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Exploring Curriculum-Industry Alignment and Career Perceptions Among Ghanaian Biomedical Engineering Undergraduates

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Abstract

Biomedical engineering (BME) is an emerging discipline in Ghana with the potential to address critical gaps in healthcare delivery, medical device innovation, and workforce development. However, a persistent disconnect between academic training and industry demands has raised concerns about graduate employability and the development of clear professional pathways.

This cross-sectional mixed-methods study investigates how undergraduate BME students in Ghana perceive their discipline, articulate their career aspirations, and evaluate the alignment of their curriculum with industry expectations. Drawing on Social Cognitive Career Theory (SCCT) and Career Construction Theory (CCT), the study surveyed 58 students across six universities using a structured questionnaire combining closed- and open-ended items. Quantitative data were analysed using descriptive statistics, chi-square tests, t-tests, ANOVA, and Spearman's correlation, while qualitative findings were derived from open-ended responses.

The results indicate that fewer than 14% of students reported high confidence in their technical readiness, and over 80% expressed concerns about limited job opportunities in the local labour market. Significant associations were observed between perceived curriculum relevance and career commitment. While most students associated BME with hospital-based roles, many expressed interest in innovation and entrepreneurship when structural support was available. Qualitative findings revealed concerns about a theory-heavy curriculum, limited clinical immersion, and insufficient exposure to device design and advanced technologies.

These findings underscore the need for curriculum reform, strengthened industry–academia partnerships, and supportive policy frameworks that foster experiential learning and professional development. As Ghana expands its investments in healthcare and innovation ecosystems, equipping biomedical engineers with applied competencies and entrepreneurial pathways is critical. This study contributes evidence-based recommendations for strengthening STEM education and advancing workforce readiness in low- and middle-income contexts.

Introduction

Biomedical engineering (BME) is an interdisciplinary field that applies engineering principles to address complex healthcare challenges through the design of medical devices, diagnostics, and therapeutic systems. Globally, it plays a pivotal role in advancing health innovation, improving clinical outcomes, and supporting health systems development (Enderle et al., 2005; Houssein et al., 2019). In low- and middle-income countries (LMICs), including Ghana, BME has been identified as a strategic discipline capable of bridging gaps in medical infrastructure and localising technology for more sustainable healthcare delivery (Zhang, 2015; Perry & Malkin, 2011). Over the past two decades, Ghana has witnessed the expansion of BME academic programs in both public and private universities, aimed at building a skilled workforce for hospital equipment management, health technology development, and clinical engineering services (Mohedas et al., 2015; GIPC, 2023).

Despite these developments, significant concerns remain regarding the ability of BME education in Ghana to prepare students for evolving professional demands. As in many LMICs, there is a persistent disconnect between university curricula and the skills required in industry and healthcare practice (Quansah et al., 2019; Haule et al., 2024). Educational programs often emphasise theoretical instruction with limited integration of practical training, interdisciplinary design, or clinical immersion. Additionally, students are rarely exposed to biomedical entrepreneurship or innovation ecosystems, narrowing their perceived career options to roles in hospital-based maintenance or technical support. These structural limitations are further compounded by a lack of clear regulatory frameworks and minimal policy support for biomedical engineering as a recognised professional pathway (WHO, 2010; Owusu et al., 2018).

Mohedas et al. (2015) offered one of the earliest empirical investigations into the perceptions of Ghanaian BME students. Their study revealed widespread concern over career uncertainty, inadequate industry engagement, and weak post-graduation pathways. However, that work predates several transformative developments, including growing investment in Ghana's health infrastructure, increased private sector participation, and the emergence of innovation-focused academic programs. It is therefore timely to revisit and extend this analysis, particularly in the wake of global disruptions to education and healthcare systems that have reshaped expectations around employability, adaptability, and innovation in STEM fields.

This study addresses these gaps by examining how current undergraduate BME students in Ghana perceive their academic experiences, define their career aspirations, and evaluate the alignment between their training and real-world professional demands. The research is guided by Social Cognitive Career Theory (SCCT; Lent, Brown, & Hackett, 1994) and Career Construction Theory (CCT; Savickas, 2005), which together offer a robust framework for understanding how students form career intentions in response to self-efficacy beliefs, outcome expectations, and contextual influences. By applying these theories, this study investigates how students interpret the relevance of their education, identify barriers to career progression, and envision their future roles within Ghana's growing biomedical and health technology sectors.

Objectives of the Study

This study draws on two established frameworks; Social Cognitive Career Theory (SCCT) (Lent, Brown, & Hackett, 1994) and Career Construction Theory (CCT) (Savickas, 2005), to examine how undergraduate biomedical engineering (BME) students in Ghana perceive and navigate their educational and career trajectories. SCCT emphasises how self-efficacy, outcome expectations, and goal setting shape individual career behavior, while CCT adds a socio-contextual lens to understand how individuals respond to environmental realities such as labor market constraints, institutional supports, and evolving industry demands.

Guided by these theories, the study investigates how students experience the BME discipline, their professional aspirations, and the alignment or misalignment between their training and the realities of

the biomedical sector in Ghana. Specifically, this study aims to:

1. Examine students' understanding of biomedical engineering as a discipline, including its perceived scope, relevance, and role in Ghana's healthcare sector.
2. Identify the key motivations influencing students' decision to pursue biomedical engineering, in relation to both personal interest and external factors such as information access and societal perceptions.
3. Explore students' career aspirations and perceptions of job availability, including opportunities in academia, industry, innovation, and health system integration.
4. Investigate the academic and structural challenges students face during their training, including limitations in curriculum content, practical training, mentorship, and professional exposure.
5. Evaluate the alignment between the current BME curriculum and industry expectations, particularly with regard to applied skills, regulatory awareness, and entrepreneurial readiness.
6. Analyse students' views on the role of government, private institutions, and industry partnerships in shaping their career opportunities and readiness for emerging roles in biomedical innovation.

These objectives collectively offer a multidimensional view of the educational-to-career pipeline in Ghanaian biomedical engineering, and generate insights that inform curriculum enhancement, institutional development, and national workforce strategy within a constrained ecosystem.

Significance of the Study

This study contributes to the growing discourse on STEM education and workforce readiness in low- and middle-income countries (LMICs). First, it expands our understanding of how biomedical engineering students in LMICs form their professional identities within emerging innovation ecosystems. By applying SCCT and CCT to a technical field like biomedical engineering in a lower-middle-income country, the study expands the use of these frameworks beyond traditional vocational psychology, and highlights how students' personal goals and motivations interact with broader institutional and structural constraints.

Second, this research addresses persistent concerns about whether STEM graduates are adequately prepared for the workforce, whether curricula meet industry needs, and how effectively education leads to employment. It offers new evidence from Ghana, where investments in health infrastructure and STEM education are growing, at a time when stronger coordination between universities, industry, and policymakers is urgently needed.

The findings offer actionable insights for curriculum reform, internship development, and innovation support. They also inform broader debates on how universities in resource-constrained settings can nurture graduates who are not only technically competent, but also entrepreneurial, adaptable, and prepared to contribute to national development priorities.

Literature Review

Biomedical Engineering Education and Workforce Development in LMICs

Biomedical engineering has been widely recognised as a critical driver of healthcare innovation, particularly in low- and middle-income countries (LMICs) where locally adapted technologies are essential for sustainable health systems (Zhang, 2015; Perry & Malkin, 2011). In many African contexts, biomedical engineers play key roles in equipment maintenance, health technology management, and device adaptation; however, the professionalisation of the field remains uneven due to limited policy frameworks and institutional support (WHO, 2010; Haule et al., 2024).

In Ghana, the expansion of biomedical engineering programmes reflects growing recognition of the discipline's strategic importance (Mohedas et al., 2015; GIPC, 2023). Nevertheless, concerns persist regarding the alignment between academic preparation and labour market demands. Graduates frequently report uncertainty about career pathways, limited access to structured internships, and underdeveloped innovation ecosystems (Quansah et al., 2019). These structural challenges mirror patterns observed across sub-Saharan Africa, where STEM graduates often encounter barriers to professional integration (Aina, 2017).

Curriculum–Industry Alignment in Engineering Education

Curriculum relevance has been identified as a central determinant of graduate employability in engineering and STEM disciplines (Froyd & Ohland, 2005; Male & King, 2019). Integrated curricula that combine theoretical instruction with experiential learning, industry collaboration, and interdisciplinary projects are associated with stronger professional preparedness and confidence.

Work-integrated learning, including internships and cooperative education programmes, plays a particularly important role in bridging academic and professional contexts (Jackson, 2015). Such experiences support the development of technical competence, communication skills, and professional identity. However, in many LMIC settings, access to structured placements remains limited, contributing to persistent skills gaps and weakened career trajectories (Quansah et al., 2019; Haule et al., 2024).

Studies in engineering education further suggest that curricula lacking applied components may undermine students' perceptions of relevance and long-term commitment to the profession (Male & King, 2019). This reinforces the importance of sustained partnerships between universities, healthcare institutions, and industry stakeholders.

Student Motivation, Career Development, and STEM Pathways

Students' decisions to enter and persist in STEM fields are shaped by complex interactions between personal interests, perceived opportunities, and social influences (Wang & Degol, 2013). In Ghana, Owusu et al. (2018) found that tertiary students' career choices are strongly influenced by family expectations, role models, and perceptions of job security.

Research on engineering students indicates that early exposure to professional contexts and accurate information about career pathways enhances motivation and retention (Male & King, 2019). Conversely, limited awareness of employment prospects may lead to uncertainty and disengagement, particularly in emerging disciplines such as biomedical engineering (Mohedas et al., 2015).

These patterns highlight the need for systematic career guidance and mentorship within STEM programmes, especially in environments where labour markets are still developing.

Entrepreneurship and Innovation in STEM Education

Entrepreneurship has increasingly been recognised as a key component of STEM education, particularly in contexts where traditional employment opportunities are limited (Rae & Melton, 2017). Innovation-oriented curricula that integrate design thinking, business development, and interdisciplinary collaboration can enhance graduates' capacity to translate technical knowledge into viable ventures.

In emerging economies, however, entrepreneurial intentions often remain unrealised due to limited access to funding, incubation facilities, and mentorship (Zhang, 2015). Without institutionalised innovation pathways, students' ambitions may remain aspirational rather than actionable.

Embedding entrepreneurship within biomedical engineering education may therefore strengthen both individual career outcomes and national innovation systems.

Theoretical Perspectives: SCCT and Career Construction Theory

Social Cognitive Career Theory (SCCT) emphasises the role of self-efficacy, outcome expectations, and goal-setting in shaping academic and career behaviour (Lent et al., 1994). Numerous studies have demonstrated that students who perceive strong links between education and employment are more likely to persist in STEM fields and pursue related careers.

Career Construction Theory (CCT) complements this perspective by focusing on how individuals construct meaning and adapt to changing professional environments (Savickas, 2005). In structurally constrained contexts, career development often involves negotiating uncertainty, redefining aspirations, and responding to limited opportunities.

Together, these frameworks provide a robust lens for examining how biomedical engineering students in Ghana navigate motivation, preparedness, and professional identity formation.

Methods

Study Design

This study employed a cross-sectional mixed-methods design to investigate how undergraduate biomedical engineering (BME) students in Ghana perceive their academic training and its relevance to future career opportunities. The design focused on five key domains: students' understanding of BME, motivations for entering the field, career aspirations, academic and structural challenges, and perceived alignment of curricula with industry needs. A cross-sectional approach was appropriate for capturing diverse perspectives across academic levels and institutions at a single point in time.

The study was grounded in Social Cognitive Career Theory (SCCT) and Career Construction Theory (CCT), which informed the design of the research instruments and analysis. SCCT emphasises the role of self-efficacy, outcome expectations, and goal-setting in shaping career choices (Lent, Brown, & Hackett, 1994), while CCT addresses how individuals construct meaning from educational experiences and navigate career pathways in response to environmental influences (Savickas, 2005).

Study Population and Sample

The target population comprised undergraduate BME students from six public and private universities in Ghana offering BME programs. A total of 58 students participated in the study, recruited through a convenience sampling strategy to ensure representation across all academic levels (Year 1 to Year 4).

Given the exploratory nature of the study and limited national data on this student population, this sampling approach was deemed appropriate for capturing early trends and identifying issues of broader systemic concern. Participation was entirely voluntary and anonymous, and data collection was conducted electronically to enhance accessibility and ensure respondent confidentiality.

Data Collection

A structured questionnaire was developed based on a synthesis of prior studies on STEM career development, BME education, and student motivation in LMIC contexts (Mohedas et al., 2015; Owusu et al., 2018; Quansah et al., 2019). The questionnaire included both closed-ended and open-ended items, structured around five thematic domains:

1. Knowledge and understanding of biomedical engineering
2. Motivations for choosing the discipline
3. Perceptions of career opportunities
4. Academic and professional challenges
5. Perceived alignment of the curriculum with industry demands

The survey instrument was reviewed for content validity by senior faculty members with expertise in biomedical engineering education and career development, and revised based on their feedback prior to

dissemination. The final survey was distributed via Google Forms through student associations, course coordinators, and faculty networks across participating institutions.

Participants were informed of the study's purpose, their right to withdraw at any time, and the anonymity of responses.

Data Analysis

A mixed-methods analytical approach was conducted to address the research objectives. The analysis was framed in the context of Social Cognitive Career Theory (SCCT) and Career Construction Theory (CCT), ensuring that both individual agency (e.g., self-efficacy, outcome expectations) and contextual realities (e.g., labor market conditions, institutional support) were considered in the interpretation of the findings.

Quantitative Analysis

Closed-ended responses were coded and analysed using IBM SPSS Statistics. The dataset was cleaned to remove incomplete or duplicate entries. Descriptive statistics (frequencies, percentages, means, standard deviations) were used to summarise demographic characteristics, curriculum alignment, confidence levels, and career intentions.

Inferential statistical analyses included:

- Chi-square tests to examine associations between categorical variables.
- T-tests and ANOVA to compare mean confidence and curriculum satisfaction scores across demographic groups.
- Spearman's correlation to explore relationships between ordinal variables.
- Cronbach's alpha to assess the internal consistency of Likert-style item groupings.

All analyses were conducted with reference to theoretical constructs from SCCT and CCT.

Qualitative Analysis

Open-ended survey responses were analysed thematically using the six-phase approach of Braun and Clarke (2006). Although themes were allowed to emerge inductively, the analysis was informed by SCCT and CCT to ensure theoretical coherence.

All qualitative data were de-identified and reviewed through a structured coding process. Initial codes were generated, refined into themes, and compared across academic levels and reported experiences. Where thematic saturation was achieved, identifiers such as academic year were reintroduced to examine shifts in confidence, exposure, and career clarity.

To enhance the trustworthiness and credibility of the analysis, coding procedures and decisions were documented in a transparent audit trail. Regular team discussions were held to resolve discrepancies, verify theme coherence, and ensure that interpretations remained grounded in the data.

Qualitative themes were used to interpret and enrich the quantitative findings, particularly in areas related to institutional support, perceived readiness, barriers to innovation, and the role of identity in career formation.

Results

Participant Characteristics

A total of 58 undergraduate biomedical engineering students from six Ghanaian universities participated in the study. The sample included students across all levels of study (Level 100 to Level 400), providing a diverse cross-section of academic experiences. Gender distribution was relatively balanced, ensuring representation of perspectives across male and female respondents (see Fig. 1a and 1b).

Figure 1b

Distribution of Respondents by Academic Level – Bar chart arranged from Level 100 to Level 400.

Objective 1: Understanding of Biomedical Engineering as a Discipline

This theme examined students' knowledge and conceptualisation of biomedical engineering and its perceived relevance to Ghana's healthcare sector.

Most respondents demonstrated a basic understanding of biomedical engineering as an interdisciplinary field combining engineering and medical sciences. However, many primarily associated the profession with hospital equipment maintenance and technical support. Fewer students referenced innovation, device development, or research-oriented roles.

Qualitative responses indicated that limited exposure to professional role models and industry engagement contributed to narrow perceptions of the field. Several students reported learning about broader applications only after enrolling in the programme.

Objective 2: Motivations for Choosing Biomedical Engineering

Students' motivations for pursuing biomedical engineering were influenced by both intrinsic and extrinsic factors (see Fig. 2). The most frequently cited motivations included personal interest in science and technology, perceived societal relevance, and encouragement from mentors or family members.

Prior to enrollment, most students had conducted some form of research into the field (M = 3.00, SD = 1.01). These efforts included online searches, speaking with professionals, and attending university outreach events. When asked to what extent their current training aligned with their personal goals and

professional aspirations, students expressed moderate satisfaction (M = 3.76, SD = 1.06). However, the standard deviation suggests variability in perceived alignment, highlighting potential differences in clarity or satisfaction across the cohort.

These early patterns point to initial motivation and alignment with the field, consistent with SCCT's emphasis on outcome expectations and goal-setting, while also indicating areas where institutional communication and orientation could be improved to reinforce student engagement.

Objective 3: Career Aspirations and Employment Perceptions

Students' career aspirations were explored in relation to perceived job opportunities and long-term professional goals (see Fig. 3).

Most respondents indicated interest in hospital-based roles, postgraduate studies, or overseas employment. Only a minority reported clear plans to pursue entrepreneurship or research careers. A significant majority, 84% (49 out of 58) believed that biomedical engineering in Ghana lacks sufficient job opportunities. Only 9 students felt confident about future employment, with many expressing uncertainties about available career pathways and long-term stability.

This widespread pessimism underscores the uncertainty students feel about their professional futures and reflects systemic barriers that reduce perceived feasibility (SCCT) and career adaptability (CCT). As a result, many respondents reported considering further education abroad, career shifts, or leaving the field entirely.

Objective 4: Academic and Structural Challenges

This theme examined barriers encountered during students' academic training, including access to practical learning, mentorship, and professional exposure.

When asked to rate their preparedness for the technical demands of a career in biomedical engineering, the average score was 2.81 (SD = 0.98), suggesting that most students felt only moderately prepared (see Fig. 5). Students who reported lower confidence often cited gaps in hands-on training, clinical exposure, and applied technology skills.

In a related question, students identified areas where they felt the curriculum lacked emphasis. The most commonly cited gaps included medical device design, programming, data analysis, and exposure to clinical settings (see Fig. 4). These responses confirm the perception of a theoretical-heavy curriculum with limited practical immersion. These are factors that undermine self-efficacy and career readiness (SCCT).

Internship Experience

Internship participation was limited. While a few students reported structured placements, most had no formal experience during their training. Among those who had interned, three themes emerged from

open-ended reflections:

- Enhanced practical understanding: Internships clarified how biomedical engineers operate in real-world settings.
- Redefined career expectations: Students reported gaining a more realistic understanding of roles available post-graduation.
- Systemic barriers: Several described role confusion or lack of structured mentorship during placements.

As one respondent shared:

In the hospital, they classified biomedical engineers as medical device repairers… there's little room to innovate unless you leave.

These themes illustrate how internships shape adaptability and career meaning (CCT), but also highlight inequities in access and institutional readiness.

Objective 5: Curriculum–Industry Alignment and Skill Development

Students were asked to evaluate the relevance of their curriculum to industry and professional practice. Moderate alignment was reported (M = 3.76, SD = 1.06), although responses varied considerably. Many students perceived the curriculum as overly theoretical, with insufficient emphasis on applied problem-solving.

Inferential analysis revealed a significant association between curriculum satisfaction and career commitment, $\chi^2(8) = 17.15$, $p = 0.029$, indicating that perceived relevance influenced professional intentions.

Figure 5a

Student Confidence in Technical Preparation — Shows most students rate their readiness as 2 or 3 on a 5-point scale, reinforcing concerns about curriculum-practice gaps.

Figure 5b

Perceptions of Job Opportunities — A clear majority believe there are insufficient job opportunities for biomedical engineers in Ghana.

Objective 6: Institutional, Policy, and Industry Support Structures

This theme examined students' perceptions of external support mechanisms, including government policy, private sector engagement, and university–industry partnerships.

Most respondents reported limited awareness of national biomedical engineering policies or structured innovation programmes. Industry collaboration was perceived as inconsistent and institution-dependent.

Despite these constraints, students expressed strong interest in future innovation and entrepreneurship (see Fig. 6), with 33 respondents anticipating leadership in biomedical startups. However, few reported current access to incubation, funding, or mentorship.

These findings suggest untapped entrepreneurial potential constrained by systemic limitations.

Inferential Analysis

To explore variation in perceptions, motivations, and confidence across subgroups and theoretical constructs, inferential statistical tests were conducted.

Curriculum Satisfaction and Career Intent

A chi-square test revealed a statistically significant association between curriculum satisfaction (low vs. high) and students' intention to pursue a career in biomedical engineering, $\chi^2(8) = 17.15$, $p = 0.029$. Students who perceived their curriculum as industry-relevant were more likely to see themselves continuing in the field. This supports SCCT's view that outcome expectations influence long-term commitment.

Research Effort and Curriculum Perception

A Spearman correlation analysis revealed a positive relationship between the extent of research conducted before enrollment and perceived curriculum alignment ($\rho = 0.37$, $p = 0.005$). This suggests that students who entered the program with clearer expectations were more likely to interpret their training as relevant, aligning with SCCT's emphasis on informed goal-setting.

Gender and Motivational Differences

A chi-square test comparing reported motivations across gender groups revealed no statistically significant differences, $\chi^2(8) = 7.70$, $p = 0.464$. Both male and female students cited similar influences, including personal interest, career opportunities, and inspiration from mentors.

Confidence by Academic Level

An ANOVA revealed a statistically significant difference in technical confidence scores across academic levels, $F(3, 54) = 3.79$, $p = 0.015$. Confidence generally increased with academic progression, suggesting that students gain self-efficacy over time, though not uniformly. This pattern supports both SCCT (self-efficacy development) and CCT (evolving adaptability) across the student lifecycle.

Summary of Findings

Overall, the findings reveal a motivated but moderately confident student body navigating structural gaps in experiential learning, curriculum relevance, and career visibility. While enthusiasm for future innovation

remains high, current limitations in internships, entrepreneurial support, and professional clarity continue to shape how students interpret their prospects. These results point to an urgent need for institutional reform, stronger academia-industry linkages, and national policy frameworks that support education-to-employment transitions in emerging STEM sectors like biomedical engineering.

Discussion

This study examined how undergraduate biomedical engineering (BME) students in Ghana understand their field, construct career aspirations, and evaluate the relevance of their academic training to emerging professional demands on healthcare. Drawing on Social Cognitive Career Theory (SCCT) and Career Construction Theory (CCT), the findings provide insight into how students navigate motivation, confidence, opportunity, and constraint within a growing but underdeveloped health technology ecosystem of low- and middle-income countries (LMICs).

Overall, the results reveal a student population that is highly motivated and socially committed, yet constrained by structural limitations in curriculum design, experiential learning, and labour market integration. These patterns reflect broader challenges in STEM education and workforce development in low- and middle-income countries (Owusu et al., 2018; Quansah et al., 2019).

Academic Preparation, Self-Efficacy, and Career Intentions

(Objectives 1, 2, and 5)

Students entered biomedical engineering programmes with moderate levels of prior research and strong initial enthusiasm, often motivated by personal interest and perceived societal relevance. Similar motivational patterns have been reported among Ghanaian and African tertiary students in STEM fields (Owusu et al., 2018). However, confidence in technical preparedness remained moderate, with fewer than 14% reporting high levels of readiness.

This finding aligns with Mohedas et al. (2015), who reported persistent concerns about curriculum relevance and professional preparedness among Ghanaian BME students. Despite institutional expansion and curricular reforms over the past decade, students in the present study continue to experience a disconnect between theoretical instruction and applied competence.

From an SCCT perspective, this misalignment weakens self-efficacy and outcome expectations, thereby influencing career persistence. Students who perceived greater curriculum–industry alignment were more likely to express commitment to biomedical engineering, reinforcing the central role of perceived relevance in shaping professional trajectories.

Experiential Learning, Industry Exposure, and Structural Barriers

(Objectives 3, 4, and 6)

Internships and industry placements emerged as critical yet unevenly distributed learning opportunities. Students who had participated in placements reported improved understanding of professional roles and greater clarity regarding career expectations. This mirrors findings from engineering education research emphasising the importance of work-integrated learning for professional identity development (Quansah et al., 2019).

However, most respondents lacked access to structured placements. Where internships existed, they were often characterised by limited mentorship and unclear professional boundaries. These findings reflect broader institutional gaps in clinical engineering systems documented by Perry and Malkin (2011) and the World Health Organization (2010), particularly in LMIC contexts where biomedical professionals are under-recognised and under-utilised.

From a CCT perspective, limited experiential learning restricts students' capacity to adapt to professional environments and construct coherent career narratives. Without sustained exposure to practice settings, students struggle to reconcile academic training with workplace realities.

Labour Market Uncertainty and Professional Identity Formation

(Objectives 3 and 6)

A dominant theme in the findings was uncertainty regarding employment opportunities. More than 80% of respondents perceived the biomedical engineering job market in Ghana as limited. Similar concerns have been reported in Tanzania and other African contexts, where weak policy frameworks constrain the professionalisation of biomedical engineering (Haule et al., 2024).

This uncertainty contributes to fragmented professional identity formation. Many students associated biomedical engineering primarily with equipment maintenance, rather than innovation or research. Such narrow role conceptualisations may reflect limited visibility of diverse career pathways and weak integration of biomedical engineers into national health systems (WHO, 2010).

CCT offers a valuable lens for interpreting these findings, as students are striving to build meaningful careers amid evolving institutional structures and limited policy support. In this context, career construction becomes a process of negotiation between aspiration and structural constraint.

Entrepreneurial Aspirations and Innovation Potential

(Objectives 3 and 6)

Despite limited current engagement in innovation, students expressed strong interest in future entrepreneurial activity. Many envisioned leadership roles in medical technology startups, artificial intelligence, and device development. This finding suggests substantial latent innovation potential.

Similar patterns have been observed in emerging STEM ecosystems, where students demonstrate entrepreneurial intent but lack access to incubation structures and funding mechanisms (Zhang, 2015). Without institutionalised innovation pathways, such ambitions remain aspirational rather than actionable.

The findings indicate that embedding entrepreneurship education, interdisciplinary collaboration, and industry mentorship within BME programmes could help translate student interest into sustainable ventures. Such reforms would strengthen both individual career outcomes and national innovation capacity.

Contribution to Theory and Practice

By applying SCCT and CCT to biomedical engineering education in a lower-middle-income country, this study extends the use of these frameworks beyond traditional vocational psychology contexts. It demonstrates how self-efficacy, outcome expectations, and adaptability interact within structurally constrained professional environments.

Practically, the findings provide evidence to inform curriculum reform, internship development, and policy alignment. They highlight the need for coordinated action among universities, healthcare institutions, industry stakeholders, and regulatory bodies to create coherent education-to-employment pathways.

Implications for STEM Education Policy and Institutional Reform

The study underscores the importance of positioning biomedical engineering within national STEM and health development strategies. As Ghana expands investments in healthcare infrastructure (GIPC, 2023), parallel investment in human capital development is essential.

Institutions should prioritise:

- Integrated clinical and industrial placements
- Applied design and innovation modules
- Structured mentorship programmes
- National accreditation and professional recognition frameworks

Such reforms would enhance graduate employability and strengthen the sustainability of biomedical engineering as a strategic STEM discipline.

Limitations and Future Directions

This study is not without limitations. The use of convenience sampling may introduce selection bias and limit the generalisability of the findings beyond the six institutions represented. Additionally, while the mixed-methods approach provided valuable insights, the relatively small sample size constrained the depth of subgroup analyses and the reliability of composite measures.

Future research should consider employing larger, multi-institutional samples and longitudinal designs to track how student perceptions and career intentions evolve over time. There is also a need to incorporate employer and faculty perspectives, particularly in understanding expectations, skill gaps, and alignment with industry demands. Methodologies such as participatory action research may also be valuable in engaging students, educators, and stakeholders collaboratively to co-design solutions and evaluate the impact of curricular or institutional reforms.

Expanding this line of inquiry across other LMIC settings would enable comparative analysis of how biomedical engineering education can best respond to diverse national development priorities, health system needs, and innovation goals.

Conclusion and Recommendations

This study examined the perceptions, motivations, and career expectations of undergraduate biomedical engineering students in Ghana, offering new insights into the relationship between STEM education and professional readiness in a lower-middle-income context. While students enter the field with enthusiasm and a sense of purpose, many face challenges related to limited industry exposure, misaligned curricula, and uncertainty about employment opportunities. These structural issues, particularly the lack of internships, hands-on training, and innovation pathways, significantly influence students' confidence in their readiness for biomedical careers.

By applying Social Cognitive Career Theory and Career Construction Theory, the study highlights how students' career intentions are shaped by both personal agency (e.g., self-efficacy, goal setting) and contextual constraints (e.g., weak policy support, limited labour market pathways). Students who engaged in early research or had access to experiential learning reported higher confidence and clearer career orientation, highlighting the value of proactive career development structures.

To address these gaps and unlock the full potential of biomedical engineering as a national asset in health innovation, several targeted interventions are recommended:

For Academic Institutions:

1. Integrate applied learning through project-based modules, design challenges, and clinical engineering exposure.
2. Establish structured internship programs in partnership with hospitals, regulators, and device manufacturers.
3. Incorporate entrepreneurial and interdisciplinary training to broaden career pathways beyond traditional clinical roles.

For Industry and Clinical Stakeholders:

1. Co-develop internship and mentorship schemes with universities to expose students to real-world challenges.
2. Support collaborative research and co-supervision models that bridge the academic and clinical engineering gap.

For Policymakers:

1. Develop national frameworks to recognise biomedical engineering as a strategic health and technology profession.
2. Incentivise innovation hubs and medtech startups with funding and incubation programs targeted at student-led ideas.
3. Facilitate regulatory and professional certification structures that clarify career progression and institutional roles.

As Ghana continues to invest in STEM education and healthcare infrastructure, equipping biomedical engineering graduates with the technical, professional, and entrepreneurial competencies they need will be vital. This study contributes evidence-based recommendations to support that mission, demonstrating that with strategic alignment between education, industry, and policy, biomedical engineers can play a central role in advancing Ghana's health technology ecosystem and broader development goals.

Declarations

Author Contributions

J.B., M.A., and Y.D. designed and administered the survey. J.B., M.A., and H.T. conducted data analysis and prepared figures. W.B. coordinated survey development. H.T. led manuscript drafting and revision. All authors reviewed and approved the final manuscript.

Funding Declaration

This research received no external funding.

Declarations

Ethical Approval

In accordance with Academic City University's institutional research governance procedures, ethical oversight for research involving human participants is provided by the **Academic City University Research Committee**. The Committee determined that this study was exempt from formal ethical review because it involved anonymous, voluntary survey responses from adult participants, presented no more than minimal risk, and did not involve the collection of sensitive personal or clinical data. The study was conducted in accordance with the University's institutional guidelines for research involving human participants.

Consent to Participate

Informed consent was obtained from all participants prior to participation in the study. Participants were informed about the purpose of the research, the voluntary nature of participation, their right to withdraw at any time, and the measures in place to ensure anonymity and confidentiality.

Consent to Publish

‘Not applicable’.

Data Availability

The raw data supporting the findings of this study are included as supplementary material in the submission.

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Figures

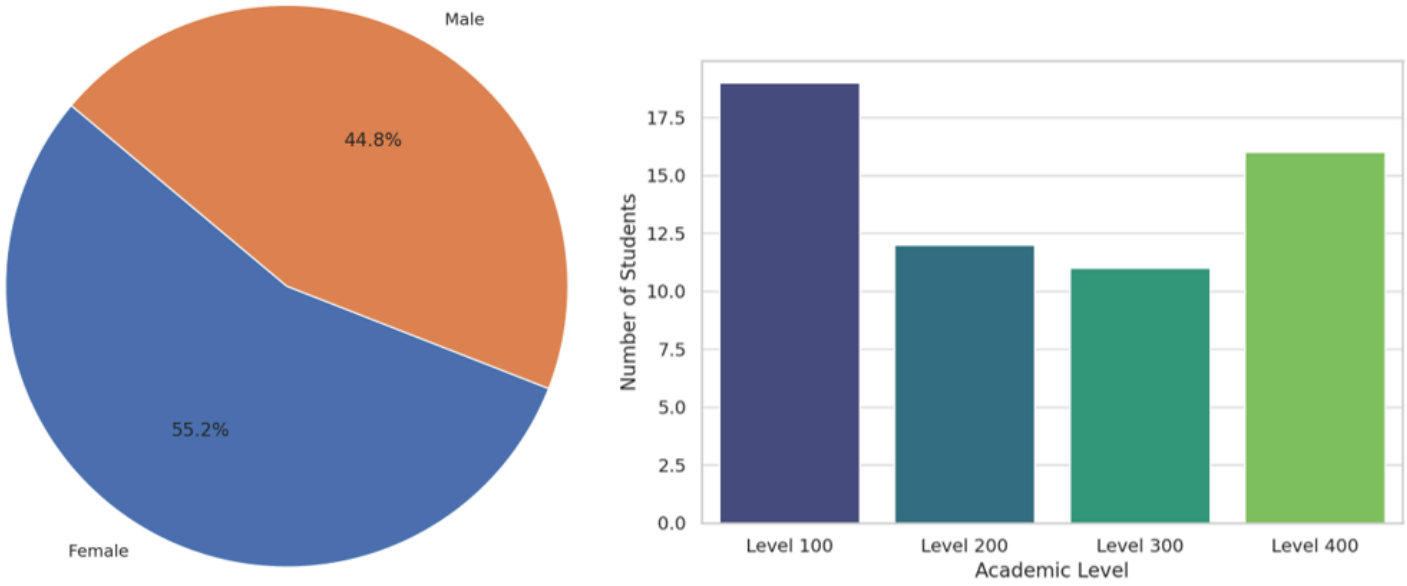


Figure 1

Figure 1a: *Gender Distribution of Respondents – Pie chart showing the gender balance in the sample.*

Figure 1b: *Distribution of Respondents by Academic Level – Bar chart arranged from Level 100 to Level 400.*

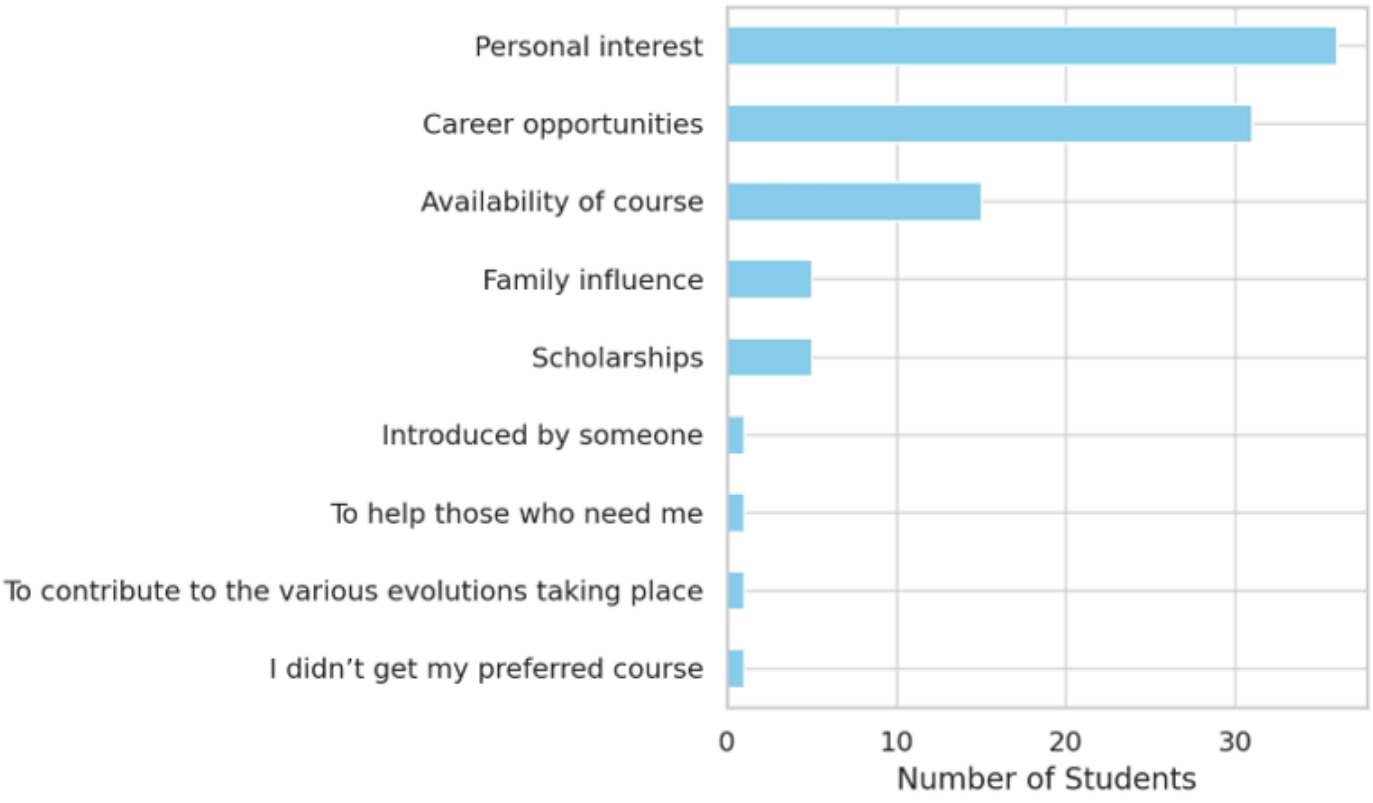


Figure 2

Motivations for Choosing Biomedical Engineering — Highlights key drivers such as personal interest, career opportunities, and influence from family or mentors.

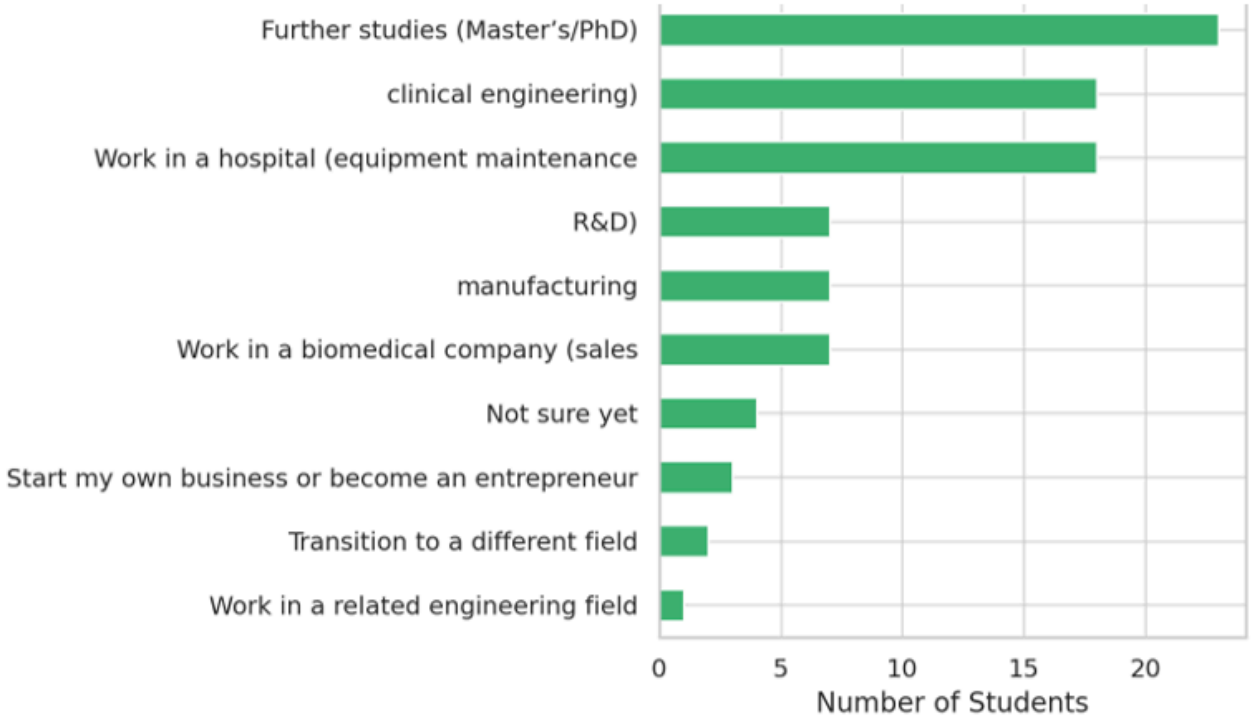


Figure 3

Career Aspirations After Graduation — Most students indicate interest in further studies or clinical/hospital-based roles, with limited mention of entrepreneurship.

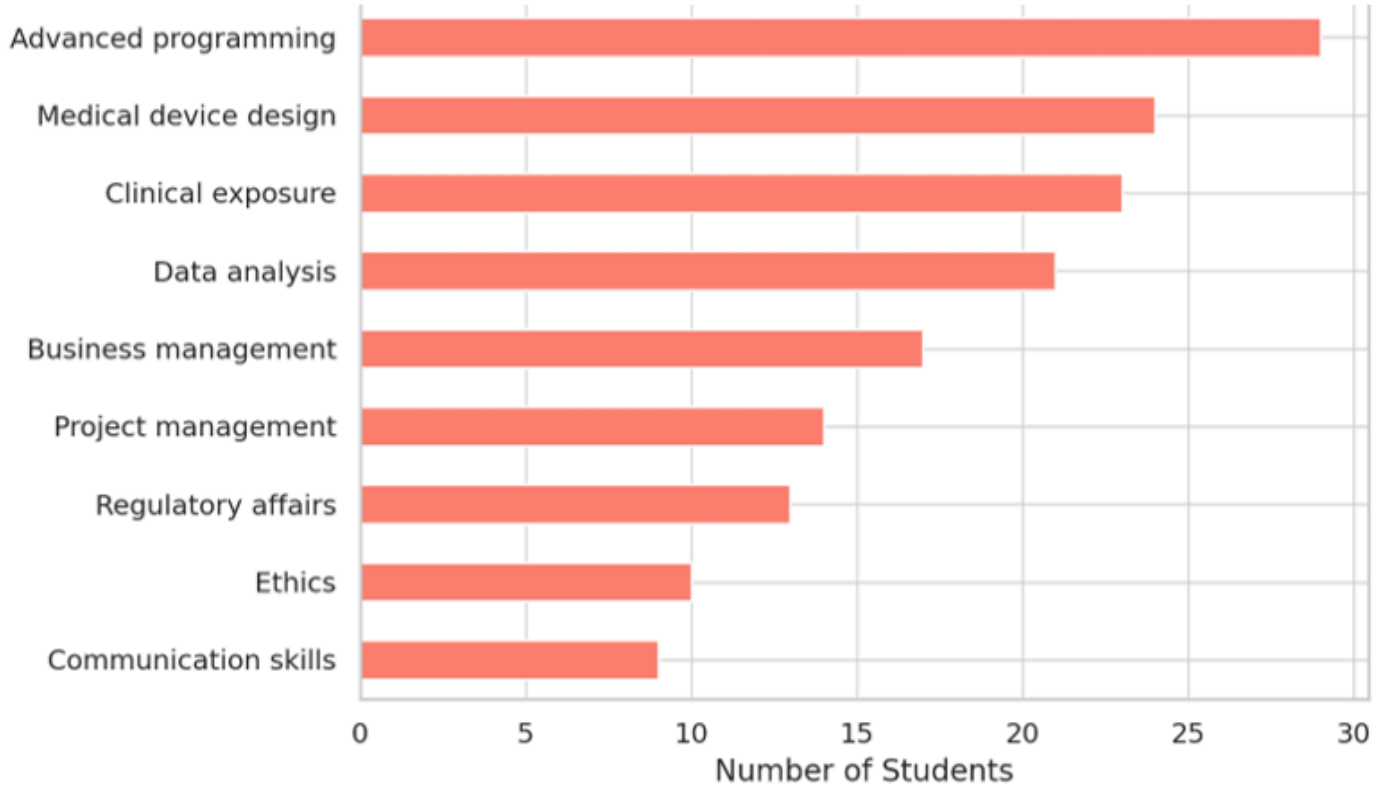


Figure 4

Reported Gaps in Curriculum — Reveals perceived deficits in areas like advanced programming, medical device design, and clinical exposure.

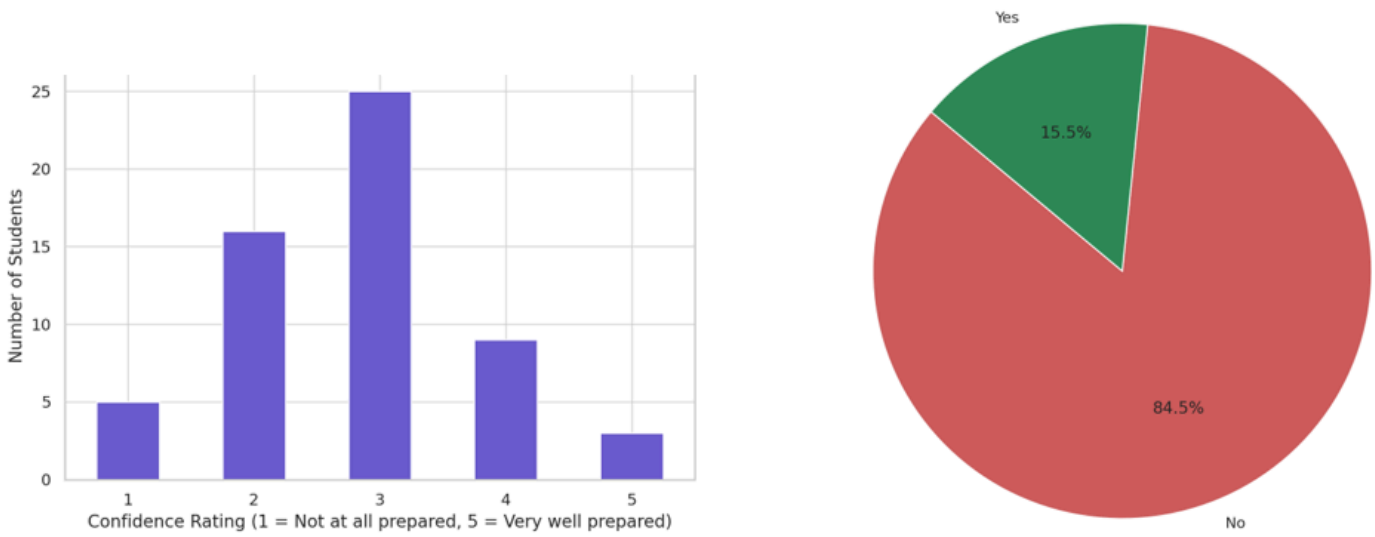


Figure 5

Figure 5a: *Student Confidence in Technical Preparation — Shows most students rate their readiness as 2 or 3 on a 5-point scale, reinforcing concerns about curriculum-practice gaps.*

***Figure 5b**: Perceptions of Job Opportunities — A clear majority believe there are insufficient job opportunities for biomedical engineers in Ghana.*

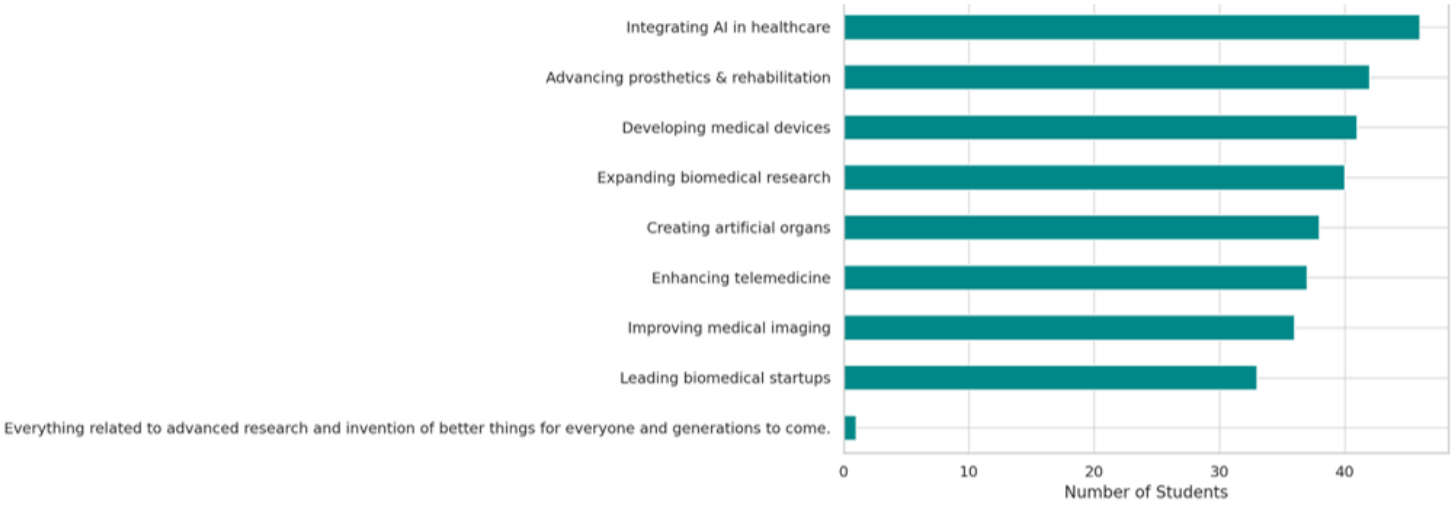


Figure 6

Students' Expectations of Biomedical Engineers in the Next 10–15 Years — The chart illustrates students' forward-looking visions, with the most common expectations centered around AI integration, rehabilitation technology, and medical device development. A notable portion of students also envision leadership in biomedical startups.