

INTEGRATING 3D TOOLS INTO MECHANICAL ENGINEERING EDUCATION: IMPACT ON STUDENT ENGAGEMENT, UNDERSTANDING AND EFFICIENCY

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Abstract: This paper investigates the impact of integrating 3D CAD tools into mechanical engineering education. By incorporating interactive 3D models through a textbook with embedded QR codes, students were able to engage more effectively with complex systems, improving their spatial reasoning and understanding of mechanical structures. The research highlights how 3D visualization enhances student comprehension, particularly for first- and second-year students who struggled with traditional 2D drawings. Results from surveys and interviews revealed increased confidence, accuracy, and engagement with the 3D models, with students noting their value in visualizing internal mechanisms and functional relationships. This approach fosters problem-solving skills and promotes collaboration, making it a beneficial tool for both novice and advanced learners. The study emphasizes the importance of adapting curricula to modern technological advancements, ensuring that students are prepared for the evolving demands of the engineering industry.

Key words: 3D models, QR codes, mechanical engineering, students, interactive learning, educational tools.

1. INTRODUCTION

Mechanical engineering is a field that traditionally relies on technical drawings, blueprints, and 2D representations of mechanical systems. While these methods have proven effective over time, they are increasingly challenged by the needs and cognitive preferences of modern students, who are accustomed to digital, interactive environments. In response, engineering educators are turning to 3D technology to enhance the teaching and learning experience. This study aims to assess the impact of integrating 3D models into mechanical engineering education through interactive tools, specifically focusing on the use of QR codes in textbooks. By scanning QR codes, students gain access to 3D models that they can manipulate on their devices, providing a dynamic and engaging way to explore complex mechanical systems.

One of the challenges in mechanical engineering education is ensuring that students, particularly those in their early years of study, can effectively understand the intricacies of mechanical systems. Traditional 2D drawings, while necessary, can be difficult for students to interpret, particularly when it comes to complex assemblies [1] or systems with multiple moving parts [2]. This study explores whether 3D interactive models can bridge this gap, offering a more intuitive and engaging way for students to learn.

The incorporation of 3D CAD tools into the curriculum has demonstrated significant improvements in students' ability to visualize and analyze complex designs, contributing to a more comprehensive understanding of engineering concepts [3]. Furthermore, 3D environments offer a dynamic platform for active learning methods, such as problem-based learning (PBL), which challenge students to apply their knowledge to real-world engineering scenarios [4]. This approach not only enhances their problem-solving abilities but also encourages teamwork, as students collaborate to address complex and multifaceted challenges [5].

The objective of this research is to evaluate whether integrating QR codes linked to 3D models into textbooks [6] enhances student comprehension, engagement, and retention, and how it compares to traditional 2D methods.

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2. METHODOLOGY

The research involved 120 students from the Faculty of Technical Sciences, University of Novi Sad, enrolled in mechanical engineering programs. The students were divided into four groups based on academic year: first-year, second-year, third-year and fourth-year students. Each student was given a textbook with embedded QR codes that linked to 3D models of conveyor systems relevant to their coursework, figure 1.



Figure 1. Conveyor textbook with embeded QR codes of conveyors

The study employed both quantitative and qualitative data collection methods. A pre-test and post-test were administered to measure students' understanding of mechanical systems before and after using the 3D models. The tests focused on the students' ability to identify components in a mechanical assembly, interpret their function, and analyze the relationships between different parts. In addition, a survey was conducted at the end of the semester to measure the students' engagement, satisfaction, and confidence in using 3D models for learning. The survey included Likert-scale questions as well as open-ended questions to gather qualitative feedback. Interviews were also held with a subset of students from each group to gain deeper insights into their experiences.

The quantitative data from the pre- and post-tests were analyzed to determine whether there were significant improvements in students' comprehension and understanding of mechanical systems after interacting with the 3D models. The survey responses were analyzed for trends in student engagement, with particular focus on how different year groups responded to the use of 3D tools. The qualitative data from the open-ended questions and interviews were analyzed thematically to identify recurring themes in student experiences.

3. RESULTS AND DISCUSSION

The results of the pre- and post-tests revealed a significant improvement in students' understanding of mechanical systems after using the 3D models. The mean score on the post-test was 15% higher than on the pre-test, with a p-value of <0.01 , indicating that the use of 3D models significantly enhanced students' comprehension of mechanical concepts. The survey results revealed that 92% of students found the 3D models engaging and stated that they were motivated to use them frequently throughout the semester. Among first-year students, 95% agreed or strongly agreed that the 3D models helped them better understand the material, and 90% reported that they felt more confident in their ability to interpret mechanical systems after using the models. Second-year, third-year and fourth-year students also reported high levels of engagement, with 87%, 85% and 82%, respectively, agreeing that the 3D models contributed positively to their learning experience. Qualitative responses further supported these findings, with students praising the ability to interact with and manipulate the models. Many first-year students noted that the 3D models made the material feel more "real" and tangible, compared to traditional 2D drawings, which they often found abstract and difficult to relate to. Fourth-year students, while already familiar with the material, appreciated the ability to visualize complex systems in three dimensions, which allowed them to refine their understanding and streamline their problem-solving processes.

The data also revealed differences in how students from different academic years responded to the 3D tools. First- and second-year students showed the most significant improvements in confidence and understanding, likely due to their limited exposure to complex mechanical systems in traditional 2D formats. These students expressed that the 3D models allowed them to visualize how components fit together and interact, providing clarity and reducing confusion. In contrast, third- and fourth-year students, who had more experience with 2D drawings, found the 3D models useful for reinforcing their knowledge and improving their efficiency in problem-solving. While all year groups reported positive experiences with the 3D models, the most notable improvements were seen in first-year students, who were the least familiar with technical drawings. These findings suggest that integrating 3D models into early courses can provide significant benefits, potentially easing the learning curve for students who may struggle with traditional 2D diagrams. Overall, the use of 3D models resulted in enhanced learning outcomes. Not only did students achieve better test scores, but they also developed a deeper, more intuitive understanding of mechanical systems. The ability to rotate, zoom, and dissect the models allowed students to explore the systems in ways that were not possible with 2D drawings. Furthermore, students reported that the models helped them identify potential design flaws and visualize the consequences of different engineering decisions before they attempted them in real-world applications.

4. IMPLICATIONS FOR EDUCATION

The findings suggest that integrating 3D tools into mechanical engineering curricula can foster a more student-centered, interactive learning environment. The use of QR codes in textbooks is a practical and cost-effective solution that can be easily incorporated into existing

educational materials. Furthermore, this approach aligns with the digital preferences of modern students, who are accustomed to using mobile devices and interactive tools.

Incorporating 3D models into engineering education also addresses the challenge of visualizing abstract mechanical concepts. Traditional methods, such as static diagrams, often fail to fully convey the dynamic nature of mechanical systems. By using 3D tools, students can interact with the systems, experiment with different scenarios, and gain a more holistic understanding of how components work together in real life.

Future research could explore the long-term impact of 3D tools on student performance, particularly as students progress through more advanced courses. Additionally, research could investigate the potential for combining 3D models with other emerging technologies, such as augmented reality (AR) or virtual reality (VR), to create even more immersive learning experiences.

5. CONCLUSION

This study demonstrates that integrating 3D models into mechanical engineering education can significantly improve student engagement, comprehension, and confidence. The results show that the use of QR codes linked to 3D models enhances students' ability to understand complex mechanical systems, particularly for those in the early stages of their studies. As engineering education continues to evolve, embracing 3D technology offers a promising avenue for improving learning outcomes and better preparing students for the challenges of a technology-driven world.

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