to enrich students' knowledge and skills while fostering a deeper appreciation for the practical applications of engineering principles. This study paves the way for further exploration of innovative teaching methods and their impact on engineering education.

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