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Enhancing Libya's Healthcare System Through Technical and Vocational Education in Medical Engineering

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الملخص:

يواجه النظام الصحي في ليبيا تحديات مزمنة، منها تقادم البنية التحتية وضعف صيانة الأجهزة الطبية ونقص المهندسين الطبيين المؤهلين، مما يؤثر في جودة الرعاية وسلامة المرضى. وتشير التقارير إلى أن أكثر من 40٪ من الأجهزة الطبية في بعض المستشفيات خارج الخدمة بسبب نقص الدعم الفني المتخصص.

تبحث الدراسة في دور تطوير تعليم وتدريب الهندسة الطبية في تعزيز القطاع الصحي، من خلال تحديث المناهج، وإنشاء مراكز تدريب عملي، وتعزيز التعاون بين الجامعات والمستشفيات. كما توصي بالاستثمار في هذا المجال لتقليل الاعتماد على الخبرات الأجنبية وتحسين كفاءة وجودة الخدمات الصحية في ليبيا.

الكلمات المفتاحية: الهندسة الطبية، الرعاية الصحية في ليبيا، التدريب المهني، المعدات الطبية، تطوير التعليم.

ABSTRACT: Libya's healthcare system faces longstanding challenges, including outdated hospital buildings, poorly maintained medical equipment, and a shortage of qualified medical engineers. These issues compromise patient safety and care quality. Medical engineering, which integrates medicine, technology, and engineering, is essential to ensure medical devices function correctly and safely. However, education and training in this field in Libya remain limited, creating a gap between the demand for skilled professionals and their availability. This study explores how developing medical engineering education and technical training can strengthen healthcare in Libya. By reviewing international practices and comparing them with local conditions, it highlights the need to update university curricula, establish hands-on training centers, and foster collaboration between hospitals and academic institutions. Reports indicate that over 40% of medical equipment in Libyan hospitals is out of service, mainly due to insufficient specialist support, increasing costs and posing risks to patients. Recent initiatives, including the First International Conference on Medical Engineering Sciences and Technologies in Tripoli, and efforts by institutions such as the Higher Institute of Medical Sciences and Technology in Hon and the Arab Medical and Technical University in Benghazi, reflect growing recognition of this field. Reconstruction projects in Benghazi also provide opportunities to integrate medical education with facility development.

The study recommends renewing academic programs, opening specialized training centers, and building international collaborations. Investing in medical engineering education will reduce dependence on foreign expertise and contribute to safer, more reliable, and cost-effective healthcare, ultimately supporting a healthier future for Libya's population.

Keywords: Medical Engineering, Healthcare in Libya, Vocational Training, Medical Equipment, Education Development.

I. INTRODUCTION

The healthcare system is the foundation of sustainable development in any society. As Libya's health sector faces many growing challenges, it is important to find new solutions that can improve the quality of healthcare services and increase the efficiency of workers. One way to strengthen Libya's healthcare system is through technical and vocational education in medical engineering. This field plays an important role in supporting health facilities, maintaining modern medical equipment, and ensuring their proper use. Investing in this type of education by developing curricula and training qualified staff for maintenance work can help reduce the gap between healthcare needs and human resources. It

is also a key step toward building a strong and modern healthcare system that keeps up with technological progress in medicine and reducing dependency on foreign technical support.

As part of the efforts to evaluate the healthcare system, our team conducted field visits to a number of healthcare institutions to examine the current situation and the level of collaboration between Libyan technical competencies and hospitals. Despite the limited cooperation in some institutions, these visits provided a realistic picture of the Libyan healthcare sector from technical and administrative perspectives. A survey was also conducted, involving a group of healthcare workers as well as graduates and professors of biomedical engineering, aiming to gather their opinions and evaluate the status of technical education and its relevance to the labor market and the requirements for developing the healthcare system.

The results of this study serve as a fundamental basis for proposing improvements to the healthcare system in Libya through the enhancement of technical and vocational education in the field of biomedical engineering, contributing to improving the quality of healthcare services and raising the efficiency of the workforce. This paper is divided into the following sections:

- Section Two: Reviews previous studies related to the role of technical and vocational education in developing healthcare systems.
- Section Three: Presents the research methodology and the field procedures followed.
- Section Four: Shows the results of the visits and surveys conducted.
- Section Five: Discusses the results and proposes ways to develop the Libyan healthcare system.
- Section Six: Provides the conclusion and future recommendations.

II. LITERATURE REVIEWS

Biomedical engineering plays a crucial role in linking technology and healthcare delivery, yet education and practice in this field remain underdeveloped in many low- and middle-income countries. Lustick and Zaman (2011) pointed out that most developing countries face serious shortages in biomedical engineering education and innovation, which directly limits their ability to address healthcare challenges effectively. They argued that the lack of institutional support and structured academic programs prevents the development of sustainable healthcare technologies.

De Maria *et al.* (2022) analyzed the state of biomedical engineering in low- and middle-income settings and found that medical devices are often unsuited for local environments. They studied the main weaknesses and strengths of biomedical engineering in low-income countries and noted that many devices do not work well in difficult environments because maintenance is limited. Devices tend to fail in harsh or remote conditions where maintenance capacity is weak. This mismatch between technology and context results in a high percentage of equipment being out of service, which echoes the current situation in Libya, where more than 40% of hospital devices are reportedly nonfunctional.

Similarly, Oden *et al.* (2010) introduced a new approach in bioengineering education that engages undergraduate students in solving real global health problems, beginning with freshman design projects and continuing through senior capstone experiences. Such hands-on curricula are considered effective for fostering innovation and preparing graduates for the technical realities of healthcare systems in developing regions.

Nkuma-Udah *et al.* (n.d.) have noted the importance of collaboration between institutions in developed and developing countries to strengthen biomedical engineering capacity. They argued that partnerships, such as the Engineering World Health program, can help transfer both technical expertise and educational methodologies, creating a more self-reliant engineering workforce.

Recent literature has also highlighted the opportunities that come with targeted investment in biomedical education. Raxworthy *et al.* (2022) reported that in East Africa, initiatives connecting universities, hospitals, and international partners have started to improve healthcare delivery by

strengthening engineering support systems. Such models demonstrate that collaboration, contextualized training, and policy alignment are critical to making biomedical engineering a sustainable driver of healthcare improvement.

Monzon (n.d.) observed that biomedical engineering education globally must evolve to reflect the dynamic and interdisciplinary nature of the profession. Likewise, Douglas (n.d.) proposed that programs in developing countries should prioritize local innovation and adaptability rather than merely replicating Western models. These perspectives suggest that for countries like Libya, national strategies should combine theoretical education with locally relevant applications and continuous technical training.

Abdulhay *et al.* (2017) identified weaknesses in the curriculum by tracking shortcomings in the achievement level of each outcome. Subsequently, actions were then taken to address these gaps, and these actions were also mapped to the students' medical-related outcomes.

In summary, previous research consistently shows that strengthening biomedical engineering education in developing countries is essential for ensuring the functionality, safety, and affordability of medical technologies. The evidence indicates that educational reform, hands-on training, and international cooperation can significantly enhance healthcare outcomes. In Libya, aligning these global lessons with national healthcare reconstruction could help build a stronger, more resilient health system supported by skilled biomedical professionals.

III. METHODOLOGY

This study adopts a methodology based on data collection through a survey to explore the current status of medical engineering education and its relation to the labor market in Libya.

3.1 Data Collection:

- The survey was conducted both on paper and online using an electronic form to facilitate participation and efficiently gather data.
- The survey link was sent to participants who voluntarily completed it, enabling the collection of quantitative data from healthcare workers and medical engineering graduates. The survey aimed to gather quantitative information regarding the development of technical and vocational education in medical engineering to strengthen Libya's healthcare system.
- In addition, interviews were conducted with hospital technicians, medical engineers, and academic faculty members. These interviews provided qualitative insights into the challenges, training needs, and potential strategies to improve healthcare support.

3.2 Sample Selection:

Participants were randomly selected from within the relevant field to ensure that all groups related to healthcare were represented, including medical engineering graduates as well as hospital staff with various roles and levels of experience. This approach ensured a diverse and representative sample for both the survey and interviews.

3.3 Data Analysis:

Quantitative survey data were analyzed using descriptive statistics to identify trends, gaps, and priorities. Qualitative interview data were coded and analyzed thematically to extract key patterns and recommendations.

3.4 Comparative Review:

The study also included a review of international practices in medical engineering education and hospital maintenance. These findings were compared with the Libyan context to identify applicable strategies and best practices. This methodology allows for a comprehensive understanding of the technical and educational challenges in Libya's healthcare system and provides a solid foundation for making practical recommendations to enhance medical engineering capabilities.

IV. RESULTS

Table 1: Participant Characteristics of Participants (Percentages):

As shown in Table 1, the majority of participants were female (56.1%), and most were healthcare professionals (61%). The sample included a diverse range of educational qualifications, job

positions, and years of experience, ensuring representativeness of the relevant population.

Table 1: Participant Profile (Percentages):

Category	Sub C.	Percentage (%)
Gender	Male	43.9
	Female	56.1
Educational Qualification	Diploma	22.0
	Bachelor's Degree	24.4
	Master's Degree	29.3
	PhD	24.4

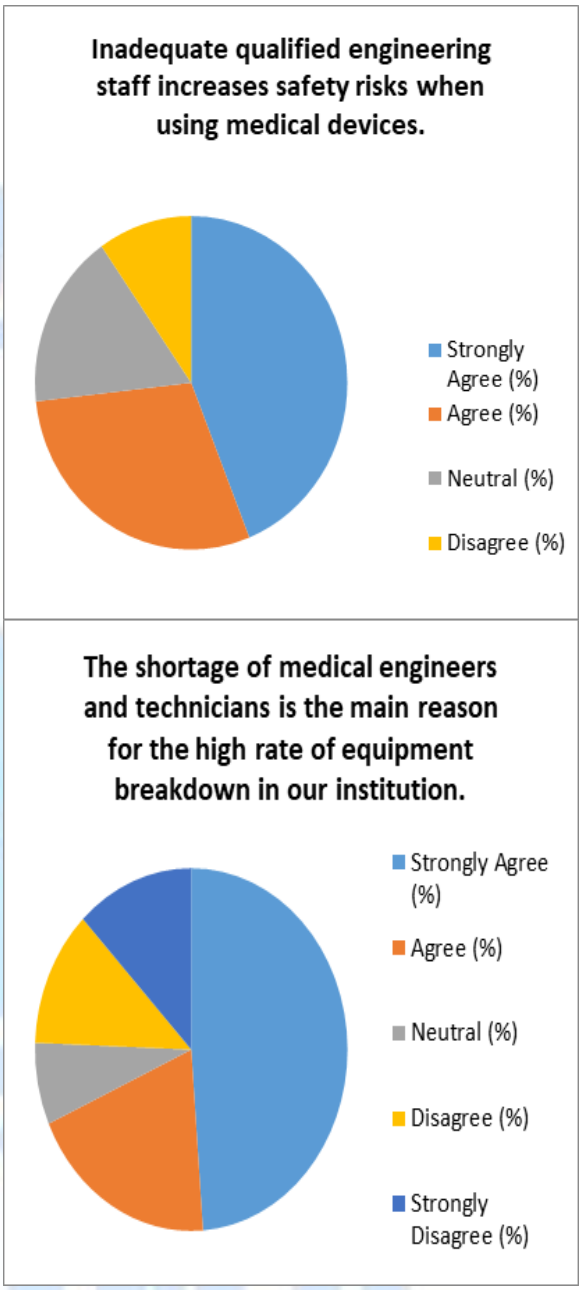
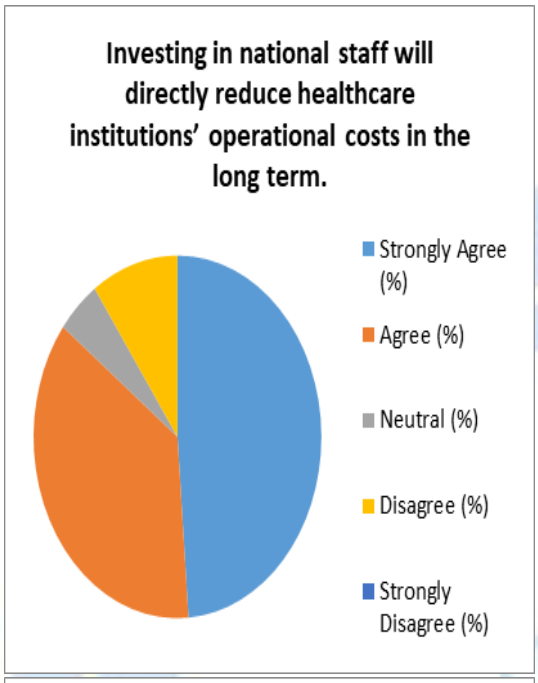
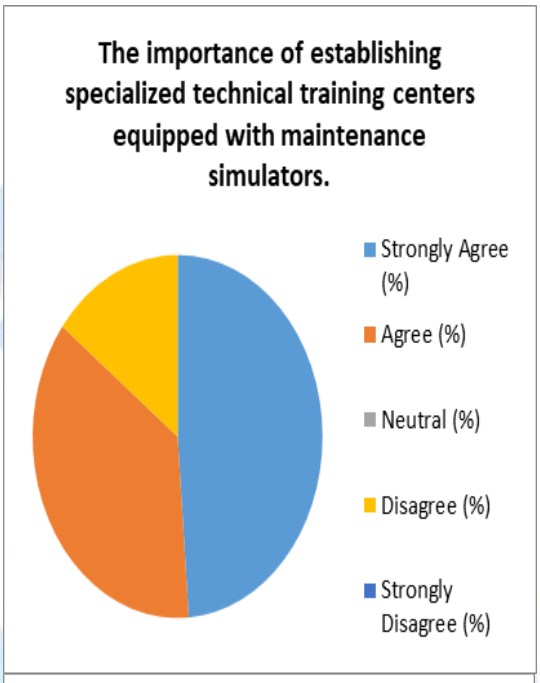
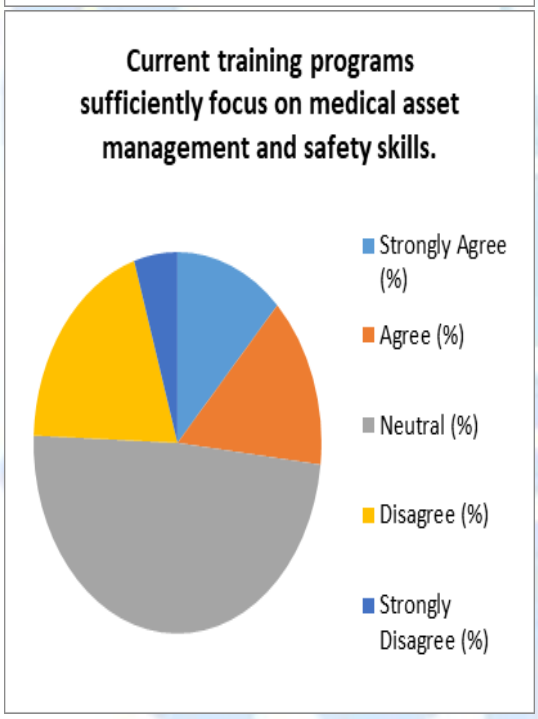


Fig. 1: Participants' Perceptions of the Effect of Inadequate Medical Engineering Staff on Medical Device Safety.







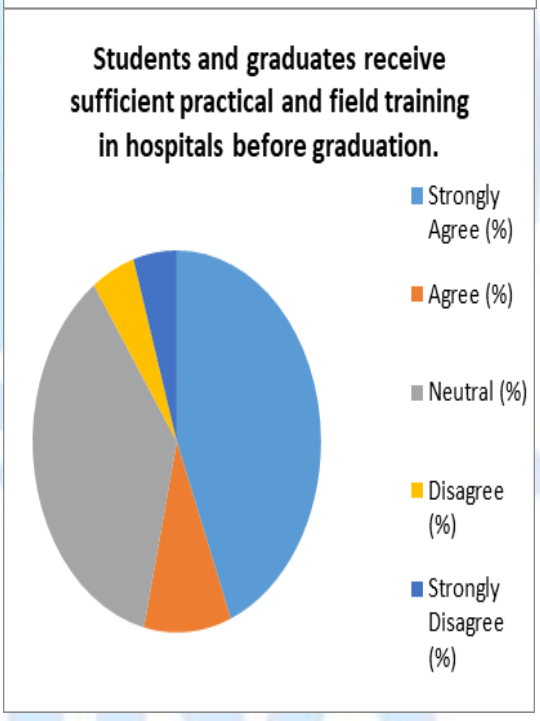
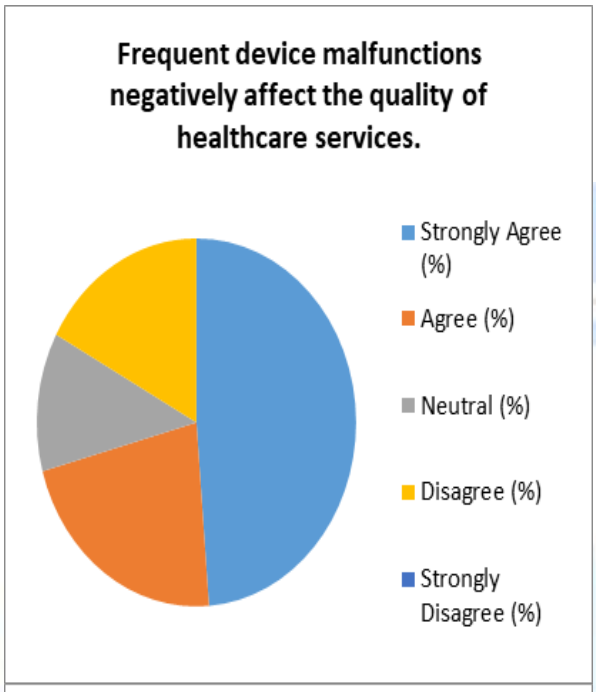
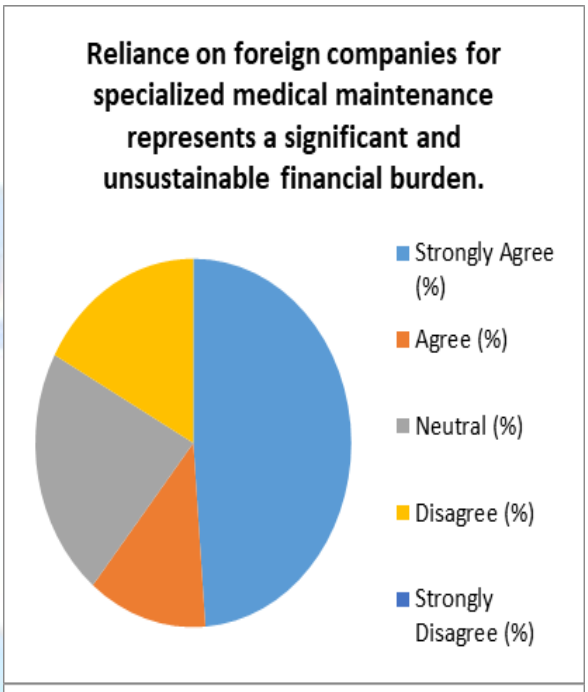
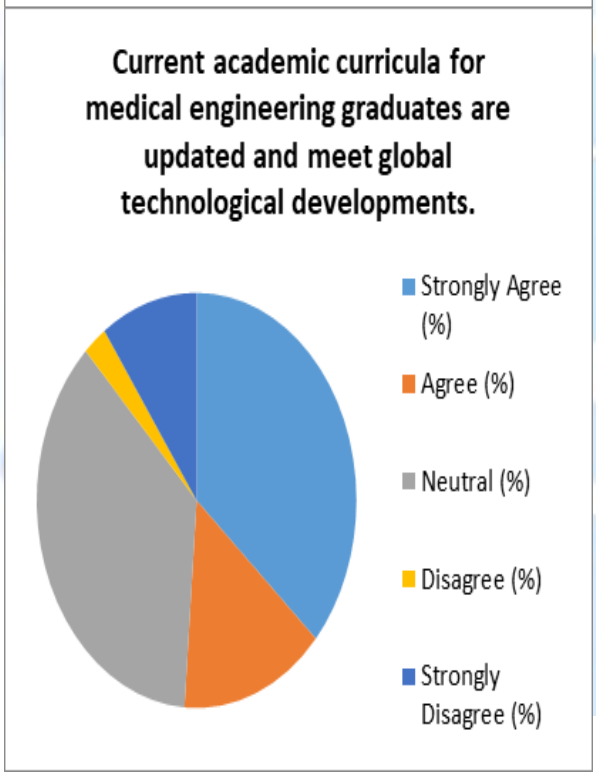


Fig. 2: Investment in National Staff and Cost Reduction and Need for Specialized Technical Training Centers.

Fig. 3: Effectiveness of Current Training Programs And Adequacy of Practical Training Before Graduation.







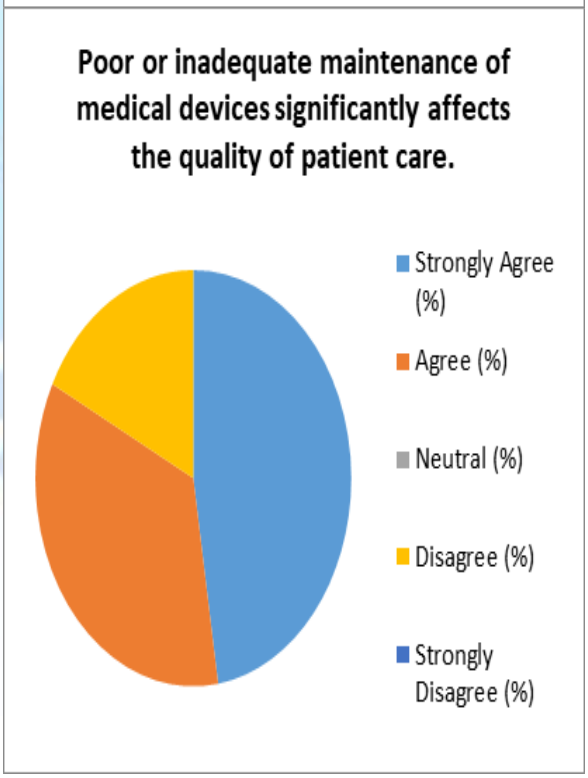


Fig.4: Frequent device malfunction and current academia curricula.

Fig.5: Relying on foreign companies, and maintenance of medical devices.

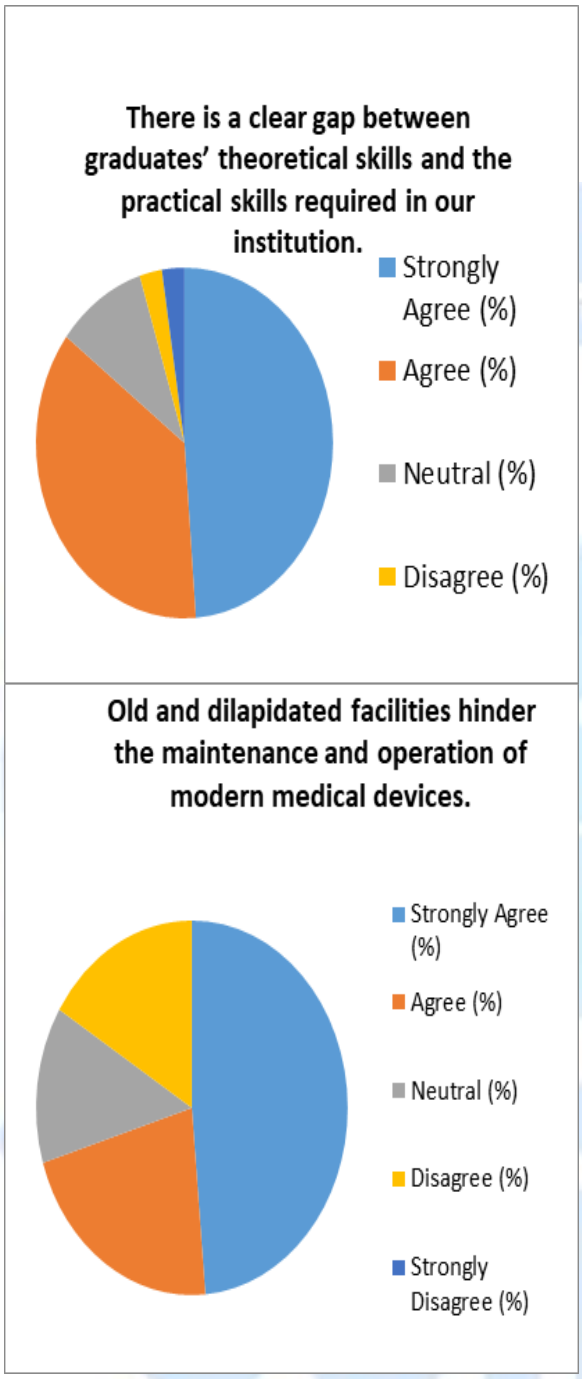
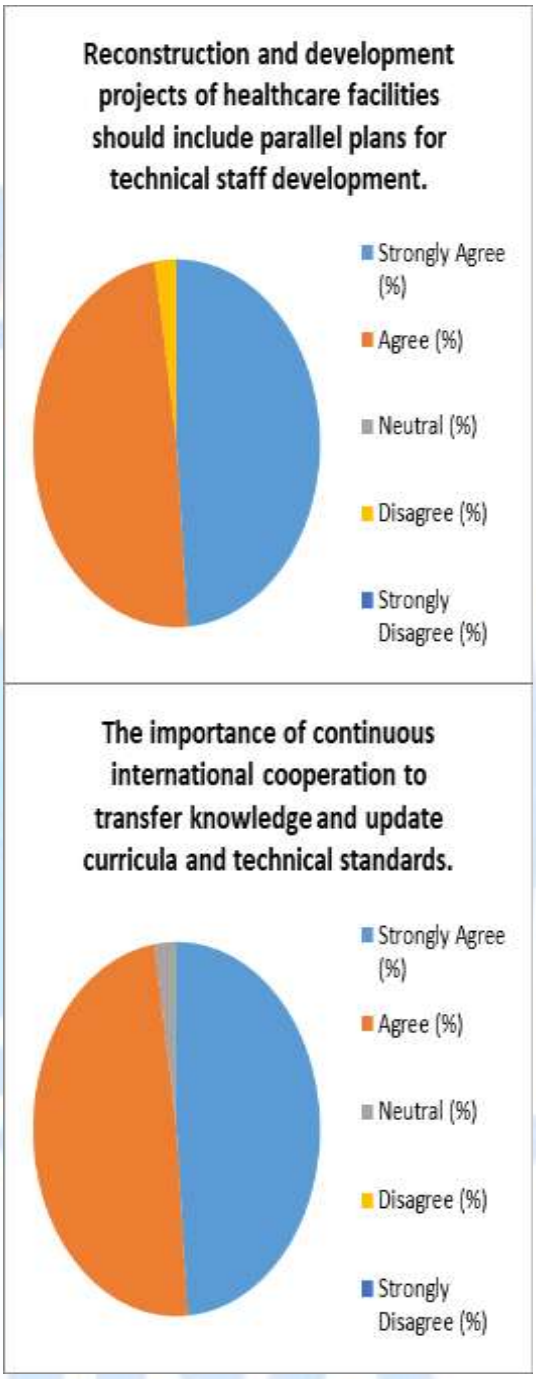


Fig. 6: Gap between graduates and theoretical and practical skills, and old with the dilapidated facilities hinders.



Fig, 7: Recon-instruction and development of HCF, and International corporation importances.

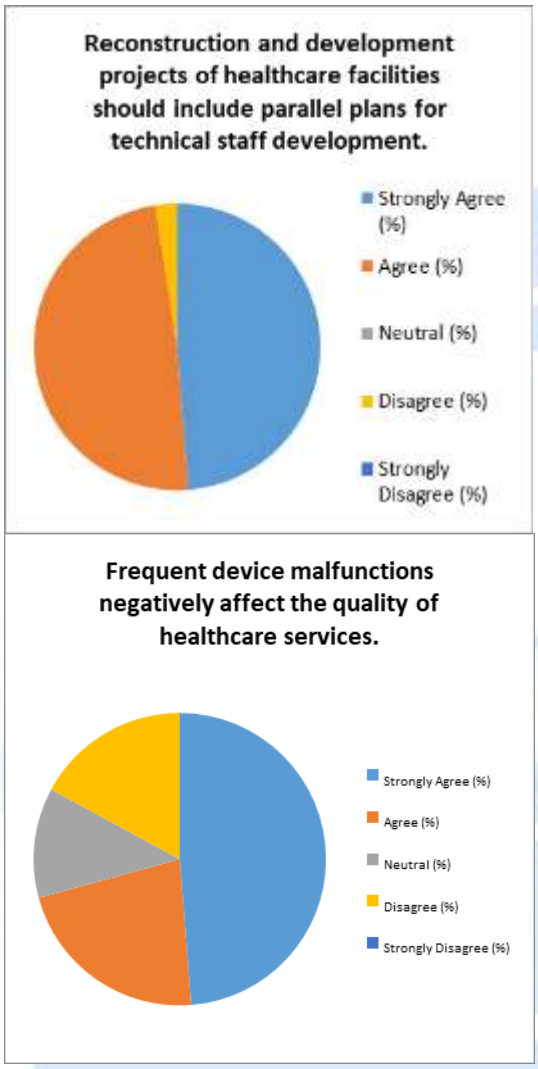


Fig. 8: Recon instruction and development project and the effect of frequent devices malfunction.

Interview Findings (Qualitative Results):

From interviews with hospital technicians, medical engineers, and academic faculty:

- Shortage of qualified personnel: Most participants emphasized the lack of skilled engineers and technicians as a major factor affecting equipment maintenance.
- Need for practical training: Several respondents highlighted that current academic programs do not provide enough hands-on experience in hospitals.
- Infrastructure challenges: Outdated or poorly maintained facilities hinder proper operation and maintenance of medical devices.
- Importance of specialized training centers: Interviewees recommended establishing technical centers with simulators for maintenance practice.
- Collaboration and international exposure: Strong interest was expressed in partnerships between hospitals, universities, and international institutions to update curricula and transfer knowledge.

V. ANALYSIS / DISCUSSION

Based on the quantitative and qualitative data collected:

1. Shortage of Skilled Personnel: Both survey and interview data indicate a significant shortage of qualified medical engineers and technicians. Approximately 48–50% of participants strongly agreed that this shortage leads to frequent equipment malfunctions and increased safety risks. Interviews highlighted that hospitals often rely on foreign companies for maintenance, increasing operational costs.
2. Gaps in Practical Training: Survey responses show a clear gap between graduates' theoretical knowledge and the practical skills required in healthcare institutions. Only a small percentage of participants agreed that students receive sufficient hands-on training before graduation. Interviews reinforced the need for structured practical training in hospitals and specialized technical centers.
3. Infrastructure and Equipment Maintenance Challenges:
   Old and poorly maintained facilities hinder the proper use and maintenance of modern medical devices. Frequent equipment failures affect the quality of healthcare delivery, as indicated by both quantitative and qualitative data.
4. Importance of Collaboration and International Exposure:
   Strong agreement exists among participants on the need for partnerships between healthcare institutions and academic bodies. International cooperation is seen as vital for updating curricula, transferring knowledge, and adopting modern technical standards.

5. Educational Program Gaps: Survey data show that current academic curricula partially meet global technological developments, but practical training and asset management skills are insufficient. Participants recommend updating curricula, integrating hands-on hospital training, and emphasizing management and safety skills.

VI. RECOMMENDATIONS

Based on the analysis, the study proposes the following recommendations:

1. Enhance Medical Engineering Education:
- Update academic curricula to reflect current technological developments.
- Incorporate structured practical training in hospitals and technical centers.
2. Establish Specialized Training Centers:
- Provide well-equipped centers with simulators for maintenance practice.
3. Strengthen Partnerships:
- Develop long-term collaborations between universities, hospitals, and international institutions to exchange knowledge and best practices.
4. Invest in National Staff:
- Focus on training local engineers and technicians to reduce dependency on foreign maintenance services and lower operational costs.
5. Integrate Training into Reconstruction Projects:
- Ensure that healthcare facility development projects include parallel plans for technical staff training and capacity building.

VII. CONCLUSION

This study highlights the critical role of medical engineering education and technical training in improving Libya's healthcare system. The findings show significant gaps in personnel, practical skills, and infrastructure that affect healthcare quality and patient safety. Implementing the proposed recommendations—updating curricula, establishing training centers, fostering partnerships, and investing in national staff—can provide a sustainable foundation for safer, more efficient, and cost-effective healthcare in Libya.

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