Enhancing Engineering Students' Critical Thinking and Creativity through Prototype - Based and Social Media-Integrated Learning

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Abstract

The twenty-first century skills refer to twelve essential abilities that students must develop to succeed in today's fast-changing, technology-driven world. These include critical thinking, creativity, collaboration, and communication skills that enable learners to think deeply, generate new ideas, work effectively in teams, and express their thoughts clearly.

But the traditional teaching approach may hinder the development of critical thinking, problem solving, and creative thinking skills that are vital in daily life. Because the traditional teaching is emphasising chalk and talk, rote learning, memorisation and standardised testing. Furthermore, students may get disinterested and unmotivated in their studies as a result of the repetitive and rigid nature of traditional teaching methods.

To address this issue, this research work focused on Prototype-driven learning method. This research work examined the effectiveness of this prototype-driven learning model in developing critical thinking, problem solving, and creative self-efficacy skills of the engineering students. Limited studies have examined its application in engineering and polytechnic education, especially within India. This research bridges that gap by exploring how combining prototype-driven learning with interactive social media environments can foster deeper engagement and skill development among students. First year subject Engineering Mechanics had been taken for the research work. A quantitative pre-post-test design method was used to collect data over a four months period from 54 first year engineering students.

Findings revealed that the prototype learning model significantly improved critical thinking and creative self-efficacy, while the use of social media for information sharing, collaboration, and academic problem-solving further strengthened students' metacognitive. The study highlights that structured prototype learning model experiences, supported by purposeful social media interaction, can serve as an effective pedagogical approach for developing essential twenty-first-century skills among engineering learners.

Keywords :

Prototype based learning; Social media integrated learning; Engineering education; Critical thinking; Creativity

Introduction

Engineering education is increasingly expected to cultivate graduates who possess not only strong technical knowledge but also advanced cognitive and creative competencies necessary to address complex real-world problems. In the context of rapid technological advancements and evolving industry demands, critical thinking and creativity have emerged as essential 21st-century skills for engineers.[Qadir et al, 2020, Mark et al, 2023] Employers and accreditation bodies worldwide emphasize the need for engineering graduates who can analyze ill-structured problems, generate innovative solutions, and adapt to dynamic professional environments.

Traditional lecture-centered teaching approaches have historically played a crucial role in supporting foundational knowledge acquisition in engineering education. However, such approaches often provide limited opportunities for active engagement, experiential learning, and the development of higher-order cognitive skills [Andrew Olewnik et al, 2021, Husin M et al, 2025]. As a result, engineering educators are increasingly adopting student-centered pedagogical strategies that promote problem solving, reflection, collaboration, and authentic engagement with engineering practices [Papp et al, 2014, Bhaumik et al, 2025, Y Han et al, 2025].

One such strategy is prototype-based learning, which emphasizes learning through the design, development, testing, and refinement of tangible or digital prototypes. Parallel to these pedagogical shifts, the widespread use of social media platforms has transformed how learners communicate, collaborate, and construct knowledge. When purposefully integrated into educational settings, social media can facilitate peer interaction, reflective learning, and knowledge sharing beyond the classroom [Findyartini et al, 2024, Gokyar et al, 2025].

Although prototype-based learning and social media-integrated learning have independently demonstrated positive outcomes [A M Sadri, 2020, Khondhaker Al Momin et al, 2023], limited empirical research has examined their combined impact on critical thinking and creativity, particularly in engineering and polytechnic education contexts in India. In many Indian institutions, teaching remains largely examination-oriented, with limited opportunities for hands-on design, reflective practice, or academic content creation [M. V. Vivakaran et al, 2018]. Students often use social media primarily for passive consumption rather than as a learning or knowledge-construction tool [Gokyar et al, 2025]. Consequently, the effectiveness of an integrated prototype-based and social media learning model may differ from results reported in other educational contexts.

Integrating prototype-based learning with structured social media content creation may offer a synergistic instructional approach. Together, these components may provide a learning environment that supports both cognitive and creative skill development

Literature Review

Engineering education has increasingly emphasized the development of higher-order cognitive skills such as critical thinking and creativity, alongside technical competence. Critical thinking enables engineers to analyze complex and ill-structured problems, evaluate alternative solutions, and make informed decisions, while creativity supports innovation and the generation of novel solutions. [C.B. Hodges et al, 2020, Larsson et al, 2025] Accreditation frameworks and industry expectations worldwide highlight these competencies as essential outcomes of engineering programs. However, several studies report that traditional assessment-driven and lecture-centered instructional approaches often provide limited opportunities for students to actively engage in problem solving, reflection, and creative exploration, thereby constraining the development of these skills [Elbilgahy et al, 2025, Qadir et al, 2020]

Conventional lecture-based teaching methods have historically been effective in delivering foundational knowledge and procedural understanding. [P. Chen et al 2021, Andrew et al, 2025] However, prior research indicates that such approaches may not sufficiently support experiential learning, contextual application of knowledge, or the cultivation of higher-order thinking skills [Bhaumik et al, 2025]. In many engineering classrooms, particularly in examination-oriented educational systems, students tend to adopt passive learning strategies focused on memorization rather than analysis and synthesis. These limitations have motivated educators to explore alternative pedagogical approaches that promote active learning, student engagement, and authentic engineering practices [Sopwan et al, 2018, Y. Han et al, 2025].

Although prototype-based learning and social media–integrated learning have been studied independently, limited research has explored their combined implementation in engineering education. Prototype-based learning is grounded in experiential and constructivist learning theories, which emphasize learning through active engagement and knowledge construction. In prototype-based learning environments, students design, develop, test, and refine physical or digital artifacts to address real-world or course-related problems. [Deininger et al, 2016, Emad Alfar et al, 2025]

Despite growing interest in innovative pedagogies, there is a paucity of empirical studies examining the combined effect of prototype-based learning and structured social media content creation on engineering students' critical thinking and creativity, especially within the Indian higher education context. Moreover, few studies employ a mixed-methods approach to simultaneously assess learning outcomes and capture students' perceptions of such integrated instructional models. In response to these gaps, the present study investigates the effectiveness of a prototype-based and social media–integrated learning approach in enhancing critical thinking, creativity, and student engagement among engineering students. By examining both quantitative learning outcomes and qualitative student perceptions, this study aims to contribute empirical evidence to the literature and provide practical insights for educators seeking to implement innovative, context-sensitive instructional strategies in engineering education.

Methodology

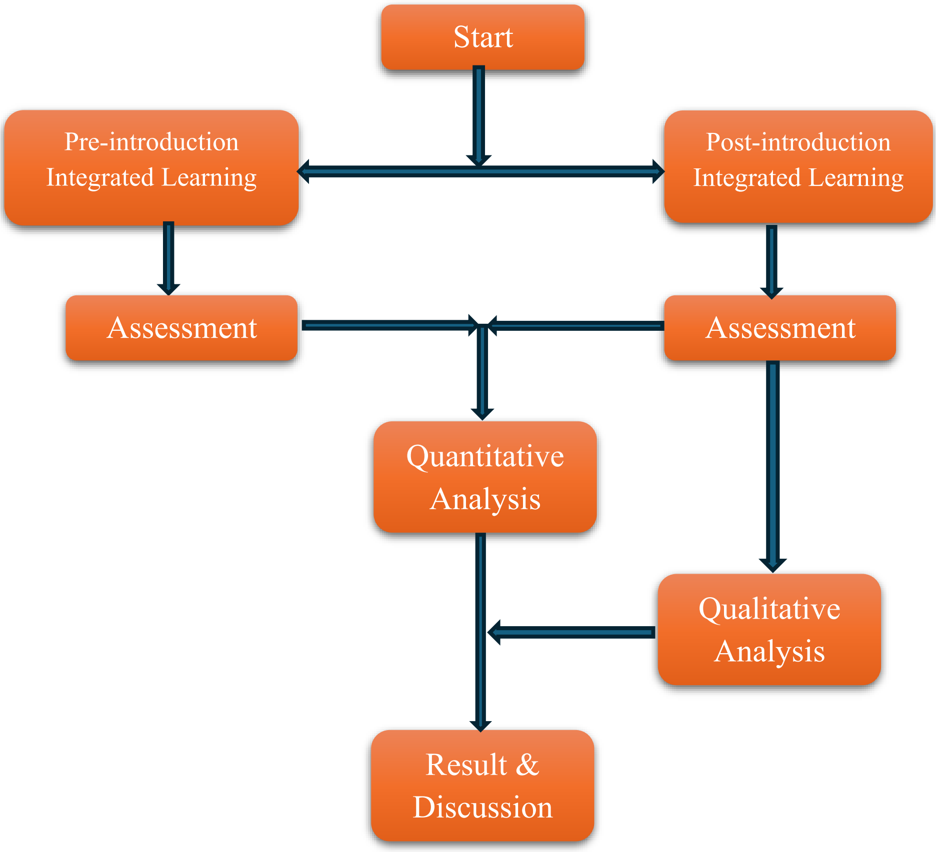


Fig. 1. Methodology flow chart

This study employed a one-group pre-test–post-test method to examine the effectiveness of a prototype-based and social media-integrated learning approach in enhancing engineering students' critical thinking and creativity. The design involved the collection of quantitative data before and after the instructional intervention, complemented by qualitative data to gain deeper insights into students' learning experiences and perceptions.

The participants of the study were undergraduate engineering students enrolled in a core engineering course at a higher education institution in India. A convenience sampling technique was employed, wherein an intact class of first year engineering students (54) was selected due to accessibility and feasibility considerations.

The instructional intervention was implemented in two distinct phases as part of regular course instruction. In the initial phase, students were taught using conventional lecture-based methods, after which a pre-test was administered to assess their baseline understanding and higher-order thinking skills related to the course content.

In the second phase, a prototype-based and social media–integrated learning approach was introduced prior to the post-test assessment. The intervention was carried out over a period of four months.

Prototype-Based Learning Component

Following the pre-test, students were engaged in hands-on prototype development activities related to core course concepts. Working individually or in small groups, students were required to conceptualize, design, and develop physical or conceptual prototype models addressing course-relevant engineering problems.

The prototyping process emphasized experiential learning, iterative refinement, and application of theoretical knowledge to practical contexts.

Social Media–Integrated Learning Component

To further reinforce learning, students were encouraged to create short educational videos based on their prototype models and conceptual understanding. These videos were designed to explain engineering concepts clearly and creatively. Students uploaded the developed short videos to YouTube/Instagram/Facebook as part of the learning activity.

As part of the multimedia learning activities, students created short educational videos demonstrating their prototype models and explaining the related engineering concepts. Students worked individually or in small groups to select a topic, prepare a script, and record a video explaining the design, working principles, and applications of their prototype. The videos included visual demonstrations, diagrams, or step-by-step explanations of the concepts. Each video was approximately 3–5 minutes in duration. The developed videos were uploaded to social media platforms such as YouTube, Instagram, Facebook, and students were required to view and provide feedback on peer submissions through comments and discussions. The instructor monitored the activities and provided guidance to ensure the accuracy and clarity of the content

The process of planning, scripting, and producing social media content required students to revisit course concepts, organize their ideas coherently, and present them in an engaging manner. Following the completion of the prototype development and social media content creation activities, a post-test was administered to evaluate the impact of the intervention on students' learning performance.

Data Collection

Quantitative Data

Quantitative data were collected using achievement-based pre-test and post-test instruments designed to assess students' higher-order thinking skills related to the course content. The tests were administered at two stages:

- **Pre-test:** Conducted after conventional classroom instruction and prior to the implementation of the prototype-based and social media–integrated learning intervention.
- **Post-test:** Administered after the completion of the instructional intervention, to evaluate changes in students' performance attributable to the intervention.

The pre-test and post-test consisted of structured items aligned with course learning outcomes and targeted higher-order cognitive skills such as analysis, application, and problem-solving.

Qualitative Data

Qualitative data were collected using a structured perception-based questionnaire administered after the intervention. The instrument captured students' perceptions of engagement, learning experiences, motivation, and perceived learning outcomes related to the integrated prototype-based and social media learning approach. These data complemented the quantitative findings by providing contextual insights into students' learning experiences.

Results & Discussion

To examine the effect of the integrated prototype-based and social media learning intervention on students' academic performance, a pre-test–post-test comparison was conducted using a paired-samples *t*-test. The descriptive statistics for the pre-test and post-test scores of 54 students are presented in Table 1.

Table 1 Comparison of Pre-test and Post-test Scores

Assessment	N	Mean	Standard Deviation (SD)
Pre-test	54	70.76	10.89
Post-test	54	75.93	09.70

The results indicate an increase in the mean score from the pre-test (M = 70.76, SD = 10.89) to the post-test (M = 75.93, SD = 9.70), reflecting an overall improvement in students' academic performance following the instructional intervention.

A paired-samples *t*-test revealed that this improvement was statistically significant, $t(53) = 7.59$, $p < 0.001$. The obtained *p*-value indicates that the likelihood of observing such an improvement by chance is extremely low, confirming the effectiveness of the intervention.

The statistically significant improvement in post-test scores demonstrates that the integrated prototype-based and social media learning approach positively influenced students' learning outcomes. The observed gain in performance may be associated by several pedagogical factors inherent in the intervention design.

First, the use of prototype-based learning enabled students to actively engage with engineering concepts through hands-on model development. This experiential learning process may have supported deeper cognitive processing by encouraging students to analyze problems, apply theoretical knowledge to practical situations, and iteratively refine their understanding. Such activities are known to promote higher-order thinking skills, which were explicitly targeted in the assessment.

Second, the integration of social media content creation, particularly the development of short educational videos, required students to reorganize and articulate their conceptual understanding clearly. Explaining concepts to an external audience through videos necessitated focused learning, repeated revision, and conceptual clarity. This process may have reinforced learning and contributed to improved performance in the post-test assessment.

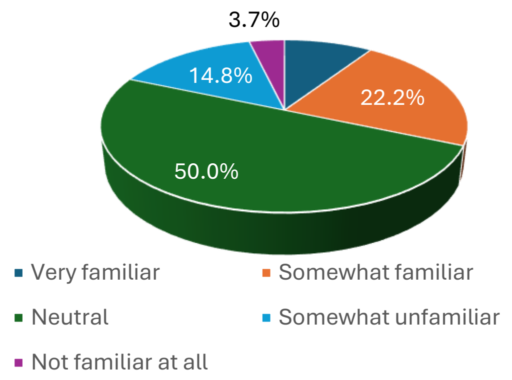
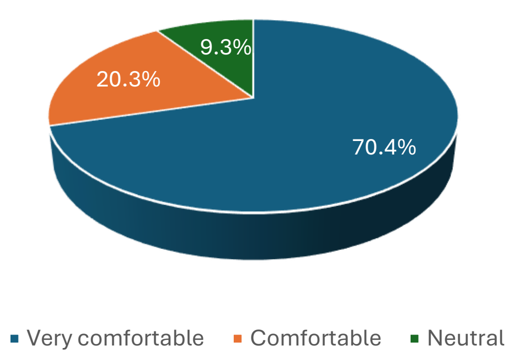
The reduction in standard deviation from the pre-test (SD = 10.89) to the post-test (SD = 9.70) further suggests a more consistent level of understanding among students after the intervention. This indicates that the integrated learning approach not only enhanced overall performance but also helped reduce disparities in student achievement.

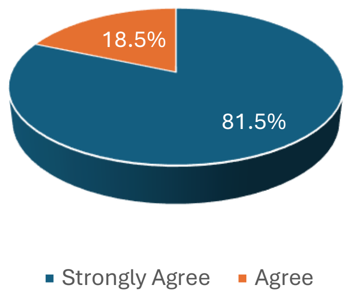
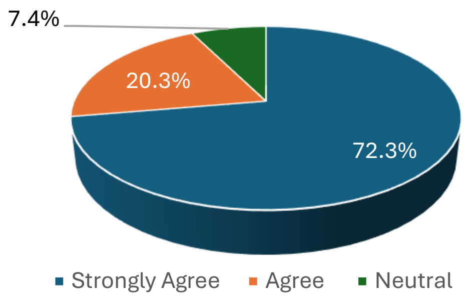
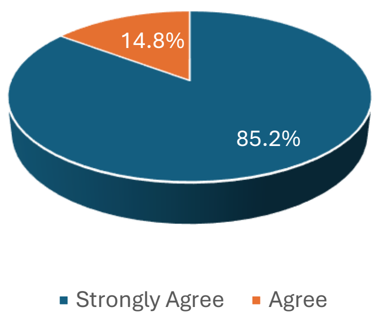
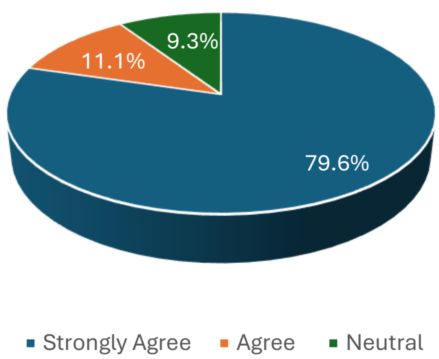
Moreover, the intervention was implemented after students had already received traditional instruction and completed the pre-test. Therefore, the observed improvement in post-test scores can reasonably be attributed to the added value of the prototype-based and social media–integrated activities, rather than initial exposure to course content.

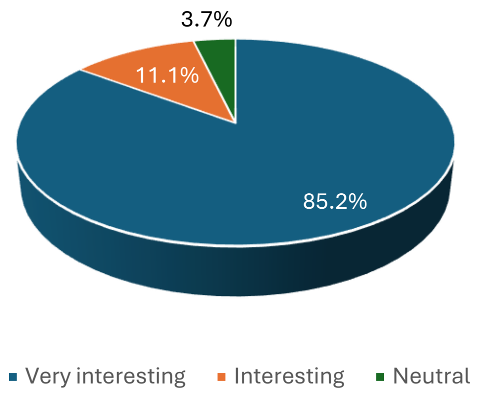
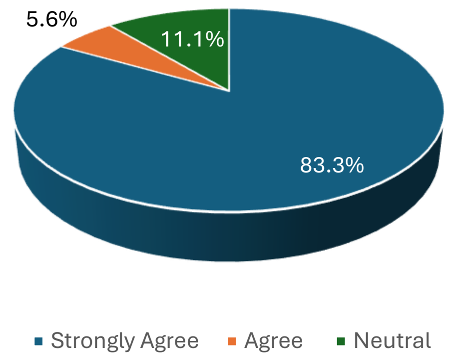
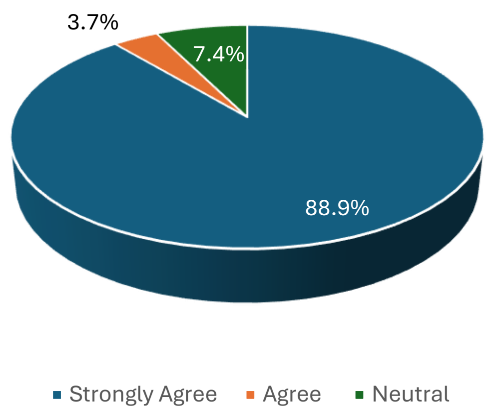
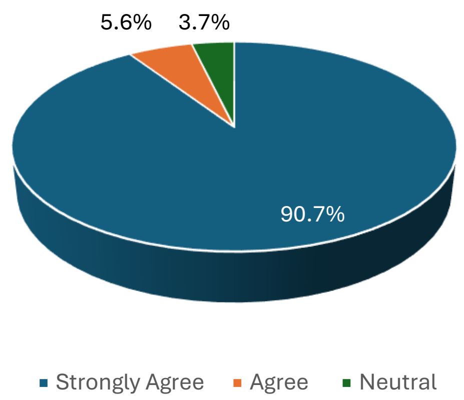
The findings of this study align with prior research in engineering education, which emphasizes the effectiveness of active learning, experiential learning, and technology-supported instructional strategies in enhancing student engagement and learning outcomes. By combining physical prototyping with digital content creation, the present study demonstrates a practical and scalable approach for improving learning effectiveness in engineering classrooms.

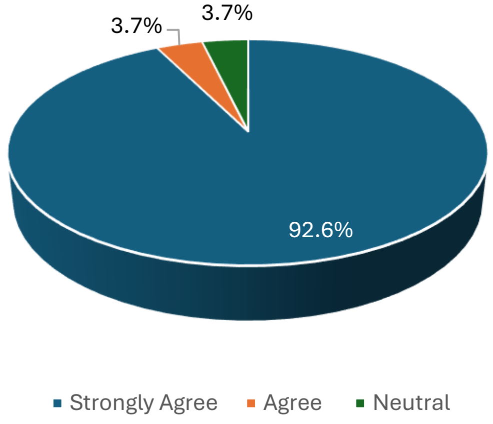
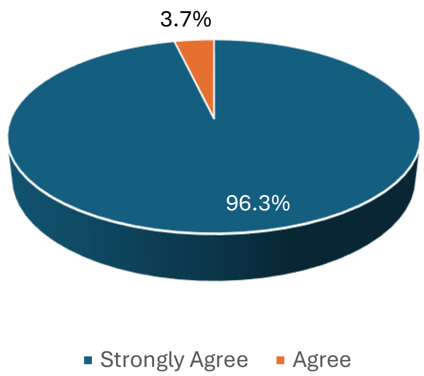
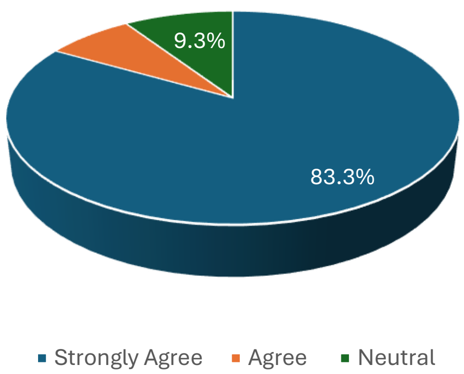
Perception-Based Assessment

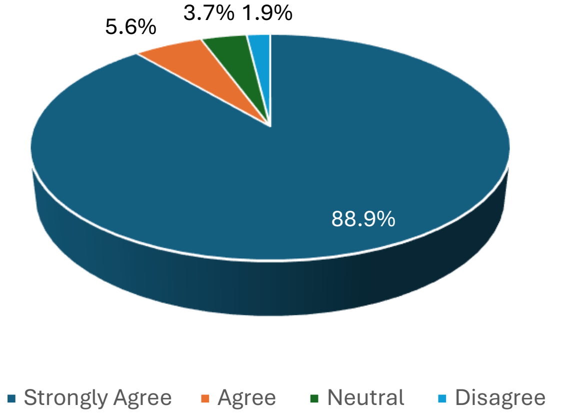
Table 2 Summary of Perception-Based Questionnaire Results

S.No.	Question	Result	Findings
Section A: Familiarity and Comfort			
1	How familiar were you with creating educational social media content before this course?		Most students had limited prior exposure to creating educational social media content
2	How comfortable are you using social media tools for academic purposes?		Majority of students were comfortable using social media tools

Section B: Prototype-Based Learning Experience			
3	To what extent did prototype models help you understand the course concepts?		Prototype models were highly effective in supporting conceptual understanding
4	To what extent did prototype-based learning help you to apply theory to practice?		Prototype based learning effectively supported the application of theory to practice
5	Compared to traditional lectures, how engaging was in learning through prototypes?		Learning through prototypes was recognized as highly engaging compared to traditional lectures, with 85.2% of students strongly agreeing and 14.8% agreeing that prototyping enhanced engagement.
Section C: Social Media Content Creation Experience			
6	To what extent did creating short educational videos enhance your understanding of the subject?		Creating short educational videos substantially enhanced students understanding

<table>
<tr><td>7</td><td>How interesting or enjoyable was the process of creating social media content for learning?</td><td>
</td><td>The process of creating social media content for learning was perceived as highly enjoyable</td></tr>
<tr><td>8</td><td>To what extent did creating videos help you organize and revise course concepts?</td><td>
</td><td>The result shows that the creating videos effectively supported organization and revision of course concepts with 83.3% of students strongly agreeing, 5.6% agreeing, and 11.1% reporting a neutral response.</td></tr>
<tr><td colspan="3">Section D: Engagement and Motivation</td><td></td></tr>
<tr><td>9</td><td>To what extent did developing and uploading videos increase your focus on course content?</td><td>
</td><td>Developing and uploading videos substantially increased students focus on course content, with 88.9% of students strongly agreeing</td></tr>
<tr><td>10</td><td>To what extent did these learning activities motivate you to spend more time studying the subject?</td><td>
</td><td>The learning activities strongly motivated students to invest more time in studying the subject, with 90.7% of students strongly agreeing</td></tr>
</table>

Section E: Learning Outcomes and Skills			
11	To what extent did this learning approach improve your problem-solving and critical thinking skills?		The findings indicate that the learning approach was highly effective in enhancing problem-solving and critical thinking skills.
12	How confident do you feel in explaining engineering concepts to others after creating videos?		The results show that students felt highly confident in explaining engineering concepts to others after creating videos, with 96.3% strongly agreeing
Section F: Overall Experience			
13	How satisfied are you with the prototype-based and social media–integrated learning approach?		The findings indicate a high level of satisfaction with the prototype-based and social media–integrated learning approach, with 83.3% of students strongly agreeing, 7.4% agreeing, and 9.3% reporting a neutral level of satisfaction.

14	Would you recommend this learning approach for other engineering courses?		It shows that they would recommend it for other engineering courses, with 88.9% of students strongly agreeing and 5.6% agreeing.

The table 2 summarizes responses from a five-section questionnaire designed to assess the effectiveness of prototype-based and social media integrated learning. The questionnaire was designed to capture students' perceptions and experiences regarding prototype based learning and social media integrated instructional practices. The responses were analyzed thematically by grouping similar patterns of opinions, levels of agreement, and recurring observations expressed by the participants. The findings are presented according to the six sections of the questionnaire, highlighting key insights derived from student feedback.

Responses to Section A (Familiarity and Comfort) indicate that students entered the course with varying levels of familiarity with educational social media, though most reported feeling comfortable using social media tools for academic purposes by the end of the course. This suggests that structured academic use of social media can enhance digital confidence among students.

Findings from Section B (Prototype-Based Learning Experience) show that prototype-based learning effectively supported conceptual understanding and application of theory to practice. Compared to traditional lectures, learning through prototypes was perceived as more engaging, highlighting the value of experiential learning in engineering education.

Responses in Section C (Social Media Content Creation Experience) demonstrate that creating short educational videos contributed positively to students' learning. Students perceived the activity as engaging and beneficial for revising and organizing course concepts, thereby reinforcing conceptual clarity.

Results from Section D (Engagement and Motivation) indicate that video development and content sharing increased students' focus on course content and motivated them to devote more time to studying. These activities promoted sustained engagement and active involvement in learning.

Findings related to Section E (Learning Outcomes and Skill Development) suggest that students experienced improvements in problem-solving and critical thinking skills and gained greater confidence in explaining engineering concepts to others.

Overall responses from Section F (Overall Experience) reflect high levels of satisfaction with the integrated learning approach, with most students expressing willingness to recommend it for other engineering courses.

Collectively, the questionnaire findings indicate that integrating prototype-based learning with social media content creation enhances engagement, supports deeper understanding, and promotes the development of essential engineering skills.

Limitations and Future Research

The findings of this study should be interpreted in light of certain limitations. The qualitative component of the study primarily relied on students' self-reported perceptions of engagement, learning experiences, and perceived learning outcomes. While such measures provide valuable insights into students' experiences and attitudes, they do not directly measure actual learning performance or demonstrated competency.

Future research may incorporate more objective measures of student learning to complement perception-based data. For instance, rubric-based evaluation methods can be developed to assess students' prototype design, conceptual understanding, and problem-solving performance. Instructor-based assessment using structured rubrics administered before and after the instructional intervention could provide more direct evidence of learning improvement by enabling comparison of students' proficiency levels across time. Additionally, future studies may consider performance-based assessments, longitudinal designs, or multi-institutional samples to enhance the validity and generalizability of findings.

Conclusion

The results of the study demonstrate that the integrated prototype-based and social media–enhanced learning approach indicated a positive impact on student performance and learning experiences. Quantitative analysis of pre-test and post-test scores revealed a statistically significant improvement in students' academic performance ($t(53) = 7.59$, $p < 0.001$), indicating enhanced understanding and higher-order thinking skills following the intervention.

Perception-based questionnaire results further support these findings. While many students reported only moderate familiarity with educational social media content prior to the course, a large majority felt comfortable using social media tools for academic purposes. Students overwhelmingly agreed that prototype models improved conceptual understanding, facilitated the application of theory to practice, and made learning more engaging than traditional lectures. Similarly, creating short educational videos was perceived as highly beneficial for deepening understanding, organizing and revising concepts, and increasing focus and motivation toward the subject.

Moreover, students reported substantial gains in problem-solving and critical thinking skills, along with increased confidence in explaining engineering concepts to others. High levels of overall satisfaction with the instructional approach were observed, and a strong majority of students expressed willingness to recommend this learning approach for other engineering courses.

Overall, the combined quantitative and qualitative results confirm the effectiveness, engagement potential, and pedagogical value of integrating prototype-based learning with social media content creation in engineering education.

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