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Engineering Report

Global Clinical Engineering Status: Post-COVID19 Review

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ABSTRACT

Many colleagues have written about the global reliance on health technologies whose innovation, deployment and support continue to improve worldwide healthcare and its delivery. The World Health Organization's-WHO 2007 Resolution WHA60.29 called for the effective use of health technologies (HT), in particular medical devices, through proper planning, assessment, acquisition and management.

The community of professional clinical engineering (CE) practitioners' pre-COVID19 stories are captured in the Global Clinical Engineering Journal. An article from 2022 shows the reasons for the increased contributions of this community especially during the pandemic in The Growing Role of Clinical Engineering: Merging Technology at the Point of Care.

This article will answer questions such as to how this global reliance was demonstrated during the COVID19 period. How the status of the Clinical/Biomedical Engineering (CE/BME) profession that serves at the point of care changed as the world emerges from the huge stresses of the pandemic. The article reviews the evolution of the CE profession since 2020, how it partnered with WHO between 2020-2022 and what lessons were learned in the process. It reports future CE priorities to improve country, regional, and global practice in 2023 and beyond. This timely preliminary report shares important findings related to patient care support services.

Keywords – *COVID 19, Clinical Engineer, Technologist, Devices, Patient, Outcomes, Engineering, Global*

INTRODUCTION

Clinical engineering professionals (CEs) support and advance patient care experience and outcomes by applying engineering, life sciences, and managerial skills to optimize healthcare technology during its life cycle deployments. CEs are sought for their system thinking expertise, to conduct independent validation of healthcare products, to identify technical support requirements, to ensure that medical device users' needs are met and that products are accessible and ready for patient care. They assess and manage the use of health technologies, which WHO defines as "the application of organized knowledge and skills in the form of (medical) devices, medicines, vaccines, procedures, and systems developed to solve a health problem and improve quality of care and/or life," including both traditional medical devices and emerging digital health tools.[1]

During 2020-2022, WHO's World Health Assembly (includes Ministers of Health-MOHs from WHO's 194 member states) focused on the need for intensive care mechanical ventilators (2020) and medical oxygen production (2021).[2] WHO has specifically recognized the clinical engineering community for expertise to optimally manage assets such as medical devices, personal protective equipment, oxygen, and digital health tools, particularly in low-resource settings.[3] Two CE organizations, the International Federation of Medical and Biological Engineering Clinical Engineering Division[4] (IFMBE CED) and the Global Clinical Engineering Alliance[5] (GCEA), add different expertise to meet global challenges, grew tremendously during the pandemic following a surge in the need for their members' expertise. In partnership with WHO, these organizations are now networked to colleagues in 200 countries, sharing best practices and solutions to common complex challenges.

Today, CED and GCEA together form a global CE community & network (Fig. 1). One key pandemic lesson learned was that this community needed to better understand how practitioners are not only distributed around the world, but how CE practice differed from country to country to help drive relevant improvement, with regional focus, and specific training. This was supported by the opportunity to build on our earlier CE practitioner Body of Knowledge (BoK) – Body of Practice (BOP) survey from 2017.

FIGURE 1. Global Clinical Engineering Leadership Teams

BACKGROUND

Prior to the pandemic, CED and WHO had been partnering closely, particularly since 2009 when Dr. Yadin David became CED Chair and Ms. Adriana Velazquez became WHO's Medical Devices/Health Technologies (HT) leader. Together, a series of International CE-Health Technology Management (HTM) Congresses (ICEHTMC) began to convene in 2015 in China, 2017 in Brazil, and 2019 in Rome. The Rome Congress had 1000 attendees from 70 countries. During these meetings, Global CE Summits events were conducted to identify and prioritize action on global CE-HTM challenges, with 15 countries participating in 2015, 30 in 2017 and 48 in 2019. A virtual Congress in 2021 drew 2100 registrants from 128 countries and had a virtual Global CE Summit with attendees representing 51 countries (Fig. 2).

FIGURE 2. Clinical Engineering Global Summits

During the period between 2015-2019, consensus priorities such as increasing professional recognition, improving training opportunities, creation of the dedicated

Global CE Journal (Fig.3), and considering professional credentialing approaches began to be addressed. This resulted in an enhanced CED website, the startup of relevant projects with an Awards program (Fig. 4), promotion of country and regional events, and a Global CE Day focus on October 21, 2015 and following years.

FIGURE 3. Global Clinical Engineering Journal Issue covers

FIGURE 4. Clinical Engineering community projects

Global CE Day is an annual recognition of contributions CEs make to healthcare in their countries daily. The program over the years grew from 1 day to 1 week, and most recently in 2022, more than a dozen streamed events in several countries over two weeks (Fig. 5). For example, the October 2020 program broadcast from China had 22 hours of streaming global content from 50 countries, had over 500,000 social media views, and introduced GCEA as the new global CE partner organization.

That same week in October 2020, WHO engaged with GCEA who utilized CED's global CE network to lead the Engineering and Management section of the WHO Compendium of Innovative Health Technologies for low-resource settings.

Since 2020 GCEA has been growing globally, has offered over a dozen global best practice webinars, and has enhanced its website - GCEA website.

FIGURE 5. Global Clinical Engineering Day and week.

Pandemic Era Results

Prior to COVID19, the Global CE community consisted a team from 100 countries. Following CED's and GCEA's 60 best practice webinars[6,7] that assisted in the global pandemic response, today the team has grown to over 560 collaborators from 200 countries with connection to 110 national CE societies (Fig. 6).

FIGURE 6. Global Clinical Engineering footprint

A key focus of over half of these webinars was implementing a global CE COVID19 Knowledge Network. The other area of focus was detailing various country approaches to demonstrating CE competencies and leadership qualities (Fig. 7); and increasingly, showing how CE competencies have had a unique COVID19 impact.

CED CE Competency Webinars series in 2020-2022

1. **HTM**: Assessing and managing health technologies (HT)
2. **Cost-Effectiveness**: Containing HT-related costs and increasing ROI
3. **Quality & Safety (Q&S)**: Improving HT-related patient & staff Q&S
4. **Innovation**: Innovating new care processes using HT
5. **Digital Health**: Using digital medicine to improve patient care, eg, Telehealth
6. **Regulation**: Addressing HT regulation challenges
7. **Policy & Legislation (P&L)**: Developing appropriate HT-related P&L
8. **Professional credentialing**: certification, continuing education, awards
9. **Partner with Clinicians**: Supporting caregivers using HT
10. **Partner with Health Leaders**: Develop communication relationships with decision-makers
11. **Partner with Allied Health**: Optimizing partnerships with other health professionals
12. **Project management methodology**

FIGURE 7. Clinical Engineering Competencies

2022 Global CE Priorities, Teams and Results

At the 4th ICEHTMC (International Clinical Engineering and Health Technology Management Congress) Virtual Congress in 2021 – besides giving voice to both the traditional competencies and to the increasing global scope of CE-HTM practice during COVID19 – e.g., digital health, PPE, facility design and oxygen management, (Fig. 8), the Global CE Summit/Community decided on the 2022-2023 Priorities as follows:

1. Capacity Building

- Sufficient volume of the right people with the right education, training, and appropriate management skills.
- Framework: CE-HTM Capacity Building Model.

2. Impact Measurement

- Measurable impact on clinical outcomes.
- Framework: CE-HTM Theory of Change (TOC) Model, utilizing WHO defined Access, Quality, Safety, Coverage, and Efficiency.

3. Credentialing

- Credentialing typically means ensuring minimum competencies and experience for the CE profession, expressed through registration and/or certification.

4. Policy

- CEs show value to MOH at national level
- As a result, CEs assist in writing National HT Policy
- CEs educate healthcare decision-makers, both public and private healthcare leaders

5. Ongoing WHO Partnership

- WHO Medical Devices Unit primary focus, but other relevant units, eg, Emergency response
- WHO Compendium of Innovations for Low-Resource Settings
- WHO COVID19 Training – Training in multiple languages over HT lifecycle of pandemic-specific devices

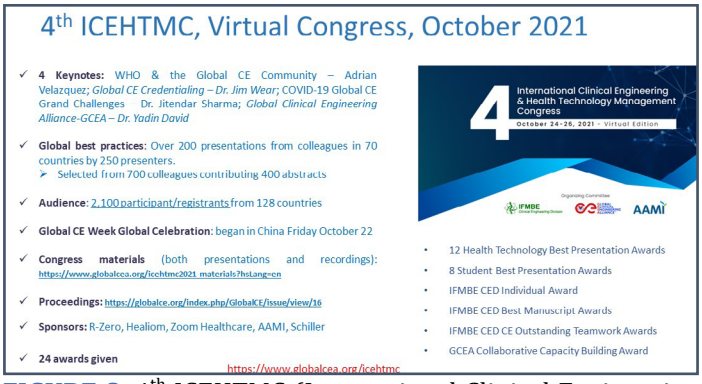

FIGURE 8. 4th ICEHTMC (International Clinical Engineering and Health Technology Management Congress), October 2021

During 2022, the CE community organized priority teams, ensuring perspectives from the following HT experts:

1. *Senior Advisors – At least one highly experienced Priority area expert to advise the team*
2. *Champion/leaders – Typically at least 2-3 experienced area leader/champions*
3. *Hospital-based*
4. *Health system-based*
5. *MOH-based*
6. *Academic-based*
7. *Industry-based*
8. *Regional understanding-Perspective across a WHO Region for a CE with multi-country experience*
9. *National CE Society or Institute-based*

Other considerations for these teams was to ensure balanced input across the 6 defined WHO Regions, from the CED-GCEA network. These include the Americas, Africa, Eastern Mediterranean, Europe, Southeast Asia, and Western Pacific, and utilizing CED-GCEA Board and Collaborator members.

The teams met periodically and reported results at Townhall sessions during 2022 Global CE Week, agreeing on next steps for 2023, focusing on sharing results from the Capacity Building (CB) / Impact Measurement Townhall; the other priority areas are currently analyzed.

POST-COVID19 GLOBAL CE COMMUNITY NEXT STEPS

In determining the optimal process to follow, realizing that the Body of Practice (BoP) had increased significantly during the pandemic, the teams decided upon the following primary data sources for examining progress and determining next steps:

2022 Body of Knowledge (BoK) & Body of Practice (BoP) Survey , September-December 2022

Current Results of the BoK-BoP (Capacity Building-CB) Survey, as of end of 2022 are shown on Figure 9.

A preliminary review of BoK-BoP data is shown in Figures 9-12. Figure 13 shows the resulting Capacity Building Framework model.

A quick summary follows:

- CE practitioners as defined by WHO serve in a variety of roles shown on Figure 11; the survey was particularly focused on those serving in the CE or BME role 'at the point of care' managing HT.
- This is a young profession globally, well-educated, needing the recognition of skills that formal credentialing provides (as in most healthcare professions).
- CEs are undergoing rapid growth in Digital Health-related responsibilities.
- An early comparison of global data with African Region data shows important regional differences.
- There was an outstanding response to the survey from 29 countries in Africa, and a statistically significant response across all Global Regions. The 2022 survey provided over 4 times the input of the 2017 survey (35 countries, 199 responses) with its 865 responses so far from 124 countries.

(n=865 responders) **124 countries' responses in 2022; LMIC in red (52 countries)**

Americas		Africa		EMRO/MENA		Europe		SEARO		WPRO	
Anguilla	1	Benin	3	Afghanistan	2	Albania	4	Bangladesh	27	Australia	4
Antigua and Barbuda	1	Botswana	1	Algeria	2	Austria	1	Bhutan	1	Brunei	5
Argentina	37	Burkina Faso	1	Bahrain	1	Belarus	1	DPRK	1	China	186
Bahamas	1	Burundi	4	Egypt	3	Bosnia and Herzegovina	3	India	18	Hong Kong	2
Barbados	1	Cameroon	1	Kuwait	5	Bulgaria	1	Myanmar	1	Japan	10
Belize	1	Central Africa Republic	1	Lebanon	3	Croatia	5	Nepal	31	Malaysia	3
Bolivia	1	Cote d'Ivoire	1	Morocco	1	Cyprus	1	Sri Lanka	2	Mongolia	2
Brazil	37	Chad	1	Pakistan	4	Czech Republic	1			Papua New Guinea	1
Canada	20	DRC	1	Qatar	2	Estonia	1			Singapore	1
Chile	2	Eswatini	1	Saudi Arabia	8	Finland	1			Taiwan	5
Colombia	9	Ethiopia	4	Somalia	1	France	3				
Costa Rica	3	Ghana	29	Sudan	9	Georgia	1				
Cuba	2	Guinea	1	Syria	1	Germany	2				
Dominica	1	Kenya	73	Tunisia	4	Greece	3				
Dominican Republic	1	Lesotho	1	UAE	1	Ireland	8				
Ecuador	2	Malawi	6	Yemen	1	Italy	12				
El Salvador	2	Mali	2			Kosovo	1				
Grenada	1	Mozambique	1			Luxembourg	1				
Haiti	2	Namibia	1			Netherlands	1				
Honduras	4	Nigeria	7			Poland	1				
Jamaica	2	Niger	1			Romania	2				
Mexico	26	Rwanda	13			Russia	1				
Nicaragua	4	Senegal	1			Scotland	1				
Paraguay	3	South Africa	40			Serbia	2				
Peru	5	Tanzania	2			Slovenia	1				
St Vincent & the Grenadines	1	Togo	1			Spain	9				
Saint Kitts and Nevis	2	Uganda	23			Switzerland	1				
Suriname	2	Zambia	12			Turkey	2				
Trinidad & Tobago	17	Zimbabwe	5			UK	5				
Uruguay	1					Uzbekistan	1				
USA	9										
Venezuela	1										
32		29		16		30		7		10		124
6		23		10		3		7		3		52
	202		238		48		77		81		219	865

Global Survey Observations

1. Young profession globally: 50% under 40 years old
2. Near fifty percent less than 10 years CE experience
3. 15% associate degree, 35% undergraduate, Masters 40%
4. 2/3 need Credentialing; 80% of those needing require it
5. Global growth of Digital Health CE involvement last 5 years

Regional Differences – eg, Africa

Countries
LMIC (World Bank designation)
Regional responders

FIGURE 9. Global 2022 BoK-BoP Survey

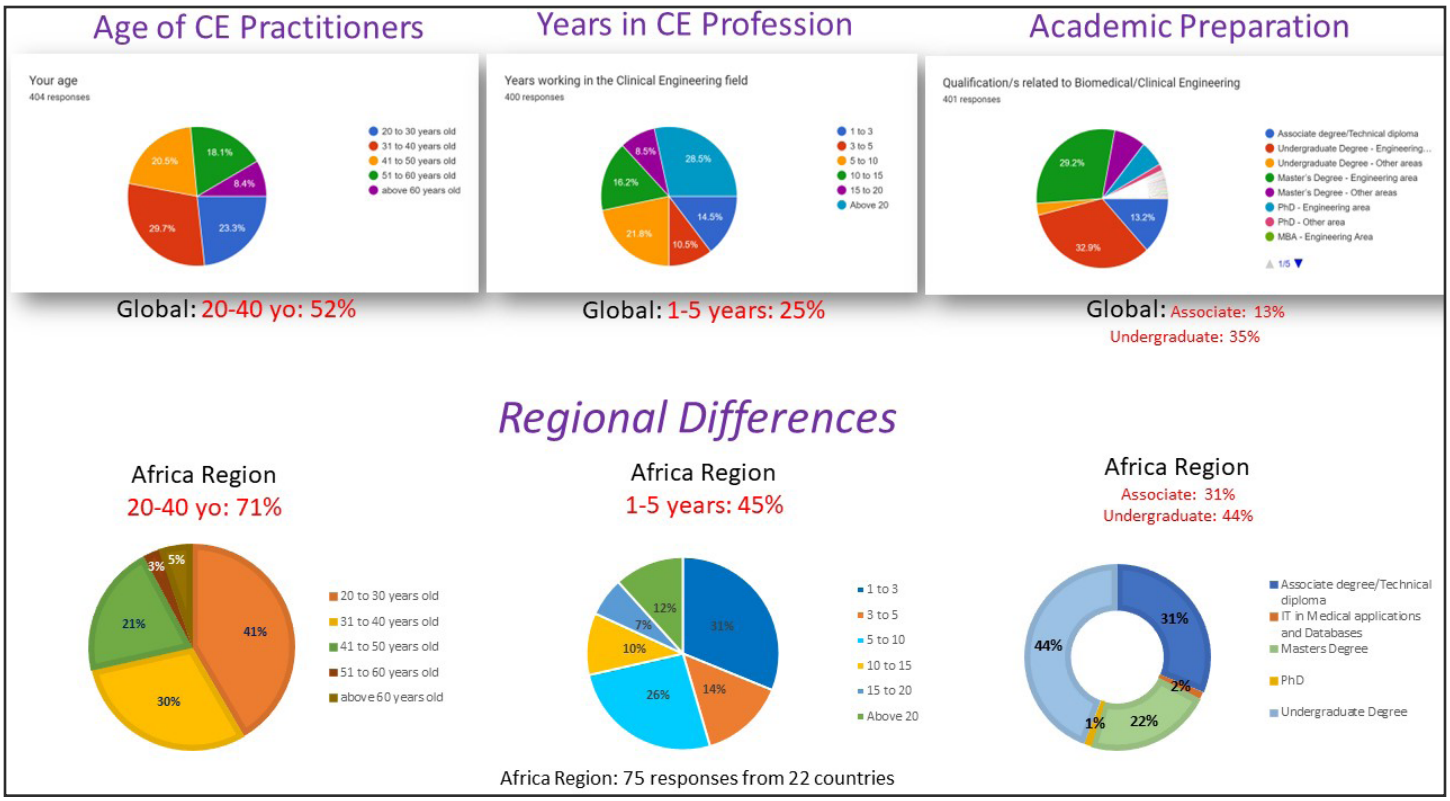

FIGURE 10. Global 2022 BoK-BoP Survey results

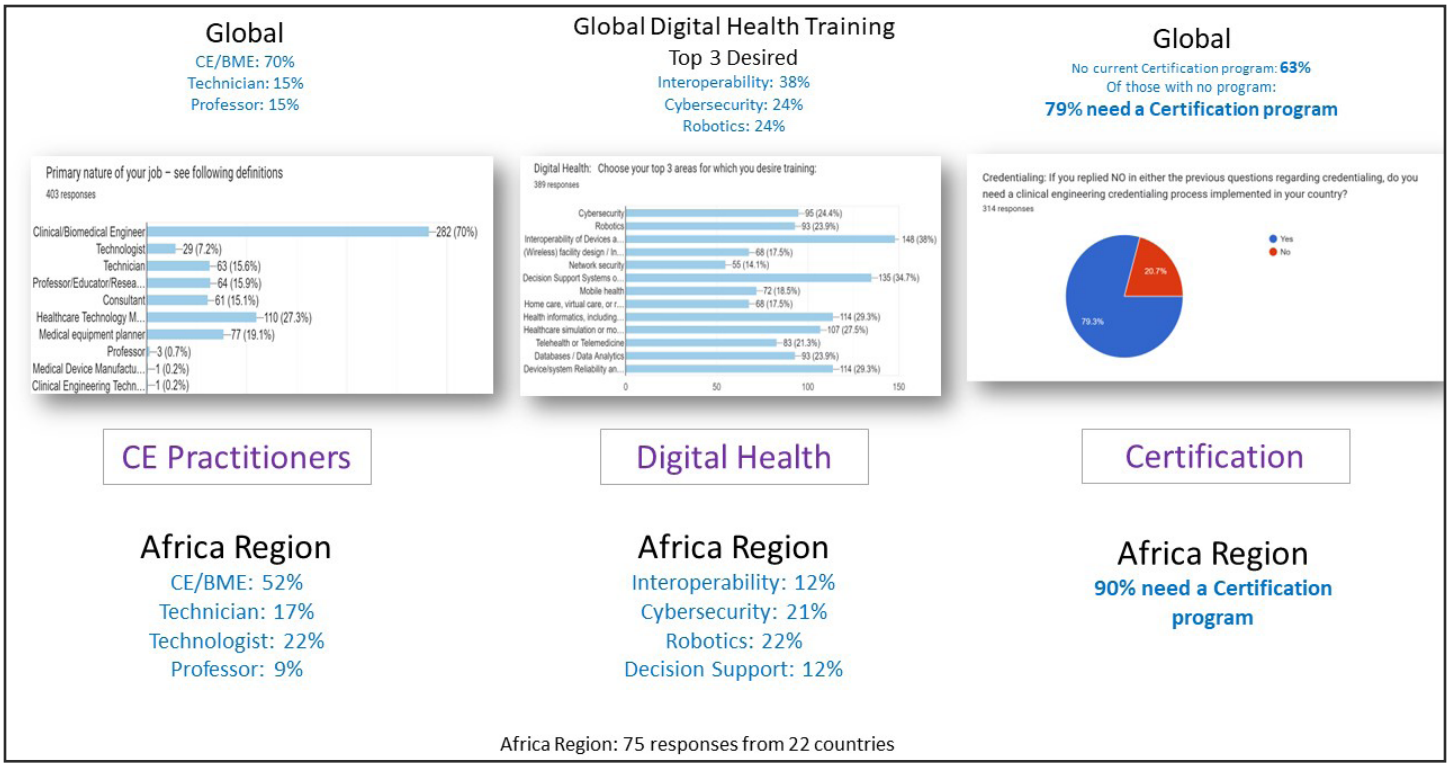

FIGURE 11. Global 2022 BoK-BoP Survey results

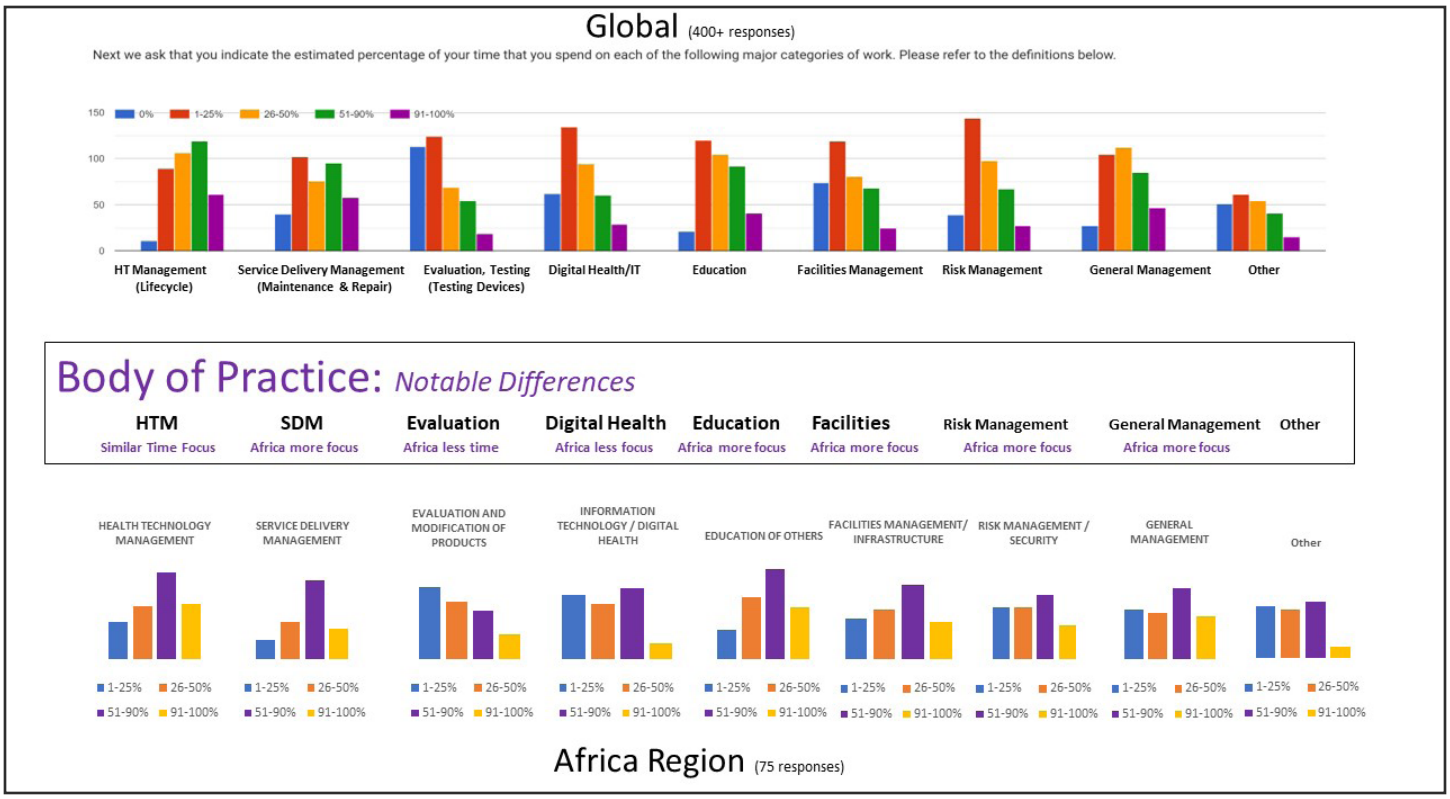

FIGURE 12. Global 2022 BoK-BoP Survey results

Status	Low	Middle	High
KNOWLEDGE			
Education (Academia)	2-4 year Academia	Academia: 4 year undergraduate & graduate	Graduate CE
Training (Academia - CPD, CEU & Industry)	Limited	Ongoing	Ongoing for typical devices plus more for high tech devices
Internships (part of Academic studies or independently in hospitals)	Absent	Limited	Available through different sources
Credentialing (Certification & Registration)	Absent	Limited	<50% Certified
Digital Health & Innovation (Knowledge used to improve devices and clinical & business workflows, etc.)	Absent	Limited	Beginning involvement
INVESTMENT			
Investment Drivers Externally (NGOs, Industry) versus internally (MOH, Universities)	Externally driven	Ministry of Health (MOH) directed	MOH driven, aligned well with University & Industry partners
Device Sources Majority Donations versus Majority Central Health Leader-driven	Majority Donations	MOH-led device planning, selection, & management	Extensive central planning, selection, & management through MOH
CE Department Staffing, Facilities & Test Equipment	Limited	Full range for typical devices & growing staff to meet needs	Extensive facilities & wide range of test systems with mature staff size matching needs
Inventory Management Manual versus CMMS	Manual	CMMS	CMMS includes Digital Health & Cybersecurity information, with ability to share data with decision makers & colleagues across hospitals
Added Value: Quality & Safety Measurement, monitoring, improvement, and risk management	Absent	Limited	Extensive
COMPETENCIES			
Scope of CE-HT Management Activities	Minimal set of devices	Full range of typical devices	Typical plus high-tech devices + Digital Health tools & Cyber
Device Preventive Maintenance & Repair	Limited PM & Repair of typical devices	Full range for typical devices	Full range PM & repair typical + high tech specialty devices
Clinician & Healthcare Team Relationships	Absent	Limited	Strong partnerships
National CE / BME Society (Bringing HT colleagues together to share best practices and training)	Absent	Beginning	Mature and able to assist other nearby countries
Leadership Development (Developing & Mentoring CE practitioners/Influencers)	Absent	Limited	Key country CE leaders mentored externally, They train & mentor others; become Influencers
Policy, Regulation, Legislation (Raising HT issues to national level in Political context)	Absent	Limited	Extensive

- CPD = Continuing Professional Development
- CEU = Continuing Education Units
- Credentialing = Certification typically achieved by Education, Experience & Testing, maintained via CPD, CEU
- Typical devices = patient monitoring, OR, ER, general care devices
- High technology devices = medical imaging, cancer treatment, clinical laboratory systems
- CMMS= Computerized Medical Devices Maintenance System

FIGURE 13. Capacity Building Framework

2022 Global Theory of Change (TOC) / Impact Measurement Survey

Current Results of the TOC (Impact Measurement-IM) Survey (TOC explanation video):

- Number of responses: 34
- Number of countries that sent specific case studies: 16
- The main focus was to ask about the areas of health-care delivery or health systems generally where our global Community of CE-BME felt they have had the most influence.
- So far, the category that was noted in most instances as being an area of impact for health systems was Patient Safety (n=24 instances were noted of this type of impact), followed by improved Diagnostics (n=17), and improved health Access (n=16), Cost savings (n=15), and hospital capacity (n=15). Given the recent pandemic, there is also evidence that Emergency Preparedness is another area where impact has been achieved (n=12).

CONCLUSIONS

Next Steps: Besides continuing to analyze the Credentialing and Policy Townhalls and related next steps as well as assess our partnership with the World Health Organization, GCEA and CED will begin to implement findings for Capacity Building and Impact Measurement.

The pandemic has made our CE/BME profession highly visible globally, e.g., with WHO and with Ministers of Health and private health system leaders. How will we take advantage of this opportunity utilizing CE best practices? We have presented and published many strategies regarding how the profession can assist MOHs and other health leaders to address their key national health priorities.

The Global CE Community encouraged the development of individual professional society and country heroes during the pandemic. The Community needs to continue to work with national CE/BME societies to raise up current and future leaders, as were recognized by CED-GCEA in 2022 (Fig. 14).

FIGURE 14. Global CE Community Emerging Leaders

The BoK-BoP survey, the Capacity Building Framework, and TOC survey: Countries can begin to drill down on their practices they provide compared globally and the gaps they will need to address to continue to expand their role and services for healthcare delivery improvement. The accepted global CE role expanded during COVID19, and the global Community can help each country and practitioner with the skills necessary to meet this increased demand. CED-GCEA can help prepare the messages and communication packages to assist this work.

Individual Site and Country Clinical Engineering Status: The data sources identified share many country best practices for CE competencies and COVID-19 CE-related solutions. The current five priority projects address the top global CE concerns and opportunities. Consider first the CE Capacity Building Framework. Analyze how your country fits in this Framework and to prioritize what gaps you want to pursue. Work with the global CE community partners and your national CE Society to determine next steps.

We have many tools, networking within, and potential external alliances available; how will each practitioner and how will the CE global community use these to further grow in our profession? CE use of the social media tool has also been very helpful; how will these tools be incorporated into going forward? Figure 15 describes the overall international track record of the utilization of these tools by CE between 2020-2022.

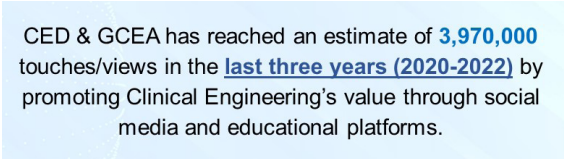

FIGURE 15. Track record of Social media and educational platforms impact

The authors intend to conduct further analysis of the collected data and report their final findings in a future publication in the Global Clinical Engineering Journal.

REFERENCES

1. WHO Health Technology definition
2. WHO World Health Assembly 2020-2022
3. WHO Priority medical devices list for the COVID-19 response and associated technical specifications
4. IFMBE CED
5. GCEA
6. IFMBE CED webinars, 2020-2022
7. GCEA webinars, 2020-2022