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Improving Industry Readiness: Insights from a Pilot Study of Biomedical Engineering Program

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Abstract
The competency of biomedical engineering graduates plays a critical role in ensuring industry readiness and meeting the evolving demands of the healthcare sector. This pilot study evaluates the reliability and validity of an assessment instrument designed to measure the competencies of biomedical engineering students. Using a structured questionnaire, data were collected from 30 students to examine their technical competencies across six domains: theory, operation, safety, servicing, repair, and management. Reliability analysis yielded high Cronbach's alpha values (ranging from 0.739 to 0.932), confirming the instrument's consistency in assessing industry-related skills. Findings reveal that while students demonstrate strong theoretical knowledge, there is a need for enhanced hands-on training, practical exposure to medical devices, and alignment between academic preparation and industry expectations. This study underscores the importance of refining industrial training modules to better equip students for roles in the maintenance, repair, planning, and procurement of biomedical equipment. The validated assessment framework provides a foundation for broader research on competency development and its application ability to other engineering discipline.
Keywords: Biomedical Engineering, Competency Assessment, Industry Readiness, Medical Devices, Training Modules, Pilot Study

Introduction

Biomedical engineering is a rapidly growing interdisciplinary field that integrates principles of engineering with medical sciences to enhance healthcare technology and patient care. The increasing reliance on advanced medical devices and emerging technologies such as artificial intelligence (AI) and the Internet of Things (IoT) in healthcare underscores the critical role of biomedical engineers in ensuring the safety, efficiency, and functionality of medical equipment. As the industry evolves, so do the expectations placed on biomedical engineering graduates, who must possess a diverse set of competencies, including technical expertise, problem-solving skills, and practical experience in medical device management.

Competency in biomedical engineering encompasses a blend of technical knowledge, practical skills, cognitive abilities, and professional attitudes essential for addressing the challenges of the healthcare industry. Biomedical engineers are responsible for ensuring the reliability and functionality of medical devices, which are critical to patient safety and clinical outcomes. Their competencies must span various domains, including the maintenance, repair, installation, commissioning, and disposal of medical equipment, as well as planning and procurement processes.

Technical knowledge forms the foundation of competency, enabling engineers to understand complex biomedical systems and technologies. Practical skills are equally vital as they involve hands-on expertise in troubleshooting, repairing, and optimizing medical devices. Abilities such as analytical thinking, problem-solving, and decision-making are necessary for adapting to the rapidly evolving technological landscape in healthcare. Additionally, attitudes such as a commitment to safety, attention to detail, and adherence to ethical practices are integral to maintaining high standards in medical device management. Competent biomedical engineers must also demonstrate the ability to work collaboratively with healthcare professionals, ensuring that technology effectively supports clinical needs.

In Malaysia, the demand for highly skilled biomedical engineers continues to rise due to advancements in healthcare infrastructure and the growing complexity of medical technology. However, despite the presence of specialized academic programs, many graduates face challenges in transitioning from university education to industry roles. Studies have shown a gap between academic preparation and industry expectations, particularly in hands-on experience, industrial exposure, and competencies related to maintenance, repair, and procurement of medical devices. This misalignment has led to concerns regarding graduates' readiness to meet real-world demands in hospital and healthcare settings.

To address this issue, this study evaluates the competencies of biomedical engineering students through a pilot study aimed at assessing their technical readiness for the industry. Using a structured questionnaire covering six key competency domains namely, theory, operation, safety, servicing, repair, and management, the research examines the extent to which students are prepared for practical applications in the workforce. The findings of this study will provide valuable insights into improving industrial training modules, curriculum development, and industry-academia collaborations, ultimately enhancing the employability and effectiveness of biomedical engineering graduates in Malaysia and beyond.

Problem Statements

Biomedical engineering is a critical discipline that integrates engineering principles with medical science to address healthcare challenges. Globally, the demand for highly skilled biomedical engineers is increasing due to rapid advances in medical technology and the increasing complexity of healthcare systems (Cruz et al., 2020a).

Despite the existence of specialized biomedical engineering programs, studies indicate that graduates often struggle to meet industry expectations due to insufficient hands-on experience. A 2020 industry report by the Malaysian Biomedical Engineering Association (MBEA) found that over 60% of biomedical graduates required additional technical training upon employment, underscoring the need for stronger alignment between academic curricula and practical industry needs. Similarly, a World Health Organization (WHO) report on the global biomedical engineering workforce readiness highlights that countries with structured competency-based training programs exhibit higher job placement rates and improved healthcare equipment management (World Health Organization (WHO), 2017)These findings indicate a growing concern regarding the preparedness of graduates in Malaysia and other developing economies. Addressing this issue is crucial to ensuring a competent workforce capable of maintaining and managing advanced medical technologies in hospitals and healthcare institutions.

This study focuses on the gap between academic training and industry expectations for biomedical engineers in Malaysia. The paper highlights that despite specialized academic programs, many graduates lack the practical experience and practical skills required for the maintenance, repair, installation, and procurement of medical devices (M. L. Cruz et al., 2020a; Mulenga & Kabombwe, 2019). A survey revealed that over 50% of Malaysian biomedical engineers work in sales and application roles as opposed to technical service roles, indicating a mismatch between education and industry needs. This competency gap poses significant risks to healthcare services as the industry continues to evolve with advanced technologies such as AI and IoT-enabled devices.

This competency gap poses a significant challenge to Malaysia's healthcare system, particularly in ensuring the reliability and safety of medical devices. Furthermore, as the industry continues to evolve with the integration of advanced technologies, the need for competent biomedical engineers who can adapt to these changes becomes even more pressing. Addressing this gap requires a comprehensive evaluation of existing training programs and the development of strategies to align academic curricula with industry requirements. This study aims to investigate these issues, providing insights to enhance the competencies of biomedical engineers in Malaysia and ensure their readiness to contribute effectively to the global healthcare landscape.

This study aims to assess the competency levels and evaluate training programs to enhance industry readiness among biomedical engineering students. Addressing this gap will help ensure that graduates are adequately prepared to face real-world challenges in medical device management and enhance the competitiveness of the Malaysian healthcare industry.

Literature Review

The literature review in this study explores various aspects of biomedical engineering competencies, focusing on competency frameworks, academic preparation, industry demands, emerging technologies, and competency assessment methods. The discussion integrates both global perspectives and Malaysia-specific findings, providing a comprehensive understanding of the challenges and opportunities within the biomedical engineering field.

Competency Frameworks for Biomedical Engineers

Competency frameworks define the knowledge, skills, and attitudes that biomedical engineers must acquire to effectively address healthcare challenges. These frameworks serve as a guideline for educational institutions and industry professionals, ensuring that graduates possess the technical expertise and problem-solving skills required for success. Structured learning that integrates engineering and life sciences is essential for fostering a deeper understanding of biomedical systems. (Gupta et al., 2020) further emphasize the importance of specialization within biomedical engineering, which can be achieved through well-designed competency frameworks.

Beyond education, competency frameworks also address the operational aspects of biomedical engineering, including the management and maintenance of medical devices. Poorly organized operations in biomedical engineering can pose significant risks to healthcare systems. According, (Kumar Karna & Jain, 2023) highlights the importance of operational competencies, emphasizing that biomedical engineers must be trained in effective maintenance and risk management strategies. This discussion demonstrates how competency frameworks not only shape educational curricula but also prepare students for industry challenges.

Academic Preparation and Training

The academic preparation of biomedical engineers requires a comprehensive curriculum that integrates problem-based learning, hands-on experiences, and ethical training to address the complex challenges of modern healthcare. Problem-based approaches, such as fabrication courses, have proven effective in fostering critical thinking and practical skills while promoting ethical awareness (Raman et al., 2016). Additionally, early exposure to advanced technologies like 3D modelling and simulation equips students to navigate the demands of evolving biomedical industries (Jia et al., 2023). These elements are essential for preparing graduates to solve multifaceted problems in the field effectively.

Ethical considerations are also a critical aspect of biomedical engineering education. Hunckler and Levine (2022) argue that embedding ethics in engineering curricula ensures that students develop a strong moral foundation, enabling them to handle sensitive healthcare challenges responsibly. Furthermore, interdisciplinary approaches, such as culturally sensitive design methods, help engineers design medical devices tailored to diverse patient populations (Abreu et al., 2022). These discussions highlight the importance of academic preparation in ensuring that biomedical engineers are equipped with both technical expertise and professional ethics.

Industry Demands and Challenges

The biomedical engineering industry is undergoing rapid technological advancements, requiring professionals to stay updated with emerging innovations. As healthcare systems increasingly integrate AI-driven diagnostics, personalized medicine, and IoT-enabled monitoring devices, biomedical engineers must possess both technical knowledge and an understanding of regulatory and ethical considerations. The demand for patient-centered care and personalized medical devices has further expanded the scope of biomedical engineering, requiring professionals to collaborate with healthcare providers, data scientists, and regulatory agencies (Evangel Chinyere Anyanwu et al., 2024).

Continuous professional development is essential for keeping pace with industry demands. The World Health Organization (WHO) emphasizes the importance of lifelong learning in biomedical engineering, particularly in adapting to new methodologies and technologies. Bridging the gap between academia and industry requires collaborative efforts between universities, industry stakeholders, and professional organizations, ensuring that graduates are well-prepared to contribute to the healthcare sector.

The Role of Emerging Technologies

Emerging technologies such as artificial intelligence, IoT, and advanced robotics are reshaping the competencies required of biomedical engineers. These technologies demand not only technical proficiency but also the ability to integrate and apply them in clinical settings. In Malaysia, the integration of such technologies into academic curricula remains limited, creating further challenges in preparing graduates for future industry needs (M. L. Cruz et al., 2020a).

Competency Assessment and Validation

The assessment of biomedical engineering competencies is essential for ensuring industry readiness. Instruments used to evaluate competencies must demonstrate reliability and validity to provide actionable insights. Pilot studies, such as the one discussed in this paper, play a critical role in validating these instruments and identifying areas for improvement in training and curriculum design (Mulenga & Kabombwe, 2019).

Research Methodology

The research methodology employed in this pilot study is designed to rigorously evaluate the effectiveness of industrial training instruments for biomedical engineering students, aiming to optimize their competence and workplace readiness. This pilot study serves as a precursor to a broader survey, intended to identify and rectify potential errors in the study design, thereby ensuring the reliability and validity of the instruments used. The methodology involves testing and verifying the consistency of each questionnaire item through a structured pilot study, as suggested (Surucu & Maslakci, 2020), which highlights the importance of such preliminary assessments in enhancing the accuracy of research findings. The pilot study will employ a mixed-methods approach, combining quantitative data from validated questionnaires with qualitative feedback from focus groups consisting of both trainees and trainers. This dual approach allows for a comprehensive evaluation of the training instruments, ensuring that they effectively measure and enhance the competencies necessary for biomedical engineers in the healthcare industry. The goal of this research is to refine and validate a set of training tools that can reliably prepare biomedical engineering students for the complex challenges they will face in professional healthcare settings.

Pilot Study

This pilot study aims to evaluate and refine the effectiveness of industrial training instruments for biomedical engineering students. The focus is on optimizing these tools to better prepare students for healthcare sector demands. The study involves a cohort of students scheduled for industrial training next semester and uses a pre-test and post-test design to measure changes in competency levels before and after the training. This approach, aligned with practices recommended (Surucu & Maslakci, 2020), ensures the reliability of the research instruments. The findings will help refine the training curriculum and methods, guiding future, more extensive research and improvements in educational practices.

Sample Size Method

The pilot study initially included 30 biomedical students following guidelines for preliminary research (Johanson & Brooks, 2010). However, one respondent's data was incomplete, reducing the final sample size to 29. Data were collected using a structured 45-minute questionnaire divided into five sections (A, B, C, D, E). Only biomedical engineers, ensuring a representative sample for evaluating the research instruments' validity and reliability.

Survey Questionnaire

The survey questionnaire for this study is organized into five sections to evaluate the competencies and preparedness of undergraduate biomedical engineering students.

Table 1. 1
Summary of the questionnaire

Section	Detail	Summary
Section A	Demographic Information	Collects basic details such as age, gender, and academic level
Section B	Awareness, Perception, and Readiness	Assesses biomedical engineers' awareness of their field, perceptions, and readiness in the industry
Section C	Human Anatomy Systems	Tests knowledge of human anatomy as it relates to medical devices
Section D	Medical Devices Categories	Evaluates familiarity with diagnostic, therapeutic, laboratory, and imaging devices
Section E	Competency Skills	Measures technical and practical skills essential for biomedical engineering

(Source: Author)

The 69-item questionnaire is designed to comprehensively assess biomedical students' awareness of their field, perceptions, and readiness in the industry, adhering to established educational research guidelines (Trochim, 2007).

Table 1. 2
Instrument for survey questionnaire

Section	Construct	Dimension	Total
Section A	Demography	Respondent	14
Section B	Awareness, Perception, and Readiness	i. Awareness ii. Perception iii. Readiness	3 3 4
Section C	Human Anatomy System	Human Skeletal	5
Section D	Medical Devices Category	i. Diagnostic and Therapeutics ii. Radiology & Imaging and Laboratory	5 5
Section E	Element Competencies	Six elements	30
Total			**69**

(Source: Author).

Results

This section presents the findings of the study, organized based on the research objectives and questions. The results are supported by descriptive and inferential statistics, with interpretations provided where relevant.

Descriptive Analysis

The pilot study involving 30 biomedical students revealed a female-dominated sample (69% female, 31% male) with most respondents aged 21-24 years. The study used statistical, reliability, and normality tests to validate the data and ensure the reliability of the measurement instruments. Descriptive statistics and reliability analysis, including Cronbach's Alpha, confirmed the consistency of responses. Normality tests validated the data distribution, supporting the use of parametric tests. These findings provide a baseline for student competency and readiness before industrial training and align with similar studies in engineering education across Asia, highlighting methodological rigor in data analysis.

Results of Mean and Standard Deviation

The pilot study's data analysis revealed critical insights through the calculation of Mean and Standard Deviation for six elemental variables, providing a detailed perspective on the competency aspects of undergraduate biomedical engineering students. As outlined in Table 1.2, the variables included theory, operation, safety, servicing, repair, and managing. The mean and standard deviation for these variables were meticulously calculated to assess the student's proficiency levels and to ensure the normality of data distribution.

The standard deviation results are as follows: theory (SD = 0.6), operation (SD = 0.71), safety (SD = 0.70), servicing (SD = 0.6), repair (SD = 0.8), and managing (SD = 0.5). These values indicate a moderate spread around the mean, suggesting that while there is some variability in students' competencies, it does not deviate excessively from the average.

Concurrently, the mean scores for each of the variables are within the range of ±2.0. This result confirms that the data is normally distributed, as values within this range typically signify that most data points are close to the average, a characteristic feature of normal distribution. This alignment with normal distribution is critical as it reinforces the validity of applying parametric statistical tests in further analysis. The findings from this pilot study align with empirical research conducted (Nithia et al., 2020) (Chua, 2018), who also emphasized the importance of Z values in the range of ±4 for accepting the reliability of survey instruments in educational research. This standard is commonly adhered to in the field and supports the robustness of our methodology.

By maintaining consistency with established academic norms and showcasing results that adhere to expected statistical parameters, this study not only highlights the reliability of the data but also enhances the credibility of the overall findings. These statistics are integral for educators and administrators aiming to fine-tune educational programs to better prepare students for the demanding field of biomedical engineering.

Table 1. 3
The results of Mean and Standard Deviation

No	Variables	N	Mean	Standard Deviation
1	Theory	29	3.875	0.687
2	Operation	29	4.000	0.715
3	Safety	29	3.931	0.705
4	Servicing	29	4.165	0.663
5	Repair	29	3.586	0.839
6	Managing	29	4.103	0.589

(Source: Nithia et al., 2020)

Reliability Test

The reliability test is a fundamental aspect of this study, ensuring that the measurement instruments used to assess various constructs are both stable and accurate. Following the framework set (J. C. Cruz et al., 2020), our study emphasized the significance of inter-item consistency and reliability in confirming the accuracy of respondents' answers across interconnected items that measure the same concept. A higher Cronbach's alpha coefficient, approaching 1.0, indicates stronger reliability and internal consistency among the items on the scale, signifying a robust measurement instrument (Nithia et al., 2020). In our reliability analysis, the questionnaire demonstrated strong internal consistency, particularly in measuring constructs related to intrinsic and extrinsic satisfaction, with Cronbach's alpha values exceeding 0.7. This high level of reliability suggests that the items designated to assess these specific constructs were effective in consistently measuring the intended concepts, thereby enhancing the credibility of the study's findings.

Table 1.4 below presents detailed results from the reliability analysis conducted during the pilot test. The Cronbach's alpha values for the elements were as follows: theory (0.896), operation (0.890), safety (0.819), and repair (0.872) indicating very good reliability. The element servicing scored excellent reliability with a Cronbach's alpha of 0.932, and the element managing scored good reliability with a value of 0.846. These results not only underscore the high reliability of our measurement instrument but also its capability to effectively capture the nuances of different competency aspects within biomedical engineering education.

Additionally, the analysis of the range of deviation and kurtosis, as noted by (Chua, 2011), falls within the range of ±2.0, suggesting that the data follows a normal distribution. This normalcy in the distribution further validates the reliability results, confirming that the findings are statistically sound and the measurement instruments are well-calibrated to the constructs being examined.

The findings are consistent with those from an earlier study (Goldin et al., 2015), which similarly assessed the reliability of assessment instruments in biomedical engineering. However, the candidate should specify the exact sample size used by Jones et al. and quantify the difference in Cronbach's alpha values between the two studies for a clearer comparison. While the candidate notes that the Cronbach's alpha values reported by Jones et al. ranged from 0.78 (operation) to 0.91 (servicing), which are slightly lower than those in their study, they have not provided the corresponding values from their research. Detailing these values would not only enhance the clarity of the comparison but also strengthen the argument about the reliability and consistency of the instruments used.

Despite these omissions, the candidate acknowledges that both studies exhibit good internal consistency, affirmatively supporting the reliability of the instruments for assessing educational outcomes in biomedical engineering. The alignment of these results with those of previous studies (Memon et al., 2019) not only reinforces the validity of our current methodological approach but also contributes to the cumulative evidence supporting the robustness of reliability and normality testing in educational research settings.

These empirical results support the study's methodology and instruments, reinforcing the overall quality and reliability of the data collected. Such strong reliability metrics are crucial for advancing educational research and enhancing curriculum development based on scientifically validated instruments.

Table 1. 4
Explanations of Cronbach Alpha

Alpha Coefficient Range	Strength of Association
< 0.6	Poor (Item needs to be repaired)
0.6 to < 0.7	Moderate (Item can accepted)
0.7 to < 0.8	Good (Item can accepted)
0.8 to < 0.9	Very Good
0.9	Excellent
Alpha Coefficient Range	Strength of Association

Source: (De Sutter, 2022)

Table 1. 5
Reliability Results of Pilot Study

No	Variables	Items involved	Cronbach's Alpha value	Skewness	Kurtosis
1	Theory	E1.1, E1.2, E1.3, E1.4, E1.5	0.896	0.107	-0.604
2	Operation	E2.1, E2.2, E2.3, E2.4, E2.5	0.890	-0.342	-0.947
3	Safety	E3.1, E3.2, E3.3, E3.4, E3.5	0.819	0.140	-1.064
4	Servicing	E4.1, E4.2, E4.3, E4.4, E4.5	0.932	-0.115	-1.259
5	Repair	E5.1, E5.2, E5.3, E5.4, E5.5	0.872	0.185	-0.996
6	Managing	E6.1, E6.2, E6.3, E6.4, E6.5	0.739	0.017	-0.865

(Source: Author)

Normality Test

The normality test is a critical statistical procedure used to determine whether data are well-modelled by a normal distribution, and it plays a crucial role in validating the applicability of parametric tests in research analyses. In this study, the normality of data was assessed through measures of skewness and kurtosis, with thresholds set based on established research norms (Kimeto, 2021). According to these researchers, data are considered to follow a normal distribution when the values of skewness and kurtosis fall within the range of ±2.0, indicating minimal deviation from the symmetry typical of a normal curve. In the current pilot study involving 30 biomedical students, the analysis of skewness and kurtosis was meticulously performed to check the normality of the distribution of responses across various competency elements measured. The results, as detailed in Table 1.5, confirm that all variables-maintained skewness and kurtosis within an acceptable range. Specifically, skewness values for theory (0.107), operation (-0.342), safety (0.140), servicing (-0.115), repair (0.185), and managing (0.017) all fell well within the normal range. Likewise, kurtosis values were also within the normal range, with theory at -0.604, operation at -0.947, safety at -1.064, servicing at -1.259, repair at 0.996, and managing at -0.865.

Comparatively, a study conducted five years ago (White et al., 2020) and following (Effendi Ewan Mohd Matore & Zamri Khairani, 2020) on a similar demographic also reported adherence to normality, with skewness and kurtosis values within the normative ranges. Their study supported the hypothesis that educational data in similar settings typically exhibit normal distribution, which validates the use of parametric tests in educational research (Mishra et al., 2019). The consistency in findings across these studies underscores the reliability of measurement instruments and the robustness of statistical analysis in educational settings. These findings suggest that the distribution of responses is approximately symmetrical, thereby supporting the use of parametric statistical tests for further analyses. The consistency in the distribution patterns across different competency elements further reinforces the reliability of the measurement instruments used in this study. Additionally, the data for the theory element was further broken down into five items, with mean and standard deviation results indicating a positive relationship among the items, highlighting internal consistency within this competency dimension.

The adherence to the normative criteria for normal distribution in this study's results is in line with prior empirical research, which has demonstrated the importance of ensuring normality in educational and psychological research to validate the conclusions drawn from statistical analyses (Kuráth & Sipos, 2020). This step ensures that the findings from the pilot study are robust and that the instruments used are suitable for assessing the intended constructs.

Limitations

There are several limitations to this study. First, the sample will be limited to biomedical students, which may affect the generalizability of the findings to other countries or regions. Second, while the survey will provide valuable insights into the perceptions of biomedical students, it may not capture the full range of experiences or challenges faced by professionals in different sectors of the biomedical engineering industry. Lastly, the study will rely on self-reported data, which may be subject to bias or inaccuracies.

Discussion and Conclusion

Discussion

The findings from this pilot study confirm the reliability and validity of the measurement instruments used to assess competencies among biomedical engineers. The Cronbach's alpha values across all competency dimensions—ranging from theory (0.896) to managing (0.739)—exceed the widely accepted threshold of 0.70 (Tavakol & Dennick, 2011), indicating strong internal consistency. These results validate the tool's effectiveness in measuring critical competencies such as awareness, perception, readiness, understanding of human anatomy, and familiarity with medical devices. These findings are consistent with prior studies that emphasize the importance of reliable measurement tools in competency assessments. For instance, (M. L. Cruz et al., 2020a) highlighted that accurately assessing technical and theoretical knowledge is crucial for enhancing professional development. Similarly, this study underscores the importance of evaluating diverse competencies, from operational skills to managerial abilities, to ensure a holistic understanding of biomedical engineering roles.

Moreover, the pilot study provides a foundation for exploring sector-specific competencies in biomedical engineering, with implications for both education and practice. The robust methodology and validated instrument can serve as a model for similar studies in other engineering disciplines, such as mechanical, chemical, or civil engineering. This aligns with (Mulenga & Kabombwe, 2019) call for interdisciplinary research to address competency gaps and foster innovation across technical fields.

While previous research has addressed competency gaps in biomedical engineering education, this study provides a unique perspective by employing a validated competency assessment framework that holistically evaluates students' technical and operational skills. Unlike traditional evaluation models that focus primarily on academic performance, this study integrates industry-relevant dimensions such as servicing, repair, and equipment management (M. L. Cruz et al., 2020b). Furthermore, the pilot study provides empirical evidence on the effectiveness of structured training modules, which can be replicated or adapted in other engineering disciplines. By bridging the gap between academia and industry, this research contributes to developing more targeted educational reforms, ultimately enhancing workforce readiness in biomedical engineering and related fields.

Conclusion

This pilot study successfully validated a comprehensive instrument for assessing competencies among biomedical students, demonstrating strong reliability across key dimensions. The findings provide a reliable foundation for further research into competency development, with significant implications for educational programs, healthcare services, and workforce readiness. The study recommends expanding this research to other engineering disciplines to evaluate and address educational gaps, fostering creativity, resilience, and competitiveness among graduates. Furthermore, the validated methodology and insights gained from this study could assist healthcare services in improving their competitiveness and robustness, leading to enhanced patient care.

In conclusion, the results of this pilot study not only affirm the robustness of the measurement tool but also underscore the critical role of competency assessment in advancing engineering education and healthcare services. Future studies should aim to replicate and extend these findings across different disciplines and industries to contribute to a more competent and adaptable global workforce.

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Ethics Approval

Ethical considerations were meticulously adhered to, with approval granted by the UTM Research Ethics Committee (UTM REC) under approval no. UTMREC-2023-16A. Prior to their participation, all study participants provided written informed consent, ensuring that they were fully aware of the study's nature and their role in it. This ethical rigour not only underscores the commitment to upholding the highest standards of research integrity but also ensures that the findings are built on a foundation of trust and ethical responsibility, enhancing the credibility and applicability of the research outcome.

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Appendix 1 – Questionnaire

SECTION A: DEMOGRAPHIC

INSTRUCTION: In this section, you are required to complete information related to demography. **Please tick ONLY ONE (✓)** according to your choice of answers.
Please fill up the blanks in the space provided.

1. Gender: [ ] Male [ ] Female

2. Age:
   [ ] < 20 years
   [ ] 21 – 24 years
   [ ] 25 - 29 years
   [ ] 30 years and above

3. Race:
   [ ] Malay
   [ ] Chinese
   [ ] Indian
   [ ] Others, please specify ____________________

4. Which country you are from?
   [ ] Malaysia
   [ ] Foreign country, please specify _____________

5. Education level before continued study at university?
   [ ] STPM
   [ ] Matriculation
   [ ] Diploma
   [ ] Foundation / A-level
   [ ] Others, please specify________________________

Please tick (✓) more than one answer according to your choice of answers.

6. What do you like about industrial training?
   [ ] I accomplished and fulfilled one of my program requirements.
   [ ] Good communication in completing assigned tasks.
   [ ] Improve my knowledge and skills in medical devices.
   [ ] I Cultivate the spirit of cooperation between the employees and myself
   [ ] Good relationships with colleagues and work in completing assigned work.

7. What do you know about the Handbook on Competency in Biomedical Engineering Services (BEMS), Ministry of Health Malaysia.
   [ ] Compulsory Competence Module (CCM)
   [ ] Plan Preventive Maintenance (PPM).
   [ ] Maintenance Certificate Level 1, 2, 3, and Product Technical Specialist.
   [ ] Corrective Maintenance.

[ ] Biomedical Technical Personnel (BTP).
[ ] Medical Device Specialization Classification.
[ ] I have no idea about it.

SECTION B: TO ANALYZE AWARENESS, PERCEPTION AND READINESS COMPETENCY SKILLS BIOMEDICAL ENGINEERS

Please use the **Agreement type Likert scale** below according to your answer choices.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

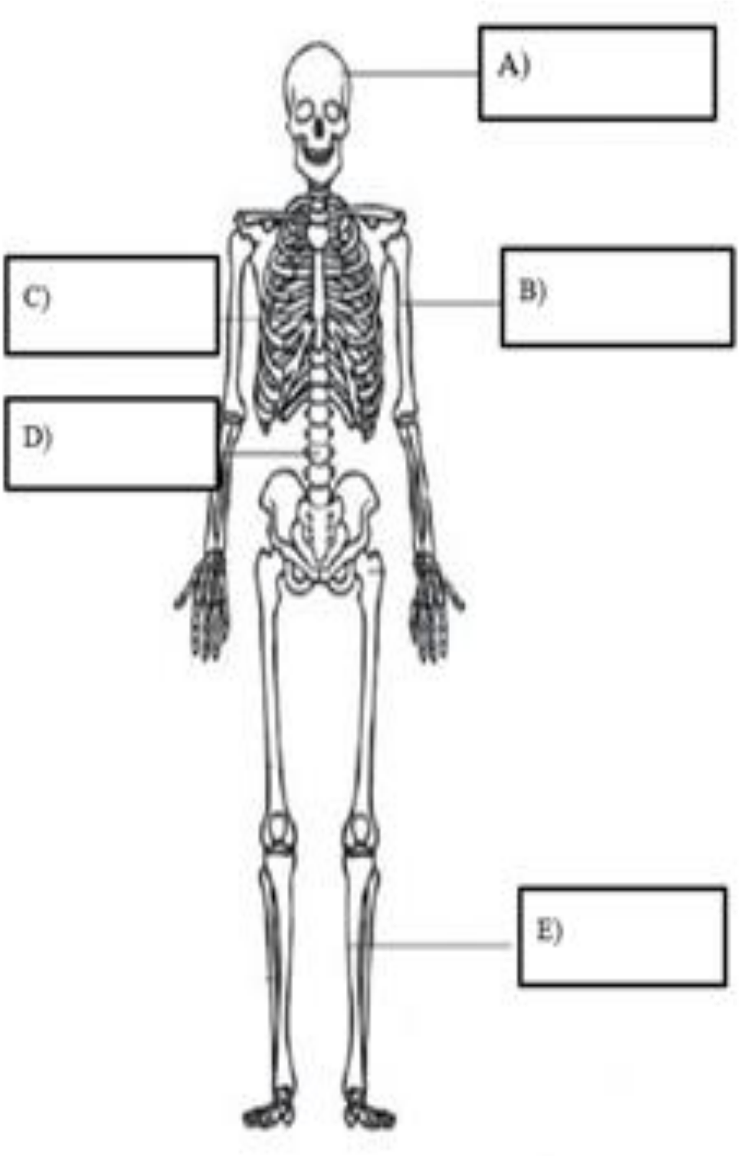
No	Questions	Scales				
		1	2	3	4	5
B1.1	I would like to undergo industrial training.					
B1.2	The period of industrial training is sufficient for me.					
B1.3	I gained more knowledge from industrial training regarding the medical device industry.					
B1.4	I believe all the theories learned in class can be implemented during industrial training.					
B1.5	I believe the experience of industrial training can help me adapt in the real work environment.					
B1.6	I learned technical knowledge and skills from industrial training.					
B1.7	I am able to communicate and interact at all levels in presenting the tasks given.					
B1.8	I can recognize and practice the concept of learning to solve medical device problems.					
B1.9	I am aware of the importance of technical competence skills during industrial training.					
B1.10	I am familiar with medical device equipment during industrial training.					

SECTION C: TO KNOWLEDGE RELATED TO THE HUMAN ANATOMY SYSTEM

Instruction
In this section, you are required to answer questions regarding **your knowledge of the human anatomy of medical devices.**

Part C: **Match the diagram of the human skeletal system** with the correct answer.

Skull	Humerus	Tibia	Ribs cage	Vertebra Lumbar



SECTION D: INTRODUCTION OF MEDICAL DEVICES

Instruction
This section is for graduate students **to learn more about medical equipment**.

Part D1: Please **state the name of the medical device shown in the diagram below** in the Diagnostic and Therapeutic categories.

Nebulizer	Syringe Pump	Hemodialysis Unit
Defibrillator	Electrocardiographs	Ventilator

(i) ....

(ii) ....

(iii) ....

(iv) ....

(v) ....

SECTION D: INTRODUCTION OF MEDICAL DEVICES

Instruction

This section is for graduate students **to learn more about medical equipment.**

Part D2: Please **state the name of the medical device shown in the diagram below** in the Radiology & Imaging and Laboratory categories.

Urine Analyzer	Biopsy guns	Microscope, Laboratory
Radiographic Mobile	Microtome cryostat	Magnetic Resonance Imaging (MRI)

(i) ....

(ii) ....

(iii) ....

(iv) ....

(v) ....

SECTION E: TO DETERMINING COMPETENCE LEVELS OF BIOMEDICAL ENGINEERS BY SKILLS

Instruction

In this section, you are required to answer questions about your knowledge of the Six-level 1 competency skills as per the Biomedical Engineering Maintenance Services (BEMS) Competency Handbook of the Ministry of Health Malaysia.

Part E: Please use the

Agreement type Likert scale below according to your answer choices.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

No	Theory	Scales				
		1	2	3	4	5
E1.1	I understand the anatomy, physiology, and active medical device classification.					
E1.2	I can identify medical devices used in hospitals.					
E1.3	I understand the concept of operating an active medical device.					
E1.4	I understand that the category of electrical safety on medical devices consists of three classes, which are class I, II and III.					
E1.5	I understand that the specialization of medical device equipment is diagnostic, therapeutic, laboratory, and radiology & imaging.					
	Operation	1	2	3	4	5
E2.1	I understand medical device operations and their applications.					
E2.2	I able to identify and verify the operation of all safety features for specific medical devices.					
E2.3	I understand that all medical devices used must use medical grade plugs.					
E2.4	I understand that the Hospital Engineering Planned Preventive Maintenance (HEPPM) checklist must be completed when carrying out the preventive maintenance plan.					
E2.5	I understand that advisory services on biomedical engineering technology are used for all active medical devices.					
	Safety	**1**	**2**	**3**	**4**	**5**
E3.1	I understand acts, regulations, and standards relevant to medical devices.					
E3.2	I can perform electrical safety tests on medical devices to ensure that medical devices work properly and are safe for patients.					
E3.3	I understand that test fixtures and test equipment are specifically used for medical devices.					
E3.4	I know safety signs and safety instructions are not displayed at my industrial training organization.					
E3.5	I abide by all the instructions of safety regulations at work during my industrial training.					
	Servicing	**1**	**2**	**3**	**4**	**5**

E4.1	I understand the manufacturer's Plan Preventive Maintenance (PPM) procedures and am able to follow the appropriate steps to complete the task.					
E4.2	I be able to perform effective performance testing and verification on specific medical devices.					
E4.3	I am able to perform PPM services, and disinfection on medical devices is not required.					
E4.4	I understand the importance of maintenance to ensure medical devices are in good condition.					
E4.5	I am able to perform an effective Electrical Safety Test procedure for medical devices.					
	Repair	**1**	**2**	**3**	**4**	**5**
E5.1	I am able to identify and perform breakdown and corrective maintenance at the point of care.					
E5.2	I am able to complete accurately the necessary biomedical Engineering related documentation, ex. Work order, electrical safety test results.					
E5.3	I am able to do common repairs such as the replacement of light bulbs, batteries, probes, electrodes, tubing, and equipment consumables.					
E5.4	I am able to repair and replace components, subcomponents, or the equipment PCB.					
E5.5	I am able to perform complex maintenance tasks that call for special skills, tools, or equipment.					
	Managing	**1**	**2**	**3**	**4**	**5**
E6.1	I am able to complete accurately the necessary biomedical Engineering related documentation, exp: work order, Heppm checklist, and result EST.					
E6.2	I am able to take quick action when solving problems.					
E6.3	I can complete tasks with the support of other colleagues.					
E6.4	I was able to fully use my thinking skills to solve problems during industrial training.					
E6.5	I know and understand my career goals in the field of biomedical engineering after undergoing practical training.					

- What other skills do you think are needed to become a biomedical engineering graduate?

Your cooperation is highly appreciated. Thank you.

Appendix 2

No	Comments Panel/Reviewer	Suggested Amendment
1	It would be beneficial to provide more compelling evidence to support the claim that this problem is significant. Cite relevant statistics or real-world examples.	Refer page 3
2	While you mention the problem, it needs to be made clearer how the current research will provide a new or unique perspective on this problem	Refer page 15