THE ASIA-PACIFIC SCHOLAR
MEDICAL AND HEALTH PROFESSIONS EDUCATION

ORIGINAL ARTICLE

Submitted: 13 June 2024
Accepted: 4 February 2025
Published online: 1 July, TAPS 2025, 10(3), 26-36
https://doi.org/10.29060/TAPS.2025-10-3/OA3439

Bridging gaps in medical education for digital healthcare: A Singapore case study

Humairah Zainal[1], Xin Xiaohui[1], Julian Thumboo[1,2,3] & Fong Kok Yong[2,3]

[1]Health Services Research Unit, Singapore General Hospital, Singapore; [2]Department of Rheumatology and Immunology, Singapore General Hospital, Singapore, [3]Duke-NUS Medical School, National University of Singapore, Singapore

Abstract

Introduction: As healthcare becomes increasingly digital, undergraduate medical students receive limited formal training in digital healthcare technologies (DHTs). Additionally, stakeholders' perspectives on essential digital health competencies (DHCs) across generations remain underexplored. This comparative study aims to identify knowledge gaps, inform evolving expectations, and promote continuous learning by comparing medical students' and senior clinicians' views on essential DHCs in Singapore.

Methods: Individual semi-structured interviews were conducted with medical students, clinical educators, and clinical teachers. Clinical-year medical students from all three local medical schools were recruited using convenience and snowball sampling, while purposive sampling ensured diverse representation of clinicians across Singapore's public healthcare organisations, focusing on those engaged in education-related activities. Data were collected from September 2020 to February 2023 until thematic saturation was achieved, and analysed using qualitative thematic analysis.

Results: Sixty-three participants took part, including 30 medical students, 12 clinical educators and 21 clinical teachers. All clinicians had more than 10 years of clinical experience and came from 24 different disciplines and 12 healthcare institutions. The findings showed unanimous support for integrating electronic health records in patient communication, and training in DHTs like telemedicine and point-of-care ultrasound. Discrepancies emerged; clinicians prioritised physical examination, while students viewed it as potentially replaceable by DHTs. Furthermore, while students valued healthcare-related smartphone applications in patient care, few clinicians shared this view, citing privacy and security concerns.

Conclusion: Evaluating stakeholders' perspectives highlights evolving clinical skills and essential DHCs for medical students, potentially informing global DHC training programmes.

Keywords: *Technology, Medical Education, Curriculum, Clinical Competence, Digital Competence, Qualitative, Singapore*

Practice Highlights

- An inter-generational perspective in medical education leverages the strengths of both medical students and senior clinicians, ensuring a balanced approach that keeps pace with technological advancements while maintaining the core principles of patient care.
- The digital health competencies deemed essential for future clinical practice are consistent across all stakeholders.
- The study highlights the emerging need for additional competencies among medical trainees so as to meet the evolving demands of healthcare delivery.
- Regularly comparing the perspectives of various stakeholders in the healthcare system enables educational institutions to adapt and refine their curricula continuously.

I. INTRODUCTION

Digital healthcare, which leverages advanced technologies to enhance, complement, or replace traditional healthcare services, is becoming increasingly common in clinical practice (Alkire (née Nasr) et al., 2020). Digital healthcare technologies (DHTs) such as electronic health records (EHR), telemedicine, and Artificial Intelligence (AI) have significantly improved data management, diagnostics, and patient care (Clay-Williams et al., 2023; Food and Drug Administration, 2019; Welcher et al., 2018;). However, many studies and

reviews have highlighted a global lack of formal and systematic training in DHTs for undergraduate medical students (Aungst & Patel, 2020; Edirippulige et al., 2018; Tudor Car et al., 2021). While recommendations for integrating digital health education (DHE) exist, they often propose standalone courses focused on specific DHTs rather than embedding DHE into the core medical curriculum (Tudor Car et al., 2021; Zainal et al., 2023a; Zainal et al., 2023b). Barriers to consistently incorporating DHE into medical curricula, as reported in countries such as Canada, Germany, the United Kingdom (U.K.), and the United States (U.S.) include limited faculty expertise, curriculum overload and fragmented implementation efforts (Gillissen et al., 2022; Hurley et al., 2011; Machleid et al., 2020; Sit el al., 2020; Sorg et al., 2022).

Furthermore, there is limited research exploring the perspectives of both medical students and senior clinicians on the relevant digital health competencies (DHCs) required for clinical care. DHCs encompass the knowledge, skills, and attitudes essential for assessing, diagnosing, and treating patients in the digital age. An inter-generational comparison of these perspectives is crucial for identifying gaps in the existing curricula and ensuring medical education aligns with the rapidly evolving healthcare landscape. Medical students can offer fresh insights into emerging tools and platforms while senior clinicians can contribute perspectives on clinical skills given their wealth of clinical experience.

Despite Singapore's advanced digitalisation, challenges remain in standardising DHE across its three medical schools: Yong Loo Lin School of Medicine at National University of Singapore (NUS), Lee Kong Chian School of Medicine at Nanyang Technological University (NTU) and Duke-NUS Medical School (Duke-NUS) (Zainal et al., 2023a). Although these institutions boast state-of-the-art facilities, a disconnect persists between medical training and clinical practice due to various institutional and structural barriers (Zainal et al., 2023a). While efforts to integrate DHE, such as virtual reality courses, have been initiated, there are variations in content and duration across institutions, underscoring the lack of a standardised approach (Zainal et al., 2023a).

This study uses Singapore as a case study to explore the perceptions of medical students, clinical educators, and teachers regarding DHCs, with the aim of improving DHE integration into undergraduate medical curricula. Specifically, it compares the views of these stakeholders in identifying any digital competencies that may be relevant for clinical practice in an increasingly digital healthcare landscape. By focusing on Singapore, this study not only sheds light on gaps in the local curricula but also provides insights that can inform global efforts to strengthen DHE integration in medical education.

II. METHODS

A. Setting and Sample

A qualitative study was conducted using individual semi-structured interviews with medical students, clinical educators, and clinical teachers. Participants were identified by Principal Investigator (P.I.) FKY, based on their year of study and clinical roles respectively, ensuring relevant knowledge and experience.

The study employed a combination of convenience sampling and snowballing technique to recruit students from all three local medical schools. Clinical-year students (third to fifth years) were included due to their potential exposure to DHTs during clinical rotations, while pre-clinical students were excluded. Convenience sampling was initially used for ease of access, and snowballing technique was subsequently employed to expand participation and capture diverse perspectives.

To ensure diverse representation among clinicians, purposive sampling was applied across Singapore's three public healthcare organisations. Clinical educators dedicating over 20 per cent of their time to education-related activities (e.g., teaching, curriculum planning, research, and administration) and clinical teachers contributing less than 20 per cent of their time to such roles were included. Clinicians not involved in educational roles were excluded from the study.

This study was classified as a quality improvement (QI) project on medical education curricula by the SingHealth Research Integrity, Compliance, and Ethics (RICE) committee. As such, it did not meet the criteria for human subject research and was granted an ethical waiver by SingHealth Institutional Review Board (Reference Number: 2020/2880). Nonetheless, this research adhered strictly to the ethical principles of the Declaration of Helsinki and institutional guidelines.

Data collection occurred from September 2020 to February 2023. Participants were invited by the P.I. via email detailing the study's purpose, procedures, potential risks, and benefits, with consent obtained before the interviews. To address potential biases due to the P.I.'s professional relationships, interviews were conducted by a research fellow without prior connections to participants. Verbal consent was recorded at the start of each Zoom session, and participants were reminded of their right to withdraw, with pre-withdrawal data retained for comprehensive analysis.

To ensure anonymity, participants were assigned coded identifiers ('MS' for medical students, 'CL' for clinicians). Identifying information and audio recordings were securely stored and separated from the main dataset. Results were reported with care to avoid identifying individuals, and the data was exclusively used for curriculum development.

B. Data Collection

The interview guide followed Kallio et al.'s (2016) framework, including pre-requisites for semi-structured interviews, literature review, expert consultation, preliminary guide development, pilot testing with five participants, and finalisation. Questions addressed clinical competencies, their relevance to digital healthcare, and ways medical schools can better prepare students for digitalisation (Tables 1 and 2). Interviews included medical students and clinicians across specialties to ensure diverse perspectives.

The study involved 63 participants, with sample size guided by theoretical and practical considerations. Data collection continued until thematic saturation was reached, ensuring all relevant perspectives were captured. Practical constraints like time and resources influenced the participant number, but the focus remained on data richness and diversity for a comprehensive exploration of the research questions.

Sixty interviews were conducted via Zoom due to COVID-19 restrictions, with three in-person interviews held under local health guidelines. Each session lasted about 40 minutes and was audio-recorded. Transcriptions were generated using Otter AI and reviewed for accuracy by the P.I. and research fellow.

No.	Topics	Questions and prompts
1.	Clinical skills that doctors should have	In general, what are the clinical skills that a medical doctor should have? Are there any clinical skills that have become less essential or relevant in this digital age? Are there any other clinical skills that have been fulfilled or transformed by digital technology? What new skills, clinical or otherwise, should a medical doctor have today and in the future especially in light of the digital age?
2.	Medical school curriculum	Do you think the clinical skills taught in your medical school have adequately prepared you for clinical practice, especially in today's modern setting? Prompts: - *Are there any modules in your formal curriculum that might have exposed you to the digital aspects of medicine, such as telemedicine, AI or healthcare informatics?* - *Are you aware of any elective courses or programmes that might have done the same?*
3.	Exposure to digital technologies in clinical practice	Have you ever adopted or come across any forms of digital technology such as robotics surgery, AI or big data in your clinical practice yet? Prompts: - *If yes, where did you encounter this?* - *What digital healthcare technologies would you be interested in learning if given the opportunity, and why?*
4.	Experience with digital technologies	Have you ever encountered any recurring challenges in clinical practice that you foresee could be overcome by digital technologies?
5.	Role of various stakeholders	What do you think medical schools can do to help doctors optimise the use of digital healthcare technologies in the future? What do you think professional bodies such as Singapore Medical Association (SMA) and Academy of Medicine can do to help doctors make full use of digital healthcare technologies in the future? What do you think the government can do to help doctors optimise the use of digital healthcare technologies in the future?
6.	Other thoughts on how the medical school curriculum can better prepare students	Do you have any other comments on how the medical school curriculum can better prepare you for future clinical practice? Any other comments on digital transformations of medicine or healthcare before we end this interview?

Table 1. Interview questions for medical students

No.	Topics	Questions and prompts
1.	Clinical skills that doctors should have	In general, what are the clinical skills that a medical doctor should have? Are there any clinical skills that have become less essential or relevant in this digital age? Are there any other clinical skills that have been fulfilled or transformed by digital technology? What new skills, clinical or otherwise, should a medical doctor have today and in the future especially in light of the digital age? Prompt: - *In your opinion, are our locally trained doctors well-equipped with these skills?*
2.	Medical school curriculum	What clinical skills are currently being covered in the local medical schools? Prompt: - *Which of these skills should be emphasised more in the medical school curriculum?* What other improvements can be made to our local medical school curriculum to better prepare the students for clinical practice in light of rapid technological advances? Prompt: - *How instructive would it be to introduce students to the basic principles of AI, big data, imaging, and digital equipment such as handheld ultrasound?*
3.	Relevance of digital technology to clinical practice	How can digital technology aid doctors' clinical practice and acumen?
4.	Role of various stakeholders	How can local medical schools improve their collaboration with professional bodies and healthcare institutions to prepare medical students for clinical practice in this era of technology? What can the healthcare system do to support medical students and young doctors in this era of digital technologies?
5.	Other thoughts on digitalisation of healthcare	Do you have any other comments on the digital transformations of medicine or healthcare before we end this interview?

Table 2. Interview questions for clinical educators and teachers

C. Data Analysis

Thematic analysis followed Braun and Clarke's six-step framework to explore curricular gaps (Braun & Clarke, 2006). Two researchers independently coded the data, resolving discrepancies through discussion to refine the codebook and ensure consistency. Credibility was enhanced by triangulating findings across participants from various medical schools and healthcare clusters, capturing diverse perspectives and minimising bias.

To contextualise the findings, comparisons were made with studies from other high-income countries undergoing similar healthcare digitalisation. Additionally, recent data from stakeholders, including medical school leaders, were analysed to understand the digital competencies needed for future clinical practice. Reporting adhered to the Standards for Reporting Qualitative Research (O'Brien et al. 2014).

III. RESULTS

Sixty-three participants took part in our study. Thirty of them were medical students who were undergoing clinical rotations in various disciplines, with 10 coming from each school. Twelve were clinical educators and 21 were clinical teachers. The clinicians were aged between 44 and 70 years. All had more than 10 years of clinical experience and came from 24 different disciplines and 12 healthcare institutions. A summary of their demographics is reported in Table 3 and illustrative excerpts are found in Table 4.

Profile		Number of participants
Gender		
Medical students:		
Male		15 (50%)
Female		15 (50%)
Clinical educators and teachers:		
Male		26 (78.8%)
Female		7 (21.2%)
Year of study/ specialty		
Medical students:		
Third year		8 (26.7%)
Fourth year		14 (46.7%)
Fifth year		8 (26.7%)
Clinical educators and teachers:		
Roles	**Clinical educator**	**Clinical teacher****
Number of participants	12	21
1 interviewee per discipline	**2 interviewees per discipline**	**3 interviewees per discipline**
Cardiology	Anaesthesiology	Emergency Medicine
Dermatology	Geriatrics Medicine	Family Medicine
Ear, Nose and Throat Surgery	Paediatrics Medicine	Rheumatology
Endocrinology		
Gastroenterology and Hepatology		
Hepatobiliary Surgery		
Infectious Diseases Medicine		
Internal Medicine		
Medical Oncology		
Neurology		
Obstetrics and Gynaecology		
Ophthalmology		
Pathology		
Public Health		
Radiology		
Renal Medicine		
Respiratory and Critical Care Medicine		
Vascular Surgery		

Table 3: Demographics of participants

Four major themes were derived from the data.

A. Limited and Inconsistent Exposure to DHTs

Students reported limited exposure to DHTs in core medical curricula, with training mainly through electives, select programmes, and student-driven initiatives. Exposure to health informatics and telemedicine was brief, with telemedicine training primarily prompted by the COVID-19 pandemic. Other DHTs like robotic surgery, virtual reality, and POCUS were inconsistently incorporated across medical schools. Some clinicians also reiterated the need for DHT exposure in public healthcare institutions, as doing so could inspire medical students to engage in innovation, research, and development in cutting-edge fields like robotics.

B. Unified Views among Clinicians and Students on Essential Competencies

Clinicians and students shared unified perspectives on incorporating key DHCs like EHR, telemedicine, and POCUS into medical curricula. These competencies are viewed as crucial for preparing students for contemporary clinical practice.

Participants emphasised the need to balance EHR use with effective patient interaction. M25, a third-year student, highlighted the importance of maintaining empathy and humanistic values, while CL27, a rheumatologist, stressed integrating EHR data into patient discussions to improve engagement and understanding of health conditions.

All groups also agreed on the importance of telemedicine training. Students expressed interest in learning how to identify conditions suitable for virtual consultations, build patient rapport, and conduct comprehensive assessments via tele-platforms. MS5 noted the challenges of teleconsultation, such as interpreting body language and addressing legal responsibilities. Clinicians like CL14 underscored the need to teach students how to select patients for teleconsultation and identify red flags effectively.

Additionally, both clinicians and students strongly supported incorporating POCUS into the curriculum. Students acknowledged its utility in bedside diagnostics, while clinicians like CL9 and CL18 highlighted its value in resource-limited settings and its role in enhancing diagnostic accuracy. They advocated for routine training in ultrasound, considering its increasing use in general practice and as a critical tool in diverse healthcare settings. These unified views suggest the need to prioritise these DHCs in medical education to meet the evolving demands of healthcare delivery.

C. Divergent Opinions on Traditional Clinical Skills

Discrepancies in opinions emerged regarding traditional clinical skills, particularly physical examination. Students often viewed diagnostic imaging and tests as superior to these skills, perceiving physical exams as less critical. For instance, M11, a Year 4 student, argued that ultrasonography provides more precise diagnoses, making physical examination less relevant.

Clinicians, however, emphasised preserving traditional skills like history-taking and physical examination, especially for resource-limited settings. CL3, an ophthalmologist, expressed concern that reliance on diagnostic tools has led to the erosion of these essential skills.

D. Emerging Technologies and Concerns

The perceived competencies for medical education varied between students and senior clinicians. Students valued wearables and healthcare apps for patient empowerment, personalised care, and strengthening doctor-patient trust. For instance, MS30, a fourth-year student, suggested that wearable data could help create personalised care plans and enhance clinical practice.

Clinicians, however, expressed concerns about the privacy and security of patient data in these apps. They emphasised the responsibility to protect patient information and were cautious about using apps that did not meet security standards. These differing opinions highlight the need for a DHE curriculum that addresses both student interests and clinician concerns.

In our sample selection, we included both clinical educators and clinical teachers to capture a range of perspectives on the integration of DHCs into medical education. However, our analysis did not reveal significant differences in the views expressed by these two groups. Both shared similar opinions on the importance of teaching DHCs such as EHR, telemedicine and POCUS. This alignment may be attributed to their shared roles in preparing medical students for clinical practice, regardless of their specific titles or responsibilities. As such, the findings reflect a unified perspective among clinicians involved in medical education, despite the initial distinction made in the sample selection.

Themes	Quotes from Participants
Limited and inconsistent exposure to DHTs	In private practice, particularly in Family Medicine, telemedicine is fairly common. But I don't think it is a model that has been adopted in public hospitals or tertiary settings yet… Telemedicine is a new thing that only came up because of COVID. (MS10, Year 4)
	In Korea, medical students are already exposed to advanced medical robots, with 40 robots used in operating theaters. Introducing a robotics module for medical students could spark interest and lead to innovations in robotics and research. (CL20, Otorhinolaryngology)
Essential competencies for clinical practice	*EHR*:
	A skill that should be taught to students is the ability to strike a balance between facing the screen and interacting with patients. In clinics, you need to face the computer to scribe your notes while talking to the patient. (MS8, Year 5).
	In the United States, students are trained in communication skills that incorporate electronic medical records into patient interactions. This training is lacking here, which is why patients often complain that doctors focus too much on the computer screen during consultations. (CL27, Rheumatology)
	Telemedicine:
	I wish to be adept at performing teleconsultation, as this seems to be the up-and-coming practice. But with this comes many ambiguities such as reading body language, building rapport, and with that comes legal liabilities and responsibilities, like what exactly are the conditions that are suitable for teleconsultation, what are the ways to circumvent issues with teleconsultation and how to best integrate it into a patient's individualized care. (MS5, Year 5)

	A skill students need to learn is how to interact well in a non-face-to-face context, like in a tele-setting. They need to learn how to select patients appropriately and spot red flags. (CL14, Respiratory Medicine)
Divergent opinions on traditional clinical skills	*POCUS:* Ultrasound is currently not taught routinely to students. It is important to know ultrasound because a lot of GPs are now using it in their clinics as an adjunct to diagnosing conditions and confirm clinical examinations. (CL9, General Surgery) Every medical student should learn ultrasound. It's a useful skill for those who may work in developing countries, where they may need to provide treatment directly at the point of care. (CL18, Orthopaedic Surgery) *Students' perspective:* When it comes to clinical signs, if a patient has a mildly enlarged liver, if we are able to feel it, we can actually do tests like ultrasound or further testing to know exactly the length, size or span of the liver. So, it doesn't actually matter whether you feel it on the physical examination or not. (M11, Year 4) When assessing heart murmurs in patients with heart conditions, it is not always important to precisely diagnose the type of murmur, as an echocardiogram will ultimately provide the exact diagnosis. Similarly, for cases like detecting abdominal masses, even if physical examination is challenging, such as with obese patients, an ultrasound can be readily ordered to confirm the findings. (MS11, Year 4) *Clinicians' perspective:* As doctors become more dependent on investigation findings and diagnostic tests, I do see basic skills such as history-taking and physical examination skills have eroded. (CL3, Ophthalmology) Imaging has somewhat replaced traditional clinical examination skills, but these skills remain important and relevant. I still emphasise teaching clinical examination as a fundamental component before turning to imaging. However, most schools now default to imaging, which might be a drawback of technological advances. We need to strike a balance by ensuring clinical examination skills are adequately taught alongside imaging. (CL9, General Surgery)
Emerging technologies and concerns • Wearables and healthcare apps	We should empower patients by improving their access to reliable medical knowledge. In this modern era, trustworthy and accurate apps can be valuable tools for disseminating information, such as red flags patients should be aware of. Apps offering verified and relevant information could greatly benefit patients by providing better guidance than what they might find through general online searches. (MS17, Year 3) Health trackers, like wearable devices for cardiovascular or gynaecological health, hold great potential. If doctors are equipped with the knowledge to interpret the data generated by these devices—many of which patients already use voluntarily—it could significantly enhance clinical practice. (MS30, Year 4)

Table 4. Illustrative quotes from interviews with participants

IV. DISCUSSION

This study contributes to the literature by comparing the views of medical students, clinical educators, and clinical teachers on essential competencies for medical school curricula. It highlights a consensus on the need for training in EHR, telemedicine, and POCUS, while also identifying emerging needs like interpreting data from healthcare devices and engaging patients with this data. Unlike previous studies that focused on either clinicians or students (Blacketer et al., 2021; Foadi et al., 2021; Gillissen et al., 2022; Hersh et al., 2017; Liu et al., 2022; Machleid et al., 2020; Pontefract & Wilson, 2019), this research explores inter-generational differences, revealing that younger trainees prioritise patient-centred care and digital health literacy. This emphasis on inclusivity and data literacy is crucial given the global challenge of inadequate health literacy, particularly among older populations (Sørensen et al., 2021; Wittink & Oosterhaven, 2018). Integrating these competencies into curricula can foster ongoing improvement in medical education.

In comparing the views of medical students and senior clinicians regarding DHCs, it is important to acknowledge that the latter group represents a diverse range of roles within the clinical environment. While this study focused specifically on clinicians involved in medical education, senior clinicians may also take on roles as clinical researchers, administrators, or leaders in healthcare innovation. These differing responsibilities could shape their perspectives on the DHCs that should be emphasised in medical curricula. The results of this study should be interpreted within the context of the clinical educators' primary role in teaching medical students, which may prioritise practical and immediate clinical skills over broader administrative or research-based digital competencies.

The integration of EHR systems into medical education has been recognised as essential. Successful models in the U.S. and U.K. have embedded EHR systems into training, such as allowing students to write notes at primary clinical sites or use de-identified patient data for practice (Pereira et al., 2018; Pontefract & Wilson, 2019; Welcher et al., 2018). These approaches ensure hands-on

learning and prepare students for modern healthcare environments. For broader applicability, partnerships with local healthcare institutions and technology providers can enable the development of localised EHR modules tailored to different healthcare contexts. However, over-reliance on EHR systems may reduce critical thinking or direct patient interaction. Mitigation strategies include embedding reflective practices into training and balancing EHR use with patient engagement activities. When successfully implemented, EHR training enhances data management skills and promotes patient interaction.

Telemedicine training varies globally, often focusing on rural healthcare placements, as seen in Australia and the U.K. (Rienits et al., 2016; Wootton, 1999). In Singapore, telemedicine exposure arose mainly during the COVID-19 pandemic's social distancing requirements, highlighting its potential in urban healthcare. To ensure comprehensive telemedicine training, curricula should include simulated consultations, role-playing exercises, and coverage of diverse scenarios, such as breaking bad news over digital platforms. To address the challenge of interpreting body language, medical schools should incorporate modules that focus on interpreting non-verbal cues, such as facial expressions and gestures, which are essential for building rapport and understanding patients' concerns. Courses that address the legal responsibilities in telemedicine, including patient confidentiality, informed consent, and documentation requirements, should also be integrated to ensure students are aware of the regulatory frameworks guiding virtual care. Case studies and real-life examples that discuss the legal implications of telemedicine can also help students navigate potential legal challenges. With regard to patient selection, it is crucial for professional bodies to develop frameworks that guide clinicians in determining when in-person care is more appropriate, especially for complex or high-risk cases. Additionally, the curricula should provide guidance on how to recognise red flags such as signs of mental health distress, urgent medical conditions, or patient non-compliance with digital tools, and escalate them appropriately. Providing continuing education opportunities for practising clinicians is also important to keep them updated on telemedicine advancements. The healthcare system can then pair students with experienced telemedicine practitioners who can provide the necessary mentorship and guidance.

POCUS has become an essential component of undergraduate medical education (Glass et al., 2021; Sheppard et al., 2023). However, its application is often limited to specific specialties, such as emergency medicine, obstetrics and gynaecology, and radiology (Glass et al., 2021). In contrast, our study advocates for a longitudinal POCUS curriculum spanning all years and specialties. Integrating POCUS training into medical curricula improves diagnostic accuracy, enhances bedside decision-making, and builds clinical confidence. A structured approach, such as Kern's six-step model, provides a robust framework for designing and implementing a standardised curriculum with consistent competency assessments (Kern, 1998). Innovative teaching methods, including handheld devices and near-peer instruction, have been shown to improve ultrasound proficiency and student performance, as evidenced by successful implementations at the University of Connecticut School of Medicine (Boivin et al., 2022). While improper use of POCUS can result in diagnostic errors, these risks can be mitigated through routine competency evaluations and guided practice, ensuring students develop the necessary skills safely and effectively.

Addressing differing opinions regarding DHC priorities in schools requires collaboration among medical educators, technology developers, and healthcare providers. Medical curricula should include training on the responsible use of DHTs, and evaluating the reliability of apps. Developers should design apps that address clinicians' data security concerns. Moreover, healthcare organisations should establish guidelines and protocols for healthcare-related app use to ensure patient safety and privacy. Integrating these competencies into medical curricula will better prepare future healthcare professionals for evolving demands of healthcare delivery.

Implementing DHC also requires consideration of diverse healthcare systems and resource availability. Local adaptations, coupled with ongoing evaluation and feedback, ensure curricula remain relevant and scalable. Training programmes must balance global standards with local needs, enabling students to navigate evolving healthcare landscapes effectively. By addressing the implementation strategies, risks, and benefits of DHTs, this study provides actionable insights for advancing DHE.

A. Strengths and Limitations

This qualitative study highlights the DHCs needed in the core medical curricula from the perspectives of students, clinical educators and teachers. The diverse sample of institutions and specialties enriched the data. Student feedback provided up-to-date information on curricula gaps, while senior clinicians' experience enhanced credibility. Interviewing participants from different generations ensured medical education remains relevant to current and future healthcare needs.

A perceived limitation of this study is its small sample size, which may affect its generalisability, validity and reliability. With a small sample, the findings might not represent the broader population and could miss the population's diversity (Sandelowski, 1995). Additionally, small sample sizes may not adequately capture the diversity within the population of interest (Sandelowski, 1995). Moreover, the unique socio-political, cultural and economic context of Singapore may limit the generalisability of our findings to other settings. Singapore's relatively small population and centralised governance create conditions that may differ from other countries. Consequently, while the insights from our study provide valuable lessons, they should be interpreted with caution when applying them to contexts with different governance structures or cultural dynamics.

Despite the limitations, this qualitative study provides a contextualised understanding of participants' expectations and concerns through in-depth narrative analysis. While not entirely generalisable, the findings have significant implications for medical curricula in other developed countries. They highlight valued competencies, informing curriculum design, training programmes and continuing education initiatives.

Furthermore, this study focused on clinicians from public healthcare institutions, which may influence their perspectives on DHCs. Public sector clinicians often work within more structured systems that prioritise certain competencies differently than in the private sector. While this focus provides insights specific to public healthcare education, it is important to note that the views of private-sector clinicians, who may face different digital health challenges, were not captured in this study. Future work comparing clinicians across both sectors could provide a more comprehensive view. The perspectives of clinicians from the private healthcare sector may also differ due to the distinct operational and financial frameworks in which they practise.

Moreover, future research could explore the perspectives of clinicians in various roles beyond medical education, such as clinical researchers, healthcare administrators, or those involved in clinical governance. By comparing these viewpoints with those of clinical educators, a more comprehensive understanding of the DHCs required across different professional pathways in healthcare can be developed. Such studies could further inform curriculum development to ensure that medical students are adequately prepared not only for clinical practice but also for the evolving demands of digital health in research, administration, and leadership.

V. CONCLUSION

In conclusion, an inter-generational perspective in medical education leverages the strengths of both medical students and senior clinicians, ensuring a balanced approach that keeps pace with technological advancements while maintaining the core principles of patient care. This collaborative model prepares future healthcare professionals to navigate the evolving landscape of healthcare technology effectively. As the findings have shown, despite their varying levels of experience and diverse medical backgrounds, the DHCs deemed essential for future clinical practice are consistent across all stakeholders. While all stakeholder groups considered most basic clinical skills important, medical students viewed physical examination as replaceable by DHTs. In contrast, the clinical educators and teachers thought otherwise. To address the needs and concerns of all groups, DHCs should complement instead of replace traditional clinical skills.

We acknowledge that the DHTs deemed important in other countries may vary from those reported in this study. However, the type of DHTs to be introduced should not distract us from the main goal of ensuring that the curricula of medical schools around the world remain updated and relevant to current and future healthcare needs. Regularly comparing the perspectives of various stakeholders in the healthcare system is crucial, as it enables educational institutions to adapt and refine their curricula continuously. This iterative process ensures that the curricula remain responsive to the dynamic nature of clinical work.

Notes on Contributors

Humairah Zainal collected and analysed the data, wrote the initial drafts, revised the manuscript for publication and approved the submitted copy of the manuscript.

Xin Xiaohui reviewed, edited, read and approved the submitted copy of the manuscript.

Julian Thumboo reviewed, edited, read and approved the submitted copy of the manuscript.

Fong Kok Yong was involved in the conception and design of the study, reviewed, edited, read and approved the submitted copy of the manuscript.

Ethical Approval

Waiver for ethical approval was granted by SingHealth Institutional Review Board (Reference Number: 2020/2880).

Data Availability

The data that support the findings of this study are available from the first author upon reasonable request.

The data cannot be uploaded to the repository as it contains some confidential views of participants.

Acknowledgements

The authors extend their gratitude to the reviewers for their insightful feedback on the manuscript drafts. Special thanks go to Anisa Muhammad for transcribing the interviews, as well as to Dr. Warren Fong Weng Seng and Dr. Ng Qin Xiang for their assistance in recruiting some of the medical students. The authors also deeply appreciate the invaluable contributions of the study participants.

Funding Statement

This study was supported by SingHealth Duke-NUS Medicine Academic Clinical Programme under Seah Cheng Siang Distinguished Professorship in Medicine.

Declaration of Interest

There are no relevant financial or non-financial competing interests to report.

References

Alkire (née Nasr), L., O'Connor, G. E., Myrden, S., & Köcher, S. (2020). Patient experience in the digital age: An investigation into the effect of generational cohorts. *Journal of Retailing and Consumer Services*, *57*, Article 102221. https://doi.org/10.1016/j.jretconser.2020.102221

Aungst, T. D., & Patel, R. (2020). Integrating digital health into the curriculum - Considerations on the current landscape and future developments. *Journal of Medical Education and Curriculum Development*, 7, Article 2382120519901275. https://doi.org/10.1177/2382120519901275

Blacketer, C., Parnis, R., B. Franke, K., Wagner, M., Wang, D., Tan, Y., Oakden-Rayner, L., Gallagher, S., Perry, S. W., Licinio, J., Symonds, I., Thomas, J., Duggan, P., & Bacchi, S. (2021). Medical student knowledge and critical appraisal of machine learning: A multicentre international cross-sectional study. *Internal Medicine Journal*, *51*(9), 1539-1542. https://doi.org/10.1111/imj.15479

Boivin, Z., Carpenter, S., Lee, G., Chimileski, B., Harrison, J., Choudhary, D., & Herbst, M. (2022). Evaluation of a required vertical point-of-care ultrasound curriculum for undergraduate medical students. *Cureus*, *14*(10), e30002. https://doi.org/10.7759/cureus.30002

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Clay-Williams, R., Hibbert, P., Carrigan, A., Roberts, N., Austin, E., Fajardo Pulido, D., Meulenbroeks, I., Nguyen, H. M., Sarkies, M., Hatem, S., Maka, K., Loy, G., & Braithwaite, J. (2023). The diversity of providers' and consumers' views of virtual versus inpatient care provision: A qualitative study. *BMC Health Services Research*, *23*(1), 724. https://doi.org/10.1186/s12913-023-09715-x

Edirippulige, S., Brooks, P., Carati, C., Wade, V. A., Smith, A.C., Wickramasinghe, S., & Armfield, N. (2018). It's important, but not important enough: eHealth as a curriculum priority in medical education in Australia. *Journal of Telemedicine and Telecare*, *24*(10), 697-702. https://doi.org/10.1177/1357633x18793282

Food and Drug Administration. (2019). *Digital health center of excellence*. https://www.fda.gov/medical-devices/digital-health-center-excellence

Foadi, N., Koop, C., Mikuteit, M., Paulmann, V., Steffens, S., & Behrends, M. (2021). Defining learning outcomes as a prerequisite of implementing a longitudinal and transdisciplinary curriculum with regard to digital competencies at Hannover Medical School. *Journal of Medical Education and Curricular Development*, *8*, 23821205211028347. https://doi.org/10.1177/23821205211028347

Gillissen, A., Kochanek, T., Zupanic, M., & Ehlers, J. (2022). Medical students' perceptions towards digitization and Artificial Intelligence: A mixed-methods study, *Healthcare (Basel), 10*(4), 723-737. https://doi.org/10.3390/healthcare10040723

Glass, C., Sarwal, A., Zavitz, J., Nitsche, J., Joyner, J., Johnson, L. L., Garcia-Vargas, J., & O'Brien, M. C. (2021). Scoping review of implementing a longitudinal curriculum in undergraduate medical education: The wake forest experience. *The Ultrasound Journal*, *13*(1), 23. https://doi.org/10.1186/s13089-021-00206-w

Hersh, W., Biagioli, F., Scholl, G., Gold, J., Mohan, V., Kassakian, S., Kerns, S., & Gorman, P. (2017). From competencies to competence: Model, approach, and lessons learned from implementing a clinical informatics curriculum for medical students. In Shachak, A., Borycki, E.M., & Reis, S.P. (Eds.), *Health professionals' education in the age of clinical information systems, mobile computing and social networks* (pp. 269-287). Academic Press. https://doi.org/10.1016/B978-0-12-805362-1.00013-9

Hurley, K. F., Taylor, B., Postuma, P., & Paterson, G. (2011). What are Canadian medical students learning about health informatics. *Electronic Journal of Health Informatics*, *6*(4), np.

Kallio, H., Pietilä, A.-M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: Developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing.*, *72*(12), 2954–2965. https://doi.org/10.1111/jan.13031

Kern, D. E. (1998). Overview: A six-step approach to curriculum development. In P.A., Thomas, D.E., Kern, M.T., Hughes & B.Y. Chen (Eds.), *Curriculum Development for Medical Education: A Six-Step Approach* (pp. 5-10). Johns Hopkins University Press.

Liu, D. S., Sawyer, J., Luna, A., Aoun, J., Wang, J., Boachie, L., Halabi S., & Joe B. (2022). Perceptions of US medical students on Artificial Intelligence in medicine: Mixed methods survey study. *JMIR Medical Education*, *8*(4), e38325. https://doi.org/10.2196/38325

Machleid, F., Kaczmarczyk, R., Johann, D., Balčiūnas, J., Atienza-Carbonell, B., von Maltzahn, F., & Mosch, L. (2020). Perceptions of digital health education among european medical students: Mixed methods survey. *Journal of Medical Internet Research*, *22*(8), e19827. https://doi.org/10.2196/19827

O'Brien, B. C., Harris, I. B., Beckman, T. J., Reed, D. A., & Cook, D. A. (2014). Standards for reporting qualitative research: A synthesis of recommendations. *Academic Medicine*, *89*(9), 1245–1251. https://doi.org/10.1097/ACM.0000000000000388

Pereira, A. G., Kim, M., Seyward, M., Nesbitt, B., & Pitt, M. B. (2018). Collaborating for competency - A model for single electronic health record onboarding for medical students rotating among separate health systems. *Applied Clinical Informatics*, *9*(1), 199-204. https://doi.org/10.1055/s-0038-1635096

Pontefract, S. K., & Wilson, K. (2019). Using electronic patient records: Defining learning outcomes for undergraduate education. *BMC Medical Education*, *19*(1), 30. https://doi.org/10.1186/s12909-019-1466-5

Rienits, H., Teuss, G., & Bonney, A. (2016). Teaching telehealth consultation skills. *The Clinical Teacher*, *13*(2), 119–123. https://doi.org/10.1111/tct.12378

Sandelowski, M. (1995). Sample size in qualitative research. *Research in Nursing & Health*, *18*(2), 179–183. https://doi.org/10.1002/nur.4770180211

Sheppard, G., Williams, K.-L., Metcalfe, B., Clark, M., Bromley, M., Pageau, P., Woo, M., Yi, Y., Devasahayam, A. J., & Dubrowski, A. (2023). Using Kane's framework to build an assessment tool for undergraduate medical student's clinical competency with point of care ultrasound. *BMC Medical Education*, *23*(1), 43. https://doi.org/10.1186/s12909-023-04030-9

Sørensen, K., Levin-Zamir, D., Duong, T. V., Okan, O., Brasil, V. V., & Nutbeam, D. (2021). Building health literacy system capacity: A framework for health literate systems. *Health Promotion International*, *36*(Supp 1), i13–i23. https://doi.org/10.1093/heapro/daab153

Tudor Car, L., Kyaw, B. M., Panday, R. S. N., van der Kleij, R., Chavannes, N., Majeed, A., & Car, J. (2021). Digital health training programs for medical students: Scoping review. *JMIR Medical Education*, *7*(3), e28275. https://doi.org/10.2196/28275

Welcher, C. M., Hersh, W., Takesue, B., Stagg Elliott, V., & Hawkins, R. E. (2018). Barriers to medical students' electronic health record access can impede their preparedness for practice. *Academic Medicine*, *93*(1), 48–53. https://doi.org/10.1097/ACM.0000000000001829

Wittink, H., & Oosterhaven, J. (2018). Patient education and health literacy. *Musculoskeletal Science and Practice*, *38*, 120–127. https://doi.org/10.1016/j.msksp.2018.06.004

Wootton, R. (1999). Telemedicine and isolated communities: A UK perspective. *Journal of Telemedicine and Telecare*, *5*(2), 27–34. https://doi.org/10.1258/1357633991933495

Zainal, H., Xiaohui, X., Thumboo, J., & Kok Yong, F. (2023a). Digital competencies for Singapore's national medical school curriculum: A qualitative study. *Medical Education Online*, *28*(1), 2211820. https://doi.org/10.1080/10872981.2023.2211820

Zainal, H., Xiaohui, X., Thumboo, J., & Kok Yong, F. (2023b). Exploring the views of Singapore junior doctors on medical curricula for the digital age: A case study. *PLOS ONE*, *18*(3), e0281108. https://doi.org/10.1371/journal.pone.0281108

Fong Kok Yong
10 Hospital Boulevard
Singapore 168582
+65 6908 8949
Email: fong.kok.yong@singhealth.com.sg