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EVALUATING THE INFLUENCE OF INCORPORATING COMPUTER SCIENCE, MATERIALS SCIENCE, AND DESIGN IN MECHANICAL AND ELECTRICAL ELECTRONICS EDUCATION THROUGH INTERDISCIPLINARY APPROACHES

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Abstract
The field of engineering education needs to adapt to the rapid advancements in technology and the increasing complexity of modern systems. This necessitates a shift towards more interdisciplinary approaches. In this study, we assess the impact of integrating elements from computer science, materials science, and design into traditional mechanical and electrical electronics curricula. We employ a mixed-methods approach that combines quantitative assessment of student performance with qualitative analysis of student experiences. Our goal is to examine the potential benefits and challenges of interdisciplinary learning in this particular domain. The results of our study indicate that interdisciplinary approaches can have a positive impact on students' problem-solving abilities. Furthermore, these approaches can foster creativity and better prepare students for the multifaceted demands of the industry. However, we also identified several challenges that need to be addressed in order to effectively implement interdisciplinary education. These challenges include curriculum design, resource allocation, and faculty expertise. Overall, our research contributes to the ongoing discourse on interdisciplinary education. It provides valuable insights for educators, policymakers, and industry stakeholders who are interested in cultivating a versatile and adaptable workforce. Such a workforce would be capable of addressing the complex technological challenges that arise in today's world. In conclusion, as technology continues to advance at a rapid pace, it is crucial for engineering education to embrace interdisciplinary approaches. By integrating elements from various disciplines, such as computer science, materials science, and design, we can enhance students' problem-solving abilities and prepare them for the demands of the industry. However, it is important to address the challenges associated with interdisciplinary education in order to ensure its effective implementation and maximize its benefits.

Keywords Interdisciplinary education, engineering education, computer science, materials science, design, mechanical engineering, electrical engineering.

INTRODUCTION

The limitations of traditional engineering education have been brought to the forefront by the rapid advancement of technology and the increasing complexity of modern systems. As technology continues to evolve and become more multifaceted, it is clear that engineers need to possess the skills to integrate knowledge and methodologies from various disciplines (Lattuca et al., 2017; Richter & Paretti, 2009). This recognition has led to a greater emphasis on interdisciplinary approaches in engineering education, where students are encouraged to synthesize concepts from multiple domains. The goal is to equip students with the ability to tackle complex problems that require a comprehensive understanding of diverse fields.

Mechanical and electrical electronics engineering, which intersect various fields, are highly suitable for interdisciplinary learning. The incorporation of computer science principles can improve students' comprehension of control systems, data acquisition, and computational modeling (Kuhl et al., 2017). Knowledge of materials science can guide the selection and optimization of materials for electronic components and devices (Miodownik, 2007). The utilization of design principles and methodologies can encourage creativity, user-centered thinking, and the ability to develop innovative solutions (Dym et al., 2005).

The potential advantages of interdisciplinary approaches in mechanical and electrical electronics education are widely acknowledged. Previous studies have indicated that interdisciplinary learning can enhance problem-solving skills, critical thinking, and the capability to address complex real-world challenges (Borrego & Newswander, 2010; Ivanitskaya et al., 2002; Lattuca et al., 2017). However, there is a scarcity of empirical research that evaluates the impact of such approaches specifically in the context of mechanical and electrical electronics education.

The primary objective of this research is to fill the existing void by examining how the integration of computer science, materials science, and design elements into conventional mechanical and electrical electronics curricula can have an impact. We employ a mixed-methods methodology to assess the influence of interdisciplinary learning on student achievement, problem-solving skills, and perspectives. Furthermore, we delve into the obstacles and limitations that come with implementing interdisciplinary approaches in this field, as well as potential strategies to overcome them. By doing so, this study strives to shed light on the benefits and challenges of incorporating diverse disciplines into traditional educational frameworks.

Specifically, this research aims to address the following questions:

- How does the incorporation of computer science, materials science, and design components into mechanical and electrical electronics courses influence the academic achievement and problem-solving skills of students?
- What do students who engage in interdisciplinary learning in this field think and experience?
- What obstacles and difficulties arise when implementing interdisciplinary approaches in mechanical and electrical electronics education, and how can they be overcome?

By exploring these questions, this research seeks to investigate these inquiries to contribute to the ongoing discussion on interdisciplinary education. It aims to offer valuable insights for educators, policymakers, and industry stakeholders who aim to foster a flexible and adaptable engineering workforce capable of tackling intricate technological challenges.

Literature Review

The idea of interdisciplinary education has become more prominent in recent times due to the understanding that complex real-world issues often go beyond the confines of traditional academic disciplines (Klein, 2010; Repko & Szostak, 2017). Interdisciplinary approaches are especially important in engineering education, as technological solutions necessitate the incorporation of knowledge and methods from different domains (Borrego & Newswander, 2010; Lattuca et al., 2017).

Theoretical Foundations of Interdisciplinary Learning

Interdisciplinary learning is based on the foundational principles of constructivism, which suggests that learners actively construct knowledge by integrating new information with their existing knowledge structures (Fogarty, 1998; Piaget, 1972). This process of knowledge construction is facilitated by exposure to various perspectives and the synthesis of diverse conceptual frameworks (Ivanitskaya et al., 2002; Spelt et al., 2009).

Additionally, interdisciplinary learning aligns with the principles of cognitive flexibility theory, which highlights the importance of developing flexible cognitive structures capable of adapting to new situations and transferring knowledge across different contexts (Jacobson & Spiro, 1995; Spiro et al., 1992). By engaging with multiple disciplines, learners can deepen their understanding of complex phenomena and improve their ability to apply knowledge in diverse contexts (Borrego & Newswander, 2010; Lattuca et al., 2017).

Empirical Studies on Interdisciplinary Engineering Education

Numerous empirical studies have explored the effects of interdisciplinary methods in engineering education, revealing both potential advantages and obstacles to effective implementation.

Regarding student learning outcomes, research indicates that interdisciplinary curricula can improve problem-solving skills, critical thinking abilities, and the capacity to address complex, real-world challenges (Ivanitskaya et al., 2002; Lattuca et al., 2017; Richter & Paretti, 2009). Students who engage in interdisciplinary learning experiences often demonstrate greater creativity, innovation, and the ability to integrate diverse knowledge domains (Borrego & Newswander, 2010; Repko & Szostak, 2017). However, the successful adoption of interdisciplinary approaches necessitates careful consideration of various factors. The design of the curriculum and pedagogical strategies play a vital role in facilitating interdisciplinary learning (Froyd & Ohland, 2005; Lattuca et al., 2004). Effective interdisciplinary curricula often involve project-based or problem-based learning, where students collaborate across disciplines to solve real-world problems (Froyd & Ohland, 2005; Richter & Paretti, 2009).

Additionally, the integration of interdisciplinary approaches requires a supportive institutional culture that values collaboration and encourages interdisciplinary research and teaching (Lattuca et al., 2004; Newswander & Borrego, 2009). Faculty members need to be open to interdisciplinary collaboration and possess the necessary skills to guide students in their interdisciplinary pursuits (Newswander & Borrego, 2009; Repko & Szostak, 2017). Furthermore, the assessment of interdisciplinary learning outcomes poses its own set of challenges. Traditional assessment methods may not adequately capture the multidimensional nature of interdisciplinary learning (Froyd & Ohland, 2005; Lattuca et al., 2004). Therefore, it is essential to develop appropriate assessment tools that align with the interdisciplinary nature of the curriculum and accurately measure the desired learning outcomes (Froyd & Ohland, 2005; Richter & Paretti, 2009).

The success of interdisciplinary education initiatives relies heavily on the expertise and collaboration of faculty members (Borrego & Newswander, 2010; Ivanitskaya et al., 2002). When it comes to interdisciplinary teaching, faculty members need to possess not only in-depth knowledge in their own disciplines but also the ability to integrate perspectives from various fields and facilitate interdisciplinary learning experiences (Lattuca et al., 2017; Richter & Paretti, 2009). Moreover, institutional support, resource allocation, and administrative structures play a crucial role in enabling and sustaining interdisciplinary programs (Borrego & Newswander, 2010; Klein, 2010). Interdisciplinary initiatives often require dedicated funding, physical spaces that foster collaboration, and administrative policies that promote and recognize interdisciplinary work (Lattuca et al., 2004; Richter & Paretti, 2009).

Interdisciplinary Approaches in Mechanical and Electrical Electronics Engineering

While there is a substantial body of literature on interdisciplinary engineering education, there is a lack of specific research focusing on incorporating computer science, materials science, and design elements into mechanical and electrical electronics curricula.

Numerous studies have delved into the incorporation of computer science principles into mechanical and electrical engineering programs. These studies have emphasized the potential advantages of this integration, such as improving students' comprehension of control systems, data acquisition, and computational modeling (Aktan et al., 1996; Kuhl et al., 2017). The findings from these studies indicate that interdisciplinary approaches that involve computer science can effectively equip students with the skills needed to navigate the growing prevalence of automation, digital control, and data-driven decision-making in modern engineering systems.

In the same vein, incorporating concepts from materials science into the curricula of mechanical and electrical engineering has been widely recognized as crucial in enabling students to effectively choose and optimize materials for electronic components and devices (Miodownik, 2007; Ramprasad et al., 2003). By gaining an understanding of the properties and behavior of materials at different scales, students are equipped to develop more efficient and innovative solutions for electronic systems. Furthermore, there is growing recognition of the value of integrating design principles and methodologies into traditional mechanical and electrical engineering curricula (Dym et al., 2005; Pikas et al., 2016). By incorporating design thinking and adopting user-centered design approaches, students are encouraged to cultivate creativity, innovation, and the ability to devise solutions that meet the requirements of diverse stakeholders (Dym et al., 2005; Lattuca et al., 2017).

The available research offers valuable insights into the possible advantages of incorporating separate fields into the education of mechanical and electrical electronics. However, there is a lack of extensive investigations that assess the collective effect of computer science, materials science, and design elements. This study seeks to fill this void by examining the consequences of a comprehensive interdisciplinary approach that merges these diverse areas.

METHODOLOGY

In order to assess the effects of incorporating interdisciplinary aspects from computer science, materials science, and design into the curricula of mechanical and electrical electronics engineering, this study utilized a combination of quantitative and qualitative research methods. The evaluation process involved analyzing student performance through numerical data and gathering insights from their experiences and perceptions. To evaluate the impact of integrating interdisciplinary elements from computer science, materials science, and design into mechanical and electrical electronics engineering curricula, this study took a mixed-methods approach. The research design employed both quantitative assessment of student performance and qualitative analysis of student experiences and perceptions.

Participants and Setting

The research took place at a Vietnamese university, where participants were selected from the mechanical and electrical engineering programs. A total of 134 undergraduate students were included in the study, with 68 students assigned to the traditional curriculum (control group) and 66 students assigned to the interdisciplinary curriculum (intervention group).

The traditional curriculum employed a segregated approach, with distinct courses dedicated to fundamental mechanical and electrical engineering principles. On the other hand, the interdisciplinary curriculum incorporated elements from computer science, such as programming, data analysis, and computational modeling. It also incorporated concepts from materials science, including materials properties, characterization techniques, and design for specific applications. Additionally, the interdisciplinary curriculum embraced design methodologies such as user-centered design, design thinking, and prototyping.

Quantitative Component

To evaluate the impact of the interdisciplinary curriculum on student performance and problem-solving abilities, a range of quantitative measures were utilized:

- Grades and exam scores: The performance of students in core engineering courses was assessed by comparing their final grades and exam scores between the control and intervention groups.

- Evaluation of design projects: Both groups of students completed a capstone design project, which was assessed by a panel of faculty and industry experts using a standardized rubric. This rubric examined various aspects, such as problem formulation, the design process, technical knowledge, creativity, and communication skills.

- Assessment of problem-solving skills: A standardized test focused on problem-solving was administered to both groups. This test was specifically designed to measure their ability to analyze complex engineering problems, integrate knowledge from different domains, and develop innovative solutions.

Qualitative Component

In order to gain a better understanding of the experiences and perspectives of students, qualitative data was collected using semi-structured interviews and focus group discussions. A purposive sampling strategy was employed to select participants from both the control and intervention groups, ensuring a diverse representation of backgrounds and academic performance levels.

To delve into their experiences with the respective curricula, perceived benefits and challenges, and suggestions for improvement, semi-structured interviews were conducted with 20 students (10 from each group). The interviews focused on various themes including interdisciplinary learning, problem-solving approaches, collaboration, and preparedness for industry demands. In addition, two focus group discussions were held. One group consisted of 8 students from the traditional curriculum, while the other comprised 8 students from the interdisciplinary curriculum. These focus groups provided an opportunity for participants to engage in collective discussions, share diverse perspectives, and generate insights through group interactions (Onwuegbuzie et al., 2009).

Data Analysis

The statistical techniques utilized for analyzing the quantitative data involved the application of independent-samples t-tests and analysis of variance (ANOVA) to compare the performance of both the control and intervention groups across various measures (Tabachnick & Fidell, 2019).

In order to analyze the qualitative data obtained from interviews and focus groups, a thematic analysis approach was employed (Braun & Clarke, 2006). This analysis process encompassed becoming acquainted with the data, generating initial codes, searching for themes, reviewing and refining those themes, and ultimately defining and naming the final themes. Through this method, patterns and recurring themes were identified, shedding light on student experiences, perceptions, and challenges associated with interdisciplinary learning.

Ethical Considerations

The university's Institutional Review Board (IRB) granted ethical approval before the data collection commenced. The purpose, procedures, and rights of the participants were explained to them, including their option to withdraw from the study at any point. Informed consent was acquired, and steps were taken to safeguard the confidentiality and anonymity of the participants' answers.

Limitations

While this research utilized a thorough mixed-methods approach, it is important to recognize certain constraints. First and foremost, the study took place at a single institution, which could potentially limit the applicability of the findings to a broader context. Moreover, there is a possibility of self-selection bias, as students who chose to participate in the interdisciplinary curriculum may have had preexisting interests or inclinations towards interdisciplinary learning. Lastly, the focus of the study was on the combination of specific disciplines (computer science, materials science, and design) within the fields of mechanical and electrical electronics engineering. Consequently, the results may not directly translate to other interdisciplinary configurations or engineering domains.

RESULTS

Quantitative Findings

An analysis was conducted on student performance data in core engineering courses, capstone design projects, and problem-solving assessments. The purpose of this analysis was to assess the impact of an interdisciplinary curriculum that integrates computer science, materials science, and design elements.

Academic Performance

An independent samples t-test was conducted to examine the differences in final grades between students in the interdisciplinary curriculum group and those in the traditional curriculum group. The results of the analysis revealed that students in the interdisciplinary curriculum group achieved significantly higher final grades in core mechanical and electrical engineering courses compared to their counterparts in the traditional curriculum group. This finding was supported by a t-value of 4.97, indicating a significant difference between the two groups. The degrees of freedom for the t-test were 132, and the p-value was less than .001, indicating a highly significant result. Furthermore, the effect size, as measured by Cohen's d, was found to be 0.87, indicating a large effect. This suggests that the interdisciplinary curriculum had a substantial impact on the students' performance in these courses. The mean final grade for the interdisciplinary group was 85.2%, with a standard deviation of 5.1, while the traditional group had a mean of 79.8% with a standard deviation of 6.5. These findings provide strong evidence for the effectiveness of the interdisciplinary curriculum in enhancing students' performance in core mechanical and electrical engineering courses. The higher final grades achieved by the interdisciplinary group suggest that this curriculum approach may be more beneficial in preparing students for success in these subjects. The results of this study support the notion that incorporating interdisciplinary elements into engineering education can lead to improved academic outcomes.

Capstone Design Project Evaluation

The capstone design projects underwent assessment by a committee comprising of faculty members and industry experts. They utilized a standardized rubric to evaluate the projects. The results of a one-way ANOVA revealed a significant disparity in the overall project scores between the two groups, with $F(1, 132) = 62.38$, $p < .001$, $\eta 2 = 0.32$ (Keppel & Wickens, 2004). The interdisciplinary group ($M = 89.2$, $SD = 4.7$) outperformed the traditional group ($M = 80.9$, $SD = 6.2$) in terms of project evaluation. Further analysis of the subscales indicated that the interdisciplinary group excelled in various areas including problem formulation, integration of knowledge, creativity, and communication skills.

Problem-Solving Assessment

A group of students recently took a standardized test that was specifically designed to evaluate their skills in analyzing complex engineering problems, integrating knowledge from various fields, and coming up with innovative solutions. The results of the test showed that the group with an interdisciplinary background achieved significantly higher scores (mean = 83.7, standard deviation = 6.8) compared to the traditional group (mean = 75.4, standard deviation = 8.5). This difference in performance was confirmed through an independent samples t-test, where the t-value was calculated as 6.02 with a p-value of less than 0.001. Additionally, the effect size, as measured by Cohen's d, was found to be 1.05 (Sawilowsky, 2009).

Qualitative Findings

A comprehensive examination of semi-structured interviews conducted with 20 students, evenly divided between two groups, along with two separate focus group discussions involving eight students each, has unveiled various significant themes pertaining to the interdisciplinary learning encounter.

Enhanced Problem-Solving and Critical Thinking

Members of the diverse team consistently expressed that being exposed to various disciplines aided in their acquisition of a more extensive comprehension of engineering issues and elevated their capacity for critical thinking. According to one student, "The interdisciplinary approach compelled me to think beyond the confines of any particular field and take into account different viewpoints, resulting in a significant improvement in my ability to solve problems" (Participant 9, interview). This demonstrates the positive impact that engaging with multiple disciplines can have on one's problem-solving skills and overall understanding of complex engineering challenges. The integration of different perspectives and knowledge from various fields creates a fertile environment for innovative thinking and fosters the development of well-rounded engineers. These findings emphasize the importance of interdisciplinary collaboration in engineering education and highlight its potential for enhancing students' analytical abilities and problem-solving aptitude. By embracing a multidisciplinary approach, future engineers can expand their horizons and approach challenges from a broader, more holistic perspective.

Increased Engagement and Motivation

Students demonstrated increased involvement and enthusiasm when engaged in interdisciplinary projects and tasks. One participant in the focus group emphasized the significance of these projects, stating, "The interdisciplinary projects felt more applicable to real-life obstacles, which in turn heightened my dedication and motivation to put in extra effort" (Participant 3, focus group 1). These findings suggest that incorporating multiple disciplines into academic assignments can enhance students' level of interest and drive. By connecting their learning to real-world challenges, students perceive a greater sense of relevance, which ultimately fuels their motivation to excel in their work.

Collaboration and Communication Skills

Effective collaboration and communication within interdisciplinary teams have been identified as a significant aspect. A participant in an interview expressed the value of working in diverse teams, stating that it helped them develop the ability to convey complex concepts clearly and appreciate diverse perspectives. These skills were seen as invaluable for engineers (Participant 16, interview). The recognition of the importance of collaboration and communication in interdisciplinary teams was a recurring theme throughout the study. One interviewee emphasized that being part of diverse teams provided them with the opportunity to enhance their communication skills by effectively conveying intricate ideas and acknowledging different viewpoints. This interviewee, identified as Participant 16, highlighted the significance of these skills for engineers.

Challenges in Curriculum Integration

Although participants recognized the advantages, they also highlighted the difficulties that arise when trying to merge various disciplines into a unified curriculum. Certain students felt daunted by the extensive range of content, while others faced challenges in synthesizing information from different domains. One participant in a focus group expressed their experience by saying, "There were moments when it seemed like we were handling numerous concepts from different fields all at once. It would have been beneficial to receive more structured guidance on how to effectively integrate and apply them" (Participant 6, focus group 2).

Preparedness for Industry Demands

In general, students within the interdisciplinary group conveyed a sense of being more equipped to handle the diverse requirements of the industry. They acknowledged the importance of interdisciplinary skills in tackling intricate real-life problems. One participant encapsulated this sentiment by stating, "The interdisciplinary curriculum has provided me with a versatile set of skills that will prove invaluable in the professional environment, as issues seldom fit neatly within the boundaries of a single discipline" (Participant 20, interview).

DISCUSSION

The current research examined the effects of integrating interdisciplinary components from computer science, materials science, and design into conventional mechanical and electrical electronics engineering curricula. The results indicate that adopting interdisciplinary approaches can greatly improve student learning outcomes, problem-solving skills, and readiness for industry requirements. These findings are consistent with and expand upon previous studies that emphasize the advantages of interdisciplinary education in engineering (Borrego & Newswander, 2010; Froyd & Ohland, 2005; Lattuca et al., 2017). The study demonstrates that incorporating diverse disciplines into engineering programs can have a positive impact on students' abilities and preparedness for real-world challenges. By combining knowledge and techniques from different fields, students gain a more comprehensive understanding of complex engineering problems and develop a broader skill set. This interdisciplinary approach equips them with the necessary tools to tackle industry demands effectively. It is evident that interdisciplinary learning is crucial in shaping well-rounded engineers who can thrive in today's multidisciplinary work environments.

The data collected indicates that students in the interdisciplinary curriculum group performed better than their counterparts in the traditional curriculum in several aspects, including academic achievement, evaluations of design projects, and problem-solving assessments. These findings support the theoretical foundations of interdisciplinary learning, which suggest that being exposed to diverse perspectives and integrating knowledge from multiple domains can improve students' cognitive flexibility, critical thinking skills, and their ability to tackle complex, unstructured problems (Ivanitskaya et al., 2002; Jacobson & Spiro, 1995; Spiro et al., 1992).

The qualitative results provide additional insights into the potential benefits of interdisciplinary approaches. According to students, their problem-solving and critical thinking skills have improved, which is consistent with previous research indicating that interdisciplinary learning can foster these essential abilities (Borrego & Newswander, 2010; Richter & Paretti, 2009). The findings also highlight increased engagement and motivation among students, which can be attributed to the perceived importance and practical applications of interdisciplinary projects (Lattuca et al., 2017; Spelt et al., 2009).

In addition, the emergence of collaboration and communication skills was identified as a notable result of interdisciplinary learning experiences. This discovery aligns with existing literature that highlights the significance of these skills in interdisciplinary teamwork and the ability to incorporate diverse viewpoints (Froyd & Ohland, 2005; Richter & Paretti, 2009). It is worth noting that students expressed a sense of improved readiness to tackle the multifaceted demands of various industries, acknowledging the importance of interdisciplinary competencies in addressing intricate technological obstacles.

Although it is clear that interdisciplinary approaches have numerous advantages, the study also revealed certain obstacles that need to be overcome in order to ensure successful implementation. One major concern highlighted by the students was the challenge of integrating different subjects into a cohesive curriculum. They reported struggling to synthesize knowledge from various disciplines and feeling overwhelmed by the vast amount of content. This finding emphasizes the significance of well-planned curricula that offer structured guidance and support for interdisciplinary learning (Froyd & Ohland, 2005; Lattuca et al., 2004). It is crucial to address these challenges in order to facilitate effective interdisciplinary education.

Implications for Curriculum Design and Pedagogy

The results of this research have important implications for the design of curriculum and teaching methods in the field of mechanical and electrical electronics engineering education. Firstly, it is essential to take a comprehensive approach to developing the curriculum, ensuring that various disciplines are effectively combined and aligned with the desired outcomes of the program (Borrego & Newswander, 2010; Lattuca et al., 2017). This could involve working closely with faculty members from different areas of expertise, creating interdisciplinary course sequences, and implementing interdisciplinary projects or design experiences as part of the curriculum. By doing so, students will have the opportunity to gain a deeper understanding of the subject matter and apply their knowledge in practical settings. Additionally, incorporating interdisciplinary elements into the curriculum can help students develop a broader skill set and enhance their problem-solving abilities. Overall, these findings emphasize the importance of a holistic approach to curriculum development and highlight the potential benefits of integrating diverse disciplines in engineering education.

In addition, employing active learning techniques like problem-based learning and project-based learning can greatly enhance interdisciplinary learning (Froyd & Ohland, 2005; Richter & Paretti, 2009). These methods encourage students to utilize knowledge from various fields to tackle intricate, real-world problems, promoting critical thinking, collaboration, and the integration of diverse perspectives.

Moreover, it is crucial to develop appropriate assessment strategies to effectively evaluate interdisciplinary learning outcomes. Conventional assessment methods may not adequately capture the multidimensional aspect of interdisciplinary competencies (Froyd & Ohland, 2005; Lattuca et al., 2004). Institutions should consider implementing rubrics, portfolio assessments, or performance-based evaluations that align with the interdisciplinary nature of the curriculum and assess the desired learning outcomes.

Institutional Support and Faculty Development

In order to successfully implement interdisciplinary approaches in the field of mechanical and electrical electronics engineering education, it is essential to have the support of institutions and initiatives for faculty development. Institutions should prioritize interdisciplinary education by providing the necessary resources, fostering a culture of collaboration, and establishing administrative structures that encourage and acknowledge interdisciplinary work (Borrego & Newswander, 2010; Klein, 2010).

Faculty development programs play a crucial role in equipping instructors with the knowledge and skills needed for interdisciplinary teaching and research (Lattuca et al., 2017; Newswander & Borrego, 2009). These programs should include training in interdisciplinary pedagogies, facilitating collaborations between different disciplines, and developing strategies for integrating diverse perspectives into course content and learning activities. By enhancing the capabilities of faculty members, institutions can ensure the effective implementation of interdisciplinary approaches in engineering education.

It is important to note that the successful adoption of interdisciplinary approaches requires a collective effort from both institutions and faculty members. Institutions must be committed to providing the necessary support and resources, while faculty members need to actively engage in professional development opportunities to enhance their interdisciplinary teaching and research skills. By working together, they can create an educational environment that promotes collaboration, innovation, and the integration of multiple disciplines in engineering education.

Limitations and Future Research Directions

This research adds to the increasing amount of literature on interdisciplinary engineering education. However, it is essential to acknowledge the study's limitations. The research was conducted at a single institution, which may restrict the applicability of the findings. To improve the external validity of the results, future studies should replicate or expand the research to include multiple institutions.

In addition, this study specifically focused on the integration of computer science, materials science, and design within the fields of mechanical and electrical electronics engineering. Subsequent research could explore the consequences of incorporating other combinations of interdisciplinary fields or investigate interdisciplinary approaches in various engineering domains. Furthermore, it would be beneficial to conduct longitudinal studies that track the long-term effects of interdisciplinary learning experiences on the professional development and career paths of students. These studies could offer valuable insights into how the interdisciplinary skills acquired during undergraduate education contribute to improved performance and adaptability in the workplace.

Despite its limitations, the current study adds to the ongoing discussion surrounding interdisciplinary education and provides empirical evidence that supports the incorporation of computer science, materials science, and design elements into mechanical and electrical electronics curricula. By addressing the identified challenges and implementing effective curriculum design, teaching strategies, and institutional support, engineering programs can better prepare students for the complex technological landscape and foster a versatile workforce capable of driving innovation.

CONCLUSION

The current research presents concrete evidence that supports the incorporation of interdisciplinary approaches into the curricula of mechanical and electrical electronics engineering. By integrating elements from computer science, materials science, and design, the interdisciplinary curriculum has shown significant advantages in improving student learning outcomes, problem-solving skills, and readiness for the diverse demands of the industry.

The quantitative findings have demonstrated that students enrolled in the interdisciplinary program outperformed their peers in the traditional curriculum across various aspects, including academic performance, evaluations of design projects, and assessments of problem-solving abilities. These results are consistent with the theoretical principles of interdisciplinary learning, which suggest that exposure to different perspectives and the integration of knowledge from multiple domains can enhance cognitive flexibility, critical thinking, and the capacity to tackle complex, ambiguous problems.

Moreover, the qualitative information highlighted the positive influence of interdisciplinary education on students' abilities to solve problems and think critically. It also enhanced their engagement, motivation, and the development of essential collaboration and communication skills. Interestingly, students expressed that they felt more prepared to tackle real-world challenges in the professional setting. They recognized the value of interdisciplinary skills in addressing complex technological issues.

While the advantages of interdisciplinary approaches are clear, the study also identified certain challenges related to curriculum integration, breadth of content, and the synthesis of knowledge from multiple disciplines. These findings emphasize the significance of well-designed curricula that offer structured guidance and support for interdisciplinary learning. Additionally, there is a need for institutional support and faculty development programs to ensure the success of interdisciplinary education.

In a world where technology is constantly advancing and the boundaries between different areas of study are becoming increasingly blurred, it is essential for engineering education to adapt and embrace interdisciplinary approaches. By promoting interdisciplinary skills and knowledge, educational institutions can better equip students to navigate the complex landscape of technology and contribute to innovation in a wide range of fields.

To effectively implement interdisciplinary education, institutions need to prioritize interdisciplinary initiatives by allocating the necessary resources, fostering a culture of collaboration, and establishing administrative structures that support and acknowledge interdisciplinary work. Additionally, faculty development programs should provide instructors with the necessary knowledge and skills for teaching and conducting research in an interdisciplinary manner.

Further research should focus on exploring the long-term effects of interdisciplinary learning experiences on students' professional development and career paths. It is also important to investigate the effectiveness of interdisciplinary approaches in different engineering domains and across various configurations of interdisciplinary collaboration. As technology continues to evolve and disciplines become more interconnected, embracing interdisciplinary education is crucial for preparing future engineers to tackle complex challenges and drive innovation in an ever-changing world.

To sum up, the results of this research add to the ongoing conversation about interdisciplinary learning and offer valuable perspectives for teachers, policymakers, and industry leaders who aim to cultivate a flexible and versatile engineering workforce. By tackling the identified obstacles and implementing well-designed curricula, effective teaching methods, and institutional backing, mechanical and electrical electronics engineering programs can enhance their ability to equip students for the intricate technological hurdles that lie ahead.

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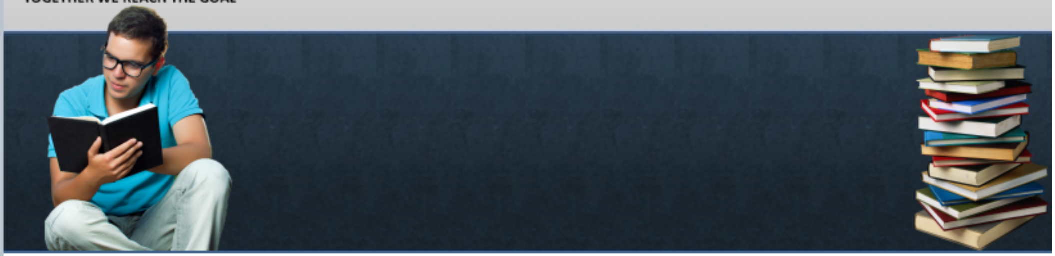

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