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Assessing the Need for Digital Tools and Emerging Technologies in Addressing Student Retention and Engagement in Engineering Education

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ABSTRACT

BACKGROUND & CONTEXT

Engineering education is evolving with rapid technological advancement and increasing emphasis on sustainability. In Pakistan, challenges such as low student engagement, retention issues, outdated curricula, limited practical exposure, and weak industry linkages continue to hinder graduate readiness.

PURPOSE

The purpose of this study was to examine factors influencing student engagement and retention in engineering education in Pakistan. It aimed to assess the relevance of existing curricula in relation to emerging technologies and sustainability requirements, while identifying gaps between educational content and industry needs to inform improvements in teaching practice.

METHODOLOGY

A mixed-methods approach was adopted to address the research objectives. Data were collected from faculty members across several engineering institutions through surveys and semi-structured interviews. The data were analysed thematically, focusing on curriculum relevance, integration of digital and emerging technologies, and faculty development, enabling a comprehensive understanding of both trends and contextual insights.

OUTCOMES

The outcomes indicate noticeable gaps in hands-on learning opportunities and limited exposure to industry-relevant technologies. Insufficient collaboration between academia and industry and constraints in faculty training emerge as key challenges. These factors directly influence student engagement and preparedness for professional practice.

CONCLUSIONS

The study concludes that curriculum modernization and sustained industry–academia collaboration are essential for strengthening engineering education in Pakistan, consistent with prior research emphasizing experiential learning and continuous curriculum updates.

KEYWORDS

Engineering Education, Student Engagement, Curriculum Modernization.

Introduction

Engineering has its etymology from the Latin word *ingenium* which means cleverness and is associated with the intellectual capacity to create something out of nothing or bring about innovation and address an intricate problem (Hansson, 2020). Engineers are a driving force behind economic progress and social growth and much of what they do helps us to enjoy a higher standard of living. In recent years engineering education has changed significantly due to rapid technological advances (Broo et al., 2022). The digital uprising is a wave of revolution where artificial intelligence (AI), communication technologies, and human-machine interfaces (HMIs) converge. Software meets hardware technology is changing the face of engineering education. However, the situation changed in the late 20th and early 21st centuries as environmental matters became more pernicious as challenges for enterprises and societies to grapple with and sustainability took one of its most notable roles ever as a primary protector of long-term corporate success.

The United Nations Decade of Education for Sustainable Development (2005-2014) put forward a spotlight on integrating the ideas of sustainability into the educational systems worldwide (Kopnina, 2020). However, a gap remains in integrating such values fully into engineering courses, where they might have a considerable impact. It suggests that engineers, as problem solvers, must be innovative but at the same time, ensure that their ideas are viable for future generations. Engineering education must respond to combined challenges of technological disruption and sustainability, catering better to educating students for an increasingly complex and interconnected world. While digital technologies like virtual reality (VR) and augmented reality (AR) are well-established to create an immersive learning environment, their applications in enhancing student learning engagement are underutilized and specifically oriented toward sustainability (Al-Ansi et al., 2023). For example, VR is an effective method to simulate the practical engineering challenges which students would experience firsthand without any kind of geographical limitation. Similarly, data analytics and AI-powered tools provide for more individual learning experiences that better cater to the needs of the students, thus increasing retention in the engineering programs according to Hernandez-de-Menendez et.al (2020). In addition, there is an urgent need to close the gap between taught capabilities through traditional engineering education and the operational needs of businesses today. Many studies have shown that more than 90 percent of engineering graduates are deemed unfit for employment due to inadequate skill sets and the poor quality of engineering education in several countries such as India and Pakistan (Singh & Tilak, 2020, Tilak & Choudhury, 2021). Contrarily, human-machine interfaces, when embedded properly, will fill this gap by offering adaptive learning settings, immediate feedback, and interactive simulations that facilitate deeper engagement in skill development in general.

The research is part of a larger project involving data collection and comparison across multiple countries. This phase of the research focuses on a developing country context, highlighting the distinct challenges and opportunities present within its educational system. This study specifically addresses the gap between Pakistan's engineering curricula and the evolving demands of industry in the context of digital transformation and sustainability. The research seeks to determine how emerging technologies, and digital tools can enhance student engagement and retention in engineering education. Accordingly, the study aims to: (1) assess faculty perceptions of current curriculum relevance and technological integration; (2) explore barriers and opportunities for incorporating emerging technologies; and (3) identify strategies to improve student engagement and retention. The following research questions guide the study:

RQ1: How do engineering faculty perceive the alignment between current curricula and industry needs?

RQ2: What role can digital tools and emerging technologies play in enhancing student engagement and retention?

RQ3: What institutional and infrastructural factors facilitate or hinder such integration?

Related Work

Engineering education is undergoing substantial change. According to Habbal et.al (2024), it is the essence of a human-centric approach even in fields such as AI, robotics and other high-tech engineering subjects, which has resulted in an evolution in curriculum. Miranda et al. (2021) emphasize the importance of future technologies in higher education, as reported by Spotighting case studies, they illustrated digital technologies and provided examples of how fully virtual or augmented reality supplemented learning across engineering disciplines. Hadgraft & Kolmos (2020) highlight how evolving learning settings, such as project-based or collaborative learning, have changed engineering education. Its contribution has centered on developing new learning environments that promote critical thinking, problem-solving abilities and active learning of students. Similarly, Soliman (2021) claims that virtual reality has become increasingly significant for engineering education; they note that the educational exposure of hands-on experience can be given in a virtual space, hence increasing student engagement.

Another significant focus of engineering education is the issue of sustainability. For example, Ruiz-Mallén & Heras (2020) presents how higher education institutions are embedding sustainability into their programs with a view to aligning with Agenda 2030 goals. Žalėnienė and Pereira (2021) supplement this with a global perspective on higher education for sustainability, emphasizing interdisciplinarity and co-operation between academia and industry as key ingredients. The disruptive role of technology in education has been one of the topics. Nidhi & Suryan (2020) address the perceptions of disruptions in engineering education in respect of how mid-career academicians' views are evolving about how digitalization is disrupting traditional teaching practices. Qureshi et al. (2021) continue to explore the role of digital technologies in Education 4.0, acknowledging these as means whereby learning becomes more effective, but only were considered in integration with pedagogical practices. Recent works such as Daun & Brings (2023, June) have placed the role of generative AI, including ChatGPT, in engineering education under the spotlight. They discuss promises and pitfalls of AI in learning environments with respect to transforming how students engage in technical content, while Mhlanga (2023) introduces an ethical layer: responsible use of AI tools within educational settings.

In the Pakistan context, Mehdi et. al. (2001) and Khan et al. (2024) have presented valuable information on problems and barriers that hinder the development of engineering education in the country. Matters noted here include inadequacy of resources, un-updated curricula, and the need for further globalization to make the educational setup at par with international standards. Abas & Khan (2020) and Umar, et al. (2024) address these challenges and insist in their current works on the legislative obstacles, presenting AI applications to overcome at least some barriers in the field of engineering education. These collectively bring to light how engineering education should adapt to the demands of the modern industry, make better use of technology, and try to find solutions for issues related to sustainability. They provide an important foundation necessary to understand issues concerned with how education reforms could help better engage and retain students, particularly in countries like Pakistan with developing economies.

While prior studies highlight the promise of VR, AR, and AI for enhancing engagement, very few have empirically examined their integration in resource-constrained engineering education systems. In the South Asian context, most work remains descriptive rather than evaluative, offering limited insights into measurable impacts on retention or alignment with industry skill requirements. This study builds on these gaps by empirically exploring faculty perspectives in Pakistan and linking them to curriculum modernization strategies aligned with both global trends and local constraints.

Research Method

The study employs a mixed-method approach, combining open-ended and closed-ended questions to collect both qualitative and quantitative data. This comprehensive strategy enhances the depth and breadth of the research, allowing for a nuanced exploration of the factors influencing engineering education in Pakistan.

Conceptual Framework

A conceptual framework as shown in Figure 1 is developed by drawing upon related literature, theoretical frameworks, and the key influences on student engagement and retention in engineering education. This conceptual framework identifies socio-economic, institutional, pedagogical, and technical factors that influence students' engagements in the engineering education landscape of Pakistan, enabling the interplay between these influences to be investigated, with a view to deepening understanding of the challenges and opportunities about engineering education in a developing country.

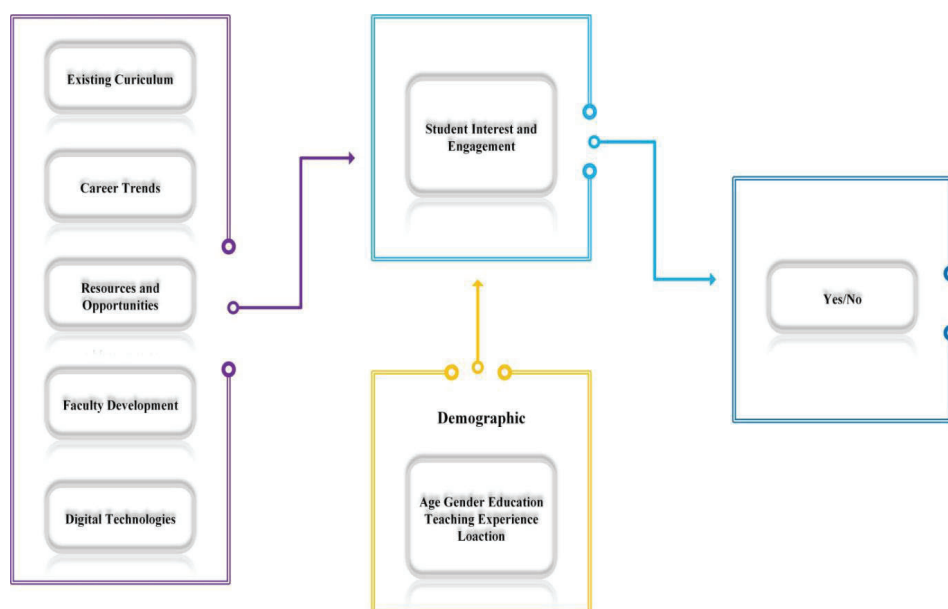


Figure 1: Conceptual Framework of the Study

Questionnaire and Survey Design

Questionnaires are one of the most efficient, reliable, and quantifiable data collection instruments, especially in education research. They are efficient in terms of time, easy to administer tests, enabling rapid collection and comparison of enormous amounts of data. The structured questionnaire was developed from an extensive literature review and pilot-tested with five senior faculty members for clarity and relevance. It consisted of five sections:

1. **Demographics** (e.g., age, gender, years of teaching experience, institution type, region).
2. **Curriculum Relevance** (e.g., “How relevant is your institution’s engineering curriculum to current industry needs?” – 5-point Likert scale).
3. **Student Engagement and Retention** (e.g., “In your view, what is the current level of student interest in engineering programs?” – multiple choice; “What factors most influence student attrition?” – ranking question).

4. **Digital Tools and Emerging Technologies** (e.g., “Rate the importance of integrating emerging technologies such as AI, IoT, and VR into the curriculum” – 5-point Likert scale).
5. **Open-Ended Items** (e.g., “In your opinion, what changes are most needed to align engineering education with industry demands?”).

This overall design for study helps in the holistic understanding of student engagement & retention drivers pertaining to engineering education in Pakistan.

Data Collection

A mixed-method approach was used in this study to acquire both quantitative and qualitative data to enable in- depth analysis of the research aims. A non-probability purposive sampling method was used to collect the primary data from a structured questionnaire in different engineering universities of Pakistan, such as public, private, and semi- public sector. The survey, conducted via Qualtrics, received 132 valid responses out of 300, yielding a 44% response rate. Responses were restricted to teaching faculties of Engineering programs. Furthermore, to have a regional view of the challenges and prospects in engineering education in Pakistan, the study sought secondary data from authentic educational databases and institutional reports. Open-ended responses were reviewed and coded to identify common themes. Coding categories were refined during the process to ensure they accurately reflected the views expressed by participants.

Data Analysis and Interpretation

Demographic Analysis

Understanding the demographic characteristics of the respondents is crucial for interpreting the study's findings. The demographic data reveals that 83% of respondents are male, indicating a gender disparity in engineering education faculty. Most participants (64%) are aged 31-40, as shown in Figure 2 suggesting a relatively experienced cohort. Educationally, more than 90% of participants hold a Postgraduate degree as highlighted in Figure 3, highlighting a high level of expertise. Additionally, 45% of respondents have 11-20 years of teaching experience, which enriches their insights into student engagement and curriculum effectiveness. Finally, 82% work at public universities, influencing their perspectives on institutional resources and industry collaboration. This demographic context is essential for interpreting the study's findings on engineering education.

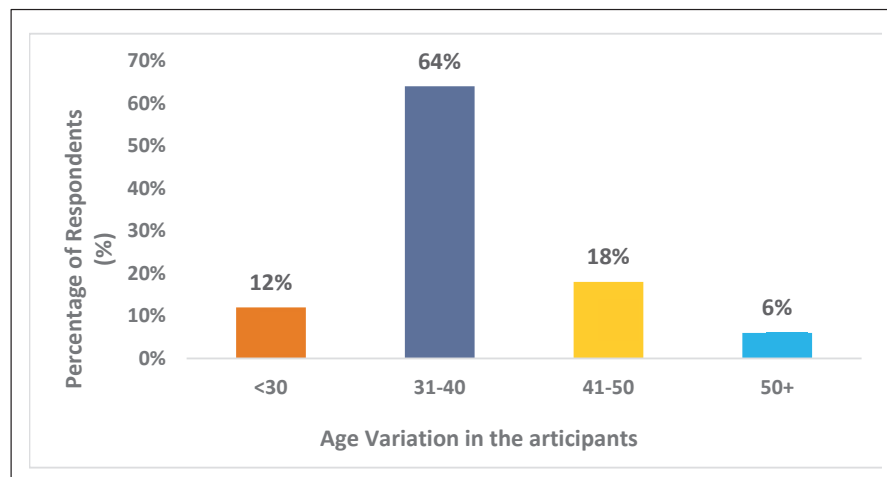


Figure 2: Age Variation in the Participants

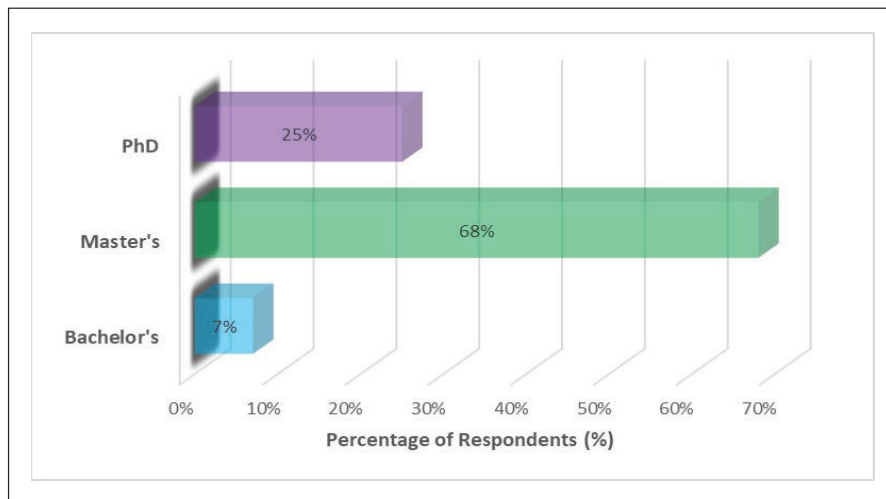


Figure 3: Educational Background of the Participants

Students Engagement and Career Trends

When evaluating the relevance of the engineering curriculum, only 11% of respondents deemed it very relevant to industry needs, emphasizing a disconnect that necessitates urgent curriculum updates. Over half of the faculty (52%) believe that a lack of job opportunities significantly influences student interest, reinforcing concerns about the current job market's impact on career choices. While 50% of faculty perceive engineering graduates as good, a notable 40% rate them as average, indicating room for improvement in graduate preparation. Additionally, a substantial 41% of faculty believe that 26-50% of engineering graduates pursue careers outside the field, suggesting a misalignment between student expectations and job market realities. Motivations for pursuing engineering often stem from external pressures, such as parental influence (50%) and social status (52%), highlighting the need for greater alignment between student aspirations and industry demands.

The survey data collected from faculty at engineering universities reveals crucial insights into student engagement and the factors influencing interest in engineering programs. A significant portion of respondents (47%) rated the current interest level of students as moderate, while 26% categorized it as low as shown in Figure 4. This suggests a growing concern about diminishing enthusiasm for engineering disciplines, which could impact future enrollment and the overall sustainability of these programs. Faculty participants identified job market saturation as the primary concern, indicating a perception that graduates face limited employment opportunities. Additionally, a lack of practical exposure and the financial burden of education were also highlighted as significant factors contributing to students' disinterest.

These faculty perceptions are consistent with wider trends in South Asia. Singh and Tilak (2020) reported that outdated curricula and insufficient industry exposure negatively impact student motivation and persistence in engineering programs. Similarly, Tilak and Choudhury (2021) found that a mismatch between engineering education and labour market needs has contributed to declining engagement and higher attrition rates. These findings reinforce the need to modernise curricula and strengthen industry linkages to improve both interest and retention.

Resources and Opportunities for Engineering Students

The analysis of survey responses regarding resources and opportunities for engineering students reveals several critical areas for improvement. Notably, only 11% of faculty rated the current engineering curriculum as very relevant to industry needs, with 73% considering it only moderately to somewhat relevant.

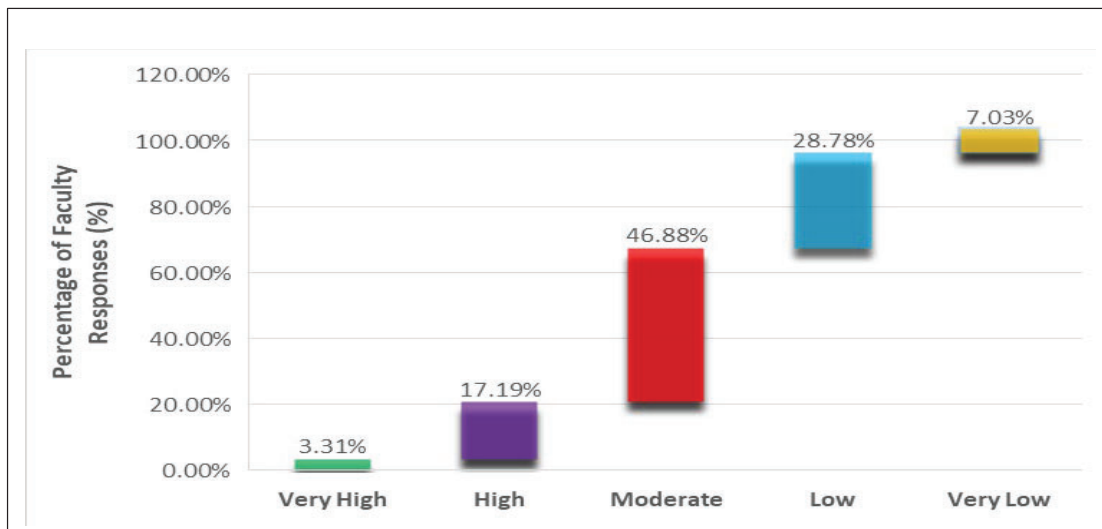


Figure 4: Assessment of Student Interest Levels in Engineering Programs

This gap between educational content and employer expectations could undermine graduates' employability and contribute to declining interest in engineering programs. Also, the effectiveness of career counseling and job placement services was alarming, as only 4% rated it very effective; the majority, 45%, perceived these services to be moderately effective. This would mean that more support should be targeted at better equipping students for the job market. Industry collaboration is another area that needs attention, as 42% of the faculty reported minimal partnerships, with only 6% indicating extensive collaboration. The strengthening of ties with industry will afford students with practical exposure and insights that are an essential part of their education. Additionally, 50% rated the communication and soft skills of graduates as average; therefore, these competencies need to be developed along with technical knowledge. Wholly lacking is support for entrepreneurial ventures, rated as poor by 41% of the respondents. In general, with some of the resources available, there is an evident need to invest in aligning curricula with industry requirements, enhancing practical learning opportunities, and improving supporting services to increase the involvement and success of students in engineering.

Familiarity with Digital Technologies: Faculty Insights

The responses on the faculty's perception about digital technologies and relevance to the curriculum are immediate adjustments that are required in the curricula of engineering. An overwhelming majority, 91%, have rated updating the curriculum in response to technological advances that are happening globally, either extremely or very important. This is further reflected in responses on integrating emerging technologies, where 75% considered that crucial for the curriculum. Each such view sheds light on the collective realization of the need for curricula in tune with today's industry demands and technological trends, especially in areas like Artificial Intelligence, IoT, and Data Science.

Faculty development also emerged as a significant factor that influences students' interest, with 87% indicating that faculty development plays a very significant or significant role. This correlation may suggest that investing in faculty training and exposure to new technologies could have a halo effect that improves the educational experience and thus makes engineering more appealing to students. However, the challenges still remain, especially in implementing digital technologies, as 50% of faculty cited a lack of resources as the major barrier, which again shows that infrastructure and support systems need to improve to enable instructors to teach effectively. Whereas 55% said they were somewhat familiar with the HMLs, 20% did not know, and more comprehensive training in their use is necessary if their full potential to improve student engagement is to be realized. Second, 96% of the faculty reported that digital

tools and simulations help students understand complex engineering concepts, and this emphatically calls for integration into teaching methodologies. In all, the data speak to a strong consensus on the need for modernization of engineering education through curriculum updating and increased faculty training; support is also needed to overcome institutional barriers in adopting digital technologies in the classroom.

Implications and Recommendations

The findings from the analysis highlight several critical implications for engineering education in Pakistan, particularly regarding curriculum relevance, faculty development, and the integration of digital technologies.

Curriculum Modernization

The overwhelming consensus among faculty regarding the importance of updating the engineering curriculum to align with global technological advancements suggests an urgent need for curriculum reforms. Institutions should undertake a comprehensive review of existing curricula, ensuring that they incorporate contemporary topics such as AI, IoT, and Data Science. Collaborating with industry stakeholders can provide valuable insights into market needs and facilitate the development of a more relevant and responsive curriculum.

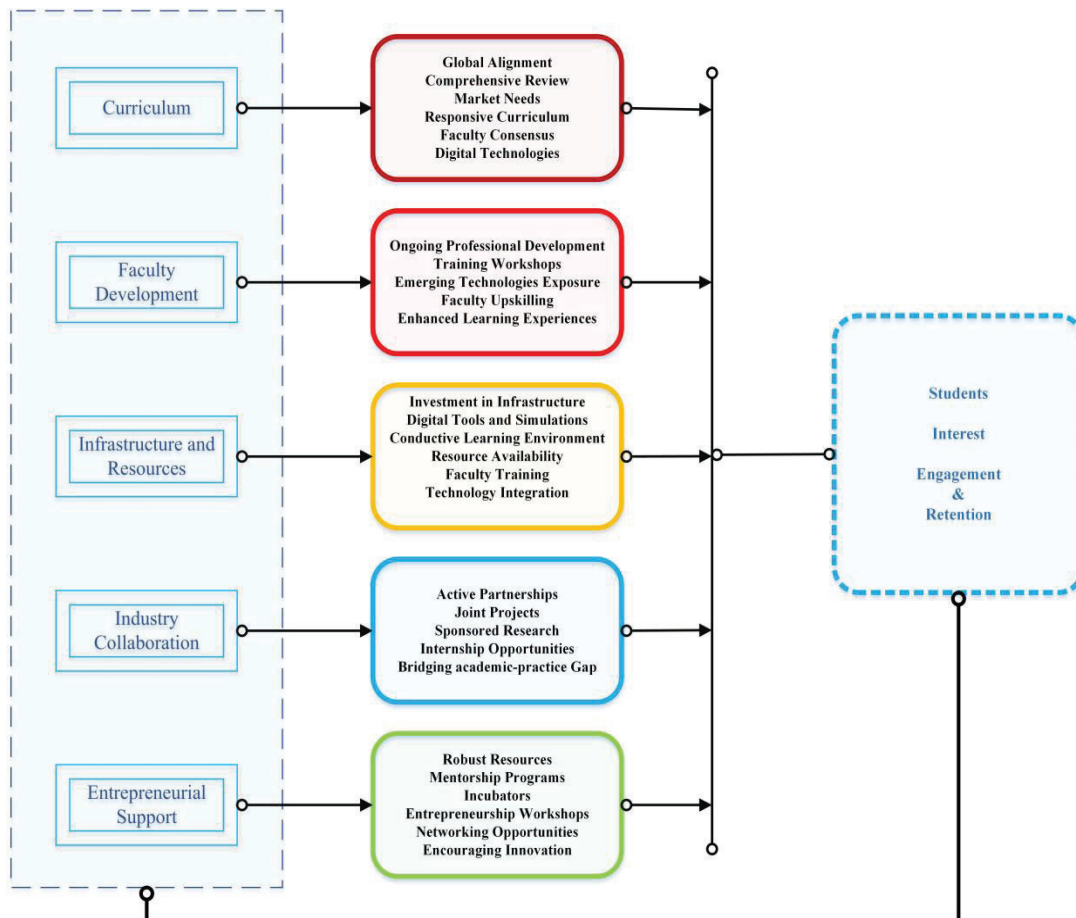


Figure 5: Key Strategies for Boosting Student Engagement and Retention in Engineering Education

Enhanced Faculty Development

Given the significant impact of faculty development on student interest, institutions should prioritize ongoing professional development programs. This could include training workshops, exposure to emerging technologies, and collaborative initiatives with industry experts. By equipping faculty with the latest knowledge and skills, they can effectively engage students and enhance their learning experiences.

Integration of Interdisciplinary Courses

The strong support for incorporating interdisciplinary courses indicates a shift toward a more holistic approach to engineering education. Engineering programs should consider integrating courses from business, management, and IT, which could attract a broader range of students and provide them with diverse skill sets that are increasingly valuable in the job market.

Improving Infrastructure and Resources

The barriers identified in implementing digital technologies highlight a critical need for improved infrastructure. Universities should invest in the necessary resources, such as digital tools and simulations, to create a conducive learning environment. Additionally, addressing the lack of resources and insufficient training for faculty will be essential for effective technology integration in the classroom.

Enhancing Industry Collaboration

The relatively low levels of industry collaboration suggest that universities must actively seek partnerships with industry players. Joint projects, sponsored research, and internship opportunities can bridge the gap between academic knowledge and practical application, ultimately benefiting both students and the engineering sector.

Fostering Entrepreneurial Support

The findings on support for entrepreneurial ventures point to a need for universities to provide more robust resources and mentorship for students interested in entrepreneurship. Establishing incubators, workshops, and networking opportunities can encourage innovation and empower students to pursue their entrepreneurial aspirations.

Key Strategies for Boosting Student Engagement and Retention in Engineering Education are summarized in Figure 5. In conclusion, these implications and recommendations aim to create a more dynamic and relevant engineering education landscape in Pakistan, ultimately enhancing student engagement and retention while preparing graduates for the challenges of a rapidly evolving industry.

Limitations

This study is subject to several limitations that should be acknowledged. Firstly, the sample size was also not large, and this may never have covered the entire range of experiences and opinions from all the institutions in the country, originating among students from various engineering faculties. Further, a tendency for self-reported data collection will always risk some bias since participants may not all equally perceive how (in)effective their own institutions are. Furthermore, the study's focus on faculty perspectives may overlook valuable insights from students, industry stakeholders, and alumni, limiting the comprehensiveness of the findings. Lastly, the evolving nature of engineering education and technology means that the results may quickly become outdated, necessitating ongoing research to continually assess and address the challenges faced in this field.

Overall, while these limitations should be acknowledged, they do not detract from the study's contributions to understanding the current state of engineering education in Pakistan and identifying areas for improvement. Despite its limitations, this study reveals important insights

regarding the relevance of the data collected.

Conclusions

The study identifies various challenges and potential areas of future exploration within the framework of engineering education in Pakistan. The key learning has been a major fall in students' interest-primarily due to labor market saturation and concerns that the curriculum is not good enough. Secondly, interaction with industry is very important, and the infusion of new technology should be integrated into the educational curriculum to make education responsive to present demands of industries. The findings stress the need for developing career counseling, internships, and faculty development in student involvement. They also form a basis for policy work directed towards renewing engineering education with a view to impending unemployment crises.

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