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PERSPECTIVES

"Technology Proficiency" in Medical Education: Worthiness for Worldwide Wonderful Competency and Sophistication

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Purpose: Advances in bioinformatics, information technology, advanced computing, imaging techniques are changing fundamentally the way physicians define, diagnose, treat, and prevent disease. New disciplines – Artificial Intelligence, Machine Learning, Computational Biology – are improving healthcare. Digital health solutions have immense scope. Education and practice need to keep pace.

Methods: We aimed at assessment of "Technology proficiency" required by medical graduates and its implementation, if found useful. All this in a conceptual framework of "TP" model, having categories (a) proper assessment (b) pertinent treatment (c) progress monitoring (d) prevention applications (e) professional standards. A search of the literature was performed using MedLine & Cochrane Central Register of Controlled Trials databases, for systematic reviews and meta-analysis articles published in the last five years using keyword "technology". Analysis of those relevant to the role all medical graduates should play. An analysis of worldwide statutory medical institutions guidelines.

Results: Twenty-three systematic studies and meta-analysis were studied. Eighteen show clear evidence for 'Technology proficiency", while 5 recommend further studies. The findings are discussed suiting the roles of doctors in the "TP" model. Medical institutions guidelines worldwide diligence suggests need of including "Technology proficiency" as a definite and distinct strategic plan. Medical Council of India mandates "use information technology for appropriate patient care and continued learning". General Medical Council, UK and Medical Council India have been proactive in technology training. GMC recommends technology use for learning, prescribing, communication, and interpersonal skills. It should be expanding technology proficiency in practice as an essential professional capability.

Conclusion: "Technology proficiency" is found pertinently fruitful. It should be included as a definitive requirement and a distinct strategic plan worldwide. Modern curriculum development is proposed (i) Educational goals and objectives as the proposed Conceptual framework "Technology proficiency" model (ii) Instructional strategies 'Five Bs' (iii) Implementation 'Five Ms'.

Keywords: assessment, treatment, monitoring, prevention, professional standards, curriculum

Plain Language Summary

New technologies for understanding diseases, diagnosis, and treatment are widely available and revolutionizing medical practice. All doctors need to be in tune with the times. Thus, a need for exploring 'technology proficiency' as a distinct competency in medical teaching worldwide. We have aimed at assessment of usefulness of 'technology proficiency' and to advance its implementation, if found useful. Our methods for this included (i) search of authentic medical literature of best quality with rigorous assessment (ii) analysis of worldwide statutory medical institutions guidelines. Only last five years literature was searched as technology is fast advancing, and old becomes obsolete sooner than later. All this is done in a conceptual framework of proposed 'TP' model, encompassing all components of medical practice comprehensively and classified into five categories (a) proper assessment (b) pertinent treatment (c) progress monitoring (d) prevention applications (e) professional standards. We find 'technology proficiency'

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pertinently fruitful based on literature analysis. The worldwide medical institutions guidelines studied suggest need of it's inclusion in medical education. This should be done as a definite and distinct strategic plan. Benefits and risks need to be balanced for success with safety. We recommend that health professional education for 'technology proficiency' should include only those which have passed rigorous health technology assessment as prescribed by the World Health Organization. Our proposed model of 'technology proficiency' for modernizing medical curricula for health care covers all aspects, for holistic health of highest standards. Worldwide competency sophistication will result in best care that is futuristic and favourable.

Introduction

Machines taking over men is not new. Machines sophisticated in the art and science of medicine will soon be available for many. New technologies for understanding diseases, diagnosis, and treatment are widely available and revolutionizing the way we practice. It becomes imperative that all doctors should be competent in their use for best practices.

The opening remark in the coveted Harrison's Principles of Internal Medicine is

> The practice of medicine has changed in significant ways, The advent of molecular genetics, sophisticated new imaging techniques, robotics, and advances in bioinformatics and information technology have contributed to an explosion of scientific information that has changed fundamentally the way physicians, define, diagnose, treat, and attempt to prevent disease.[1]

All doctors need to be in tune with the times. This is further justifiably required with new disciplines improving healthcare – The Artificial Intelligence, the Machine Learning, the Data Analytics, the Computational Biology, etc. All these are advancing at an accelerated pace with applications professional in healthcare.

Similarly, the impact of technology in surgery has been phenomenal and best summarised in the *Sabiston Textbook of Surgery*:

> The introduction of digitization, miniaturization, improved optics, novel imaging techniques, and computerized information systems in the operating room have made a dramatic change in surgical care over the past 25 years.[2]

The results of technology along with other excellence is beautifully summarised by the World Health Organization (WHO) in its "Japan Health System Review" as

> Thanks to the overall effectiveness of the health system, socio-economic development and advances in technology, Japan has enjoyed increased life expectancy for many years.[3]

Importance

The global population is increasing rapidly, and the number of people aged ≥60 years is expected to double by 2050.[4,5] A potential shortage of health care professionals is likely.[6] Technology is a possible answer, increasing the efficiency and effectiveness of healthcare by doctors.

Digital technologies are now integral to daily life. Digital health can help make health systems more efficient and sustainable, enabling them to deliver good quality, affordable and equitable care. There is immense scope for use of digital health solutions.[7] For this utilization, technology proficiency in medical education needs to be explored.

The WHO Global Observatory for eHealth, describing eHealth as the use of Information and Communication Technologies (ICT) for health, commented that it is recognised as one of the most rapidly growing areas in health today.[8] Health science education should keep pace with the developments. Weighing pros and cons of advances judiciously is necessary.

Curriculum Development for Medical Education is important. The generic approaches to curriculum development set forth by eminent medical educationists advocated the linking of curricula to health care needs.[9] Working modification in the modern world requires incorporating all modalities available for advancing health care, including technology.

The Medical Council of India (MCI), in its national meet on implementation of reforms in undergraduate and postgraduate medical education "Vision 2015", had envisioned:

> Ensure that community requirements and advancing medical technology are main streamed on an ongoing basis across disciplines.[10]

However, the pace of advances in technology suggests the need for advanced professionalism. “Technology proficiency” should be explored as a distinct competency in all medical teaching worldwide. An assessment of worldwide worthiness is imperative.

Methods

Aim

Assessment of “Technology proficiency” is required by all medical graduates to advance its implementation, if found useful.

Conceptual Framework

Conceptual frameworks represent ways of thinking about a problem or a study, or ways of representing how complex things work. Conceptual frameworks can come from theories, models or best practices.[11]

Technology is permeating all aspects of health care, hence the need for a comprehensive multi-faceted perspective and a model. We propose a Technology Proficiency model comprising five categories (Figure 1):

1. Technology for proper assessment
2. Technology for pertinent treatment
3. Technology for progress monitoring
4. Technology for prevention applications
5. Technology for professional standards

Evidence and Guidelines Analysis

Proper perspective presentation requires study of latest systematic reviews and meta-analysis for trends and statutory medical institutions guidelines for advancements.

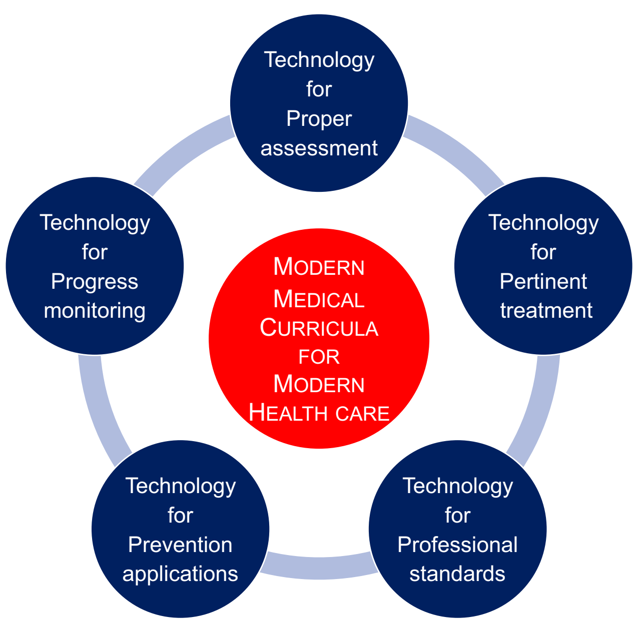

Figure 1 “Technology proficiency” model.

Systematic Reviews and Meta-Analysis

A search of the literature was performed using MedLine & Cochrane Central Register of Controlled Trials databases for systematic reviews and meta-analysis articles published in the last five years. Only last five years literature was searched as technology is fast advancing, and old becomes obsolete sooner than later. Keyword used in search was "technology". Only systematic reviews and meta-analysis were included, as individual research papers on technology are vast and systematic reviews and meta-analysis filter these on quality, with rigorous assessment. A total of 646 papers were identified with this search (615 MedLine systematic reviews and meta-analysis and 31 Cochrane reviews), which question the use of technology in medical practice and are relevant as a role all medical graduates should play. The findings of the most relevant papers, practically suiting the roles of doctors, out of these are presented in Tables 1–5, classified as "Technology proficiency" model five categories.

The following inclusion criteria were used: 1) Published in peer-reviewed journals and 2) Related to medical professionals. Exclusion criterion was articles not directly relevant to the above five categories were not studied.

Worldwide Medical Institutions

Analysis of worldwide statutory medical institutions guidelines and make recommendations.

Results

(i) The findings and analysis of reviews studied are presented in Tables 1–5. Of the total 23 systematic studies and meta-analysis analysed, 18 have shown clear evidence for "Technology proficiency". The remaining five have commented (a) Validation: Although promising, there is still a need for large-scale studies for validation.[12] (b) Cost-effectiveness: More research on cost-effectiveness is needed to determine the potential for other diseases.[13] (c) Clinical acceptance: Further studies are required for leading technologies to clinical acceptance.[15] (d) Effectiveness: Stronger primary research on the effectiveness of contact tracing technologies is needed.[27] (e) Confidence: Authors confidence in the effect estimates is limited.[29]

(ii) The findings of statutory medical institutions guidelines worldwide are given in Table 6.

Discussion

Digital transformation of health care is supportive with technologies such as the virtual care, remote monitoring, smart wearables, platforms, tools enabling data exchange and storage and tools enabling remote data capture and the exchange of data and sharing of relevant information across the health ecosystem creating a continuum of care. Technologies enabling all this are Internet of Things, artificial intelligence, big data analytics, blockchain, machine learning, robotics, and advanced computing. All this has proven potential to enhance health outcomes by improving medical diagnosis, data-based treatment decisions, digital therapeutics, clinical trials, self-management of care and person-centred care as well as creating more evidence-based knowledge, skills and competence for professionals to support health care.[42]

We discuss all this for "Technology proficiency" model comprising five categories.

Technology for Proper Assessment

History taking, clinical examination, investigations are all aided by technology. Telemedicine has evolved for this basic purpose. It increases accessibility to medical services through the Information and Communication Technology (ICT) platform.[18] Further face-to-face consultation remotely is possible with video calls, anytime, anywhere, without any waiting and thus useful in emergency also. Clinical examination is also aided. Auscultation with technology is not only possible but can provide diagnosis with standardized technology-based interpretation. This will also aid novice clinicians perfect their skills.

Video clips for paroxysmal disorders is an important case in point, aiding precise diagnosis. Paroxysmal disorders affecting humanity are plenty. Their precise characterization is important for specific management. Descriptions by eye witnesses can be varied and weird. A video recording done by a readily available mobile telephone can help in hitting the

Table 1 Systematic Review Characteristics and Findings: Technology for Proper Assessment

Study	Population	Study Aim	Technology Focus	Results	Conclusion/Comments
Clark et al 2021[12]	Typically developing (TD) and non-TD children	Technological assessment of fine and/or gross motor skills	Fine motor skill assessment solutions: force transducers, instrumented tablets and pens, surface electromyography, and optoelectronic systems. Gross motor skill assessment solutions: inertial measurements units, optoelectronic systems, baropodometric mats, and force platforms.	The review provides a guide in identifying and evaluating the variety of available technological solutions for motor skill assessment.	Although encouraging, large-scale studies needed to validate the approaches in terms of accuracy, repeatability, and usability.
Huang et al 2021[13]	Patients with pulmonary nodules and physicians	The diagnostic performance of AI-assisted CT diagnostic technology for distinguishing pulmonary nodules as benign or malignant and to analyze physicians' perceptions of this technology.	AI-assisted CT diagnostic technology	Pooled sensitivity and specificity for differentiating benign and malignant pulmonary nodules is 0.90 and 0.89, respectively. The pooled diagnostic odds ratio (DOR) is 70.33. Surveyed physicians perceptions: "reduced workload for radiologists" and "improved diagnostic efficiency" by the majority.	iDiagnostic performance good.Specificity needs improvements Supportive of 'Technology proficiency'
Nazarian et al 2021[14]	A total of 421,267 subjects	Diagnostic accuracy of smartwatches in the detection of cardiac arrhythmias.	Smartwatches based on photoplethysmography	The overall sensitivity, specificity, and accuracy reported is 100%, 95%, and 97%, respectively. The pooled PPV: 85% and NPV: 100% for detecting cardiac arrhythmias	The positive principal findings values provide a positive perspective to clinicians for the use of smartwatches in health care. More studies needed for (i) the use of these as screening tools (ii) to clearly define the ideal population for the use of these systems (iii) formulation of specific guidance on the management of device-detected disease (iv) evidence for policy making decisions by health departments in the future (v) testing to meet regulatory standards. Supportive of 'Technology proficiency'
Versluis et al 2022[15]	Mainly focused on sexually transmitted infections.	Examination of direct web-based access methods for diagnostic testing and results, in situations of non-availability of health care professional in primary care.	eHealth	(i) high use rates (ii) increased rates of follow-up treatment (iii) high preference	More research on cost-effectiveness required for useability for other diseases.

(*Continued*)

Table 1 (Continued).

Study	Population	Study Aim	Technology Focus	Results	Conclusion/Comments
Bortolani et al 2021[16]	Neuromuscular disorders (NMDs) patients	Potential of use of technological devices for motor function assessment in NMDs	Technological devices	Kinect-based outcome measures and Myotools validated in multicenter studies and for different NMDs. Excellent characteristics shown for application in clinical trials.	The potential of the different technology outcome measures in the neuromuscular field is encouraged. Supportive of 'Technology proficiency' 👍
Mennella et al 2022[17]	Hand functional assessment in individuals and patients (Neurological diseases and neuromuscular disorders)	Investigate characteristics of technology aided hand functional assessment.	Inertial measurement unit (IMU) and force sensing resistor (FSR)	Technology-aided clinical assessment procedures required for optimization of healthcare services. Besides the studies to quantify gross motor movements of shoulder, arm, and forearm, there is need for including hand functioning domains.	Future studies for (i) pathophysiological content (ii) clinimetrics properties (iii) clinical acceptance. New technologies should be adopted as complementary tools to conventional clinical procedures for optimization of diagnosis and treatment outcomes.
Alhasan et al 2021[18]	COVID-19 pandemic	(i) Explore modern healthcare technologies and Artificial Intelligence (AI) use during COVID-19 crisis (ii) define AI concepts and clinical usefulness in the mitigation of COVID-19 (iii) investigate AI-enabled technology use in medical imaging during COVID-19	(A) Digital technologies (B) AI clinical role (C) AI and medical imaging	(A) Digital technologies useful in addressing the impact of the pandemic (B) AI useful in (i) remote detection and diagnostics (ii) COVID-19 vaccine and therapeutics facilitation (iii) clinical workflow changes (iv) knowledge dissemination to systematically address the novelty of COVID-19 (v) enabling autonomous responses to COVID-19 (C) Digital interventions usefully magnified the role of medical imaging amid the COVID-19 crisis.	Digital interventions have enhanced the responses to COVID-19 and provided healthcare professionals the opportunity of contactless care. Supportive of 'Technology proficiency' 👍

Note: 👍 - Favourable.

Table 2 Systematic Review Characteristics and Findings: Technology for Pertinent Treatment

Study	Population	Study Aim	Technology Focus	Results	Conclusion/Comments
Vieira et al 2020[19]	Type 2 diabetes patients	Evaluate the effectiveness of technology interventions on management of type 2 diabetes distress.	Web-based interventions	Six out of nine articles show positive impact on diabetes distress scale scores. Among the six articles, five showed a greater reduction in the diabetes distress scores from control interventions. Web-based interventions are good when used along with personalized feedback and routine caregiver support and attention.	Reduction of diabetes distress and improvements in the outcome and quality of life of patients with type 2 diabetes mellitus. Supportive of 'Technology proficiency'
Gauhar et al 2022[20]	Benign Prostatic Enlargement (BPE) patients	Comparison of perioperative parameters, early outcomes, and complications after Holmium laser enucleation of the prostate (HoLEP) with MOSES technology LEP (MoLEP) for BPE.	Moses technology, introduces a pulse-shape modulation for Holmium YAG; optimizing energy transmission to the target tissue, leading to more concise incisions and better coagulation profile.	MoLEP performs better in terms of intraoperative outcomes compared to standard HoLEP, with shorter enucleation, haemostasis, and total surgical times for similar energy delivered. In addition, reduced postoperative hospitalization with an early trial of catheter favours MoLEP, making it suitable as a day surgery procedure.	MOSES laser system can improve intraoperative performance, resulting in a same-day discharge surgery. Supportive of 'Technology proficiency'
Cao et al 2021[21]	Acetabular fracture patients	Evaluation of three-dimensional (3D) printing technology in the surgery for acetabular fractures.	3D printing technology	3D printing-assisted surgery advantageous with decreased (i) operation time by 38.8 minutes (95% CI: −54.9, −22.8) (ii) intraoperative blood loss by 259.7 mL (95% CI: −394.6, −124.9) (iii) instrumentation time by 34.1 minutes (95% CI: −49.0, −19.1). Traditional surgery as compared to 3D printing-assisted surgery is (i) less likely to achieve good/excellent function of hip (RR, 0.53; 95% CI: 0.34, 0.82) (ii) more likely to have complications (RR 1.19; 95% CI: 1.07, 1.33).	3D printing technology is efficacious in the treatment of acetabular fractures. It may improve surgery-related and clinical outcomes. Supportive of 'Technology proficiency'
Carswell et al 2021[22]	Neurological disorder (stroke, Parkinson's disease and multiple sclerosis) patients	To gain insight in use of digital technology in neuro-rehabilitation	Digital technologies: virtual reality (VR), robotics, wearable sensors and telehealth	The majority of the literature (84%) favours use of digital technologies in the management of neurological dysfunction, and only some papers have a "neutral" or "against" standpoint. The studied technologies found to be highly acceptable by patients, helping to improve function, reducing anxiety and making therapy more accessible to patients living in more remote areas.	The most successful therapies are those that use a combination of conventional therapies and new digital technologies. Supportive of 'Technology proficiency'

Note: - Favourable.

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Table 3 Systematic Review Characteristics and Findings: Technology for Progress Monitoring

Study	Population	Study Aim	Technology Focus	Results	Conclusion/Comments
Dawes et al 2021[23]	Surgery patients post-operative	Explore how mHealth has been used to track patients after surgery and study differences in postoperative recovery.	Mobile health: using smartphone or tablet computer for capture and transmission of health-related patient information	Advantageous with (i) fewer emergency department visits (odds ratio 0.42, 95% CI: 0.23, 0.79) (ii) readmissions (odds ratio 0.47, 95% CI 0.29, 0.77) (iii) accelerated improvements in quality of life after surgery. Limited data on other postoperative outcomes.	Remote home monitoring via mHealth is feasible, adaptable, and promotes effective postoperative care. Physicians and policymakers should integrate mHealth for high-quality clinical care. Supportive of 'Technology proficiency'
Doshi et al 2021[24]	Chronic asthma patients	Evaluate the impact of Technology Based Interventions (TBI) on Patient Reported Outcomes (PRO) in the management of chronic asthma.	TBIs of different types, most commonly using multimedia education.	Positive outcomes reported in 12 of 14 studies.	TBIs improve PROs overall in patients with asthma. Future trials should include standardized PROs as endpoints for better understanding Supportive of 'Technology proficiency'
Marthick et al 2021[25]	People With Cancer	Evaluation of digital health interventions for supportive cancer care.	Digital supportive care interventions included interactive voice response, tele and video counseling, internet-based patient-provider communication, exercise based on the internet, support systems, symptom monitoring, and self-management, mobile phone-based remote monitoring, and activity monitoring with tracking devices.	Twenty randomized controlled trials analysed. Significant positive outcomes in most studies in (i) patient-reported symptoms (ii) levels of fatigue and pain (iii) health-related quality of life (iv) functional capacity (v) depression levels	Digital health interventions are effective for supportive care of patients with cancer. Further, there is a need for high-quality research. Supportive of 'Technology proficiency'
Jameel et al 2021[26]	Severe mental illness (SMI) people	Evaluate the use of mHealth technology forassessment, monitoring and reduction of functioning difficulties in people with SMI.	Smartphones (most popular) ; personal digital assistants; wearables; tablets	mHealth is acceptable and feasible. Preliminary findings suggest it can support functional recovery by (i) augmentation of intervention (ii) simplifying assessment (iii) increasing monitoring frequency (iv) providing more detailed information.	Better than traditional monitoring. Considerations for overcoming barriers to implementation, recommendations for future research to establish effectiveness, personalisation and specification of mHealth devices and methodologies need attention. The value for remote delivery of recovery based interventions also needs consideration. Supportive of 'Technology proficiency'

Note: - Favourable.

Table 4 Systematic Review Characteristics and Findings: Technology for Preventive Applications

Study	Population	Study Aim	Technology Focus	Results	Conclusion/ Comments
Botene et al 2021[27]	General	Analyze the use of blockchain technology in the struggle against the COVID-19 pandemic	Block chain	Adoption of the blockchain can effectively help in the fight against the coronavirus	Opportunities for academics and professionals in the application focus of the blockchain. Supportive of 'Technology proficiency'
Navidad et al 2021[28]	School children	Preventing obesity with (i) improvement in knowledge or nutrition habits and the promotion of physical activity (PA) (ii) use of new information and communications technologies (ICT) for this.	New information and communications technologies (ICT)	Beneficial effects of interventions in improved eating habits and increased PA. The effect on BMI found to be limited. ICT use can be of help at a motivational level for the maintenance and fulfilment of the health objectives.	New technologies use shows positive results in changes in behaviour and in the acquisition of improved habits. Supportive of 'Technology proficiency'
Anglemyer et al 2020[29]	General population, contact tracing in infectious diseases epidemics	Assessment of personal digital contact tracing solutions for identifying contacts of an identified positive case of an infectious disease.	Digital solutions	Modelling studies provide low-certainty evidence of a reduction in secondary cases if digital contact tracing is used together with other public health measures such as self-isolation. Cohort studies provide very low-certainty evidence.	Stronger research on the effectiveness of contact tracing technologies is needed

Note: - Favourable.

bull's eye in the differential diagnosis list. For example, differentiating epileptic seizures from paroxysmal events that mimic epilepsy, including pseudo-seizures, can be done with a video clip interpretation by an expert.

Telemedicine

The prospect of remote healthcare services is one of the gold standards of telemedicine. It increases accessibility to medical services through the ICT platform.[18] It is useful in conditions where distance is a critical factor, making available of experts from anywhere in the world, conveniently and economically.

Competency Tip

In a telephone consultation, it is important to pick up cues such as – pace, pauses, and change in voice intonation.[43]

Receptive and alert for advanced and real problem solving.

Technology for Pertinent Treatment

Selecting right medications, rightly planned surgeries, right counselling are all benefitted by technology. There is now good evidence that the routine use of ICT will contribute greatly to the use of real-time data to support clinical decisions.[44]

Computer-generated prescriptions have many benefits, including links to software that highlights risks from drugs or drug–drug combinations.[45]

3D printing is enabling precision surgery. Virtual surgical planning using information regarding patient anatomy and medical devices to be used in surgery increase confidence and knowledge before surgery for better outcomes. The digital plan is transferred to patient care by way of 3D printed templates, guides, or models.[46]

Artificial intelligence is making rapid strides. The principle of artificial intelligence is to make machines and programmed computer systems able to work like the human with capacity to learn, interpret, and develop resolutions

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Table 5 Systematic Review Characteristics and Findings: Technology for Professional Standards

Study	Population	Study aim	Technology focus	Results	Conclusion/Comments
Nabovati et al 2021[30]	Physicians treating patients with acute respiratory infection (ARI)	Examine the effects and characteristics of IT interventions on improving antibiotic prescribing	Information technology (IT) interventions	In 12 studies out of the 18 studies included, IT interventions improved the level of antibiotic prescribing; in 8 of these 12 studies the effect was statistically significant. Seventeen studies used clinical decision support systems for the intervention.	IT interventions potentially improve prescription of antibiotics for patients with ARIand change physicians' behaviours in this regard. Supportive of 'Technology proficiency' 👍
Gonçalves-Bradley et al 2020[31]	- Primary care providers consulting hospital specialists - Emergency physicians consulting hospital specialists - Community health workers or home-care workers consulting clinic staff	Assessment of the effects of mobile technologies versus usual care for (i) healthcare providers' performance (ii) acceptability and satisfaction (iii) healthcare use (iv) patient health outcomes	Mobile technologies	(i) Slightl decrease in the time to deliver health care, as well as the number of face-to-face appointments, when compared with usual care (ii) probable increase in the number of people receiving clinical examinations for some conditions, including an eye exam for people with diabetes (iii) little or no impact on healthcare workers' and participants' satisfaction, health status or well-being	Authors confidence in the effect estimates is limited
Devin et al 2020[32]	Hospital prescribers	(i) Quantitative assessment of the Health information technology (HIT) that reduces prescribing errors in hospitals (ii) Identify the behaviour change techniques (BCTs) associated with effective interventions.	Health information technology (HIT)	Thirty-five studies included. rprescribing HIT of varying sophistication as compared to paper-order entry was associated with decreased rates of prescribing errors (median OR 0.24, IQR 0.03–0.57). BCT analysis limited due to poor reporting.	Prescribing HIT is associated with a reduction in prescribing errors in a variety of hospital settings. Supportive of 'Technology proficiency' 👍
Kruse et al 2021[33]	Long-term care facilities inNorth America, Europe, and Australia.	Determine usefulness of health information technology (HIT) in the improvement of prescription administration in long-term care facilities.	HIT with electronic health records and electronic medication administration records	HIT beneficial in many healthcare organizations, with-term reductions in adverse drug events caused by medication errors	HIT can reduce prescribing errors. Comparison of various forms of HIT at improving medication safety across healthcare facilities. Supportive of 'Technology proficiency' 👍
Keyworth et al 2018[34]	General Practitioners	(i) Identification of interventions with a technological component that are successful at changing professional practice (ii) Determine if and how such interventions are theory-based (iii) Examine barriers and facilitators to successful implementation.	Technology to support professional practice change	Technological intervention providing decision support to healthcare professionals with knowledge and/or person-specific information to assist with patient management found to be the most successful.	Promising are the healthcare professional decision support interventions developed using recognized psychological theory such as providing instruction on how to implement interventions. Supportive of 'Technology proficiency' 👍

Note: 👍 - Favourable.

Table 6 Statutory Guidelines

Medical Institution	**Guideline for Technology**
World Federation of Medical Education (WFME)	Ensure training in the new information technologies.[35]
MCI India	"Information technology competency for appropriate patient care and continued learning". This is a core competency in General Medicine for undergraduates.[36]
GMC UK	Under Graduate (UG) *Outcomes for graduates*: newly qualified doctors from all medical schools who award UK primary medical qualifications should know and be able to do these. Outcomes 2 - Professional skills - Communication and interpersonal skills "Use methods of communication used by patients and colleagues such as technology-enabled communication platforms, respecting confidentiality and maintaining professional standards of behaviour" - Prescribing medications safely "Access reliable information about medications and be able to use the different technologies used to support prescribing".[37]
	Postgraduate (PG) Generic professional capabilities framework (i) Domain 8: Capabilities in education and training "Use simulation or technology-enhanced learning appropriately in protecting patients from harm" (ii) Domain 9: Capabilities in research and scholarship "Understand and apply: informatics".[38]
	UG & PG- 'Promoting excellence: standards for medical education and training' "The opportunity to develop their clinical, medical and practical skills and generic professional capabilities through technology enhanced learning opportunities, with the support of teachers, before using skills in a clinical situation".[39]
CanMEDS 2015 Physician Competency Framework	Competency (i) Communicator: Enabling competency *- Assist patients and their families to identify, access, and make use of information and communication technologies to support their care and manage their health* *- Communicate effectively using a written health record, electronic medical record, or other digital technology* (ii) Leader: Key concept *Information technology for health care* (iii) Professional: Enabling competency *Exhibit professional behaviours in the use of technology-enabledcommunication.*[40]
Liaison Committee on Medical Education (LCME) of United States and Canada	Continuous quality improvement.[41]

to a particular issue. Artificial intelligence techniques include machine learning, deep learning, and natural language processing algorithms. AI applications are in diagnostics and making treatment recommendations. Medical professional should have a thorough understanding of AI applications in healthcare for (i) if things go wrong, understanding of what was being done will be a prerequisite for corrective steps and (ii) monitoring effects of AI for advancements. A current example is PAGER (proactive healthcare management), an application that improves patient treatment through making health care recommendations.

Competency Tip

Many trends in the delivery of health care tend to make medical care impersonal. This includes increasing reliance on technological advances and computerization.[1] Personal touch with tactful professionalism should be part of "Technology proficiency".

> Compassion and humane understanding of whom you are treating and not only what you are treating is required and better done with doctor oversight.

Technology for Progress Monitoring

Monitoring is required, useful, and remotely done is advantageous. Technology is useful for all this. Fast data transmission for favourable timely actions is the ultimate aim. Tele-critical care (TCC) is useful.[18] Remote monitoring is possible and technology provides timely alerts.

Competency Tip

> Intricacies and involvement in follow-up for fruitfulness, Energised and simplified with technology for excellence and success.

Technology for Prevention Applications

eHealth

The three prominent but overlapping domains of eHealth are (1) Health in our hands: use eHealth technologies to monitor, track, and inform health for action by self; (2) Interacting for health: use digital technologies to enable health communication among practitioners and between health professionals and patients); and (3) Data enabling health: collecting, managing, and using health data.[47] To maximize the likelihood of a successful eHealth intervention, healthcare professionals must acquaint themselves with the tool.[48]

Doctors have an essential role to play in all three. "Health in our Hands" has to be developed guided by doctors. Its practical and pertinent use has to be motivated by doctors. Proficiency in "Interacting for health" is required and the way forward. Actions on "Data enabling health" is doctors' duty for larger impacts with prevention applications.

Internet of things (IoT) is a useful technology for preventive applications. Computer scientists stimulated IoT systems have the capability to provide public data on health matters accessible to the general population. Proficient doctors can guide actions based on the data for communities and populations.

Competency Tip

As a general rule, the most successful man in life is the man who has the best information. Health information provides reliable, relevant, up-to-date, adequate, timely, and reasonably complete information.[49] Actions need to be advanced from these.

> Data diligence for distinctive delight,
>
> professional advice pragmatically advanced with technology right.

Technology for Professional Standards

Attainment, maintaining, and improvement of professional standards is all possible with technology. Technology proficiency will make these efficient. Progressive attitude required for professional standards is best summarised as

> The challenges of contemporary surgical practice not only necessitate attention to the lessons of the past but also contemplation of the future. Reflection, self-assessment, and deliberation about what it means to be a good surgeon are essential.[50]

Reflection, self-assessment, and deliberation aid in attaining the highest professional standards. Reflection along with worldwide evidence and practices; self-assessment for improvements of best abilities and correction of weak areas; deliberations with colleagues, seniors, and juniors, at bedside, in classrooms, conference rooms, etc, lead to professional standards. Technology aids all these, subjectively and objectively.

Progress in technological applications for healthcare are contributing to advancements for high standards. Excellent examples for "Professional standards" are

Programmable Actual Leads

Pharmacogenomics research and precision medicine practice is making useful progress, and its utilization in prescribing is professional standards par excellent. Bringing the knowledge contained in biomedical literature to be of use practically on particular clinical situations and improving patient care requires "Technology proficiency". GeneDive is a web application for pharmacogenomics researchers and precision medicine practitioners. It makes gene, disease, and drug interactions data easily accessible and usable. A superb advantage of this is that the interactive search-visualization loop enables relationship discoveries between diseases, genes, and drugs. These are most useful practically and might not be explicitly described in literature but are emergent from the source medical corpus and deductive reasoning.[51]

Pointing Advantageous Leads

Treatment regimens for many prevalent complex diseases are frequently ineffective. Technology is enabling in selection of best treatment choices. Han et al have developed a novel "NetPTP – a Network-based Personalized Treatment Prediction framework" for making personalized drug ranking. The framework captures and models measured drug effects from gene expression data and applies them to patient samples to generate personalized ranked treatment lists.[52] The ability to use all these useful developments with "Technology proficiency" will ensure highest professional standards.

Progressive Advanced Leads

Clinical practices are dynamically evolving. Incorporating a continuous stream of new data is advantageous. It is required as historical data does not predict new therapeutics or diseases. Constantly updated latest data allows automated methods to rapidly detect and adapt to shifting practice changes and alert authors to dynamic areas in need of additional decision support. Automatic data-mining of clinical practice patterns from electronic health records (EHR) can enable prediction of future practices as a form of clinical decision support (CDS).[53]

Google Flu Trends has been shown to detect local flu activity more rapidly than conventional methods.[54] Similar advances for many more affections are favourably possible for practical applications with "Technology proficiency".

Precision at Large

Clinical wisdom of years and machine learning: Experience in clinical practice leads to the realization that patients with a shared diagnosis often fall into subsets that "look" the same. These often respond to similar treatment strategies. These are not described in standard texts and are usually recognized only after years of experience. The best clinical teachers convey these distinctions to their trainees.[55] Machine learning simplifies these classifications and categorizations.

A great deal of knowledge and skill is required to practise as a doctor.[56] Anything facilitating, simplifying, and contributing to this is a welcome step, and "Technology proficiency" will advance this.

Another example is gene-based supervised machine learning classification models. These have been widely used to (i) differentiate disease states, (ii) predict disease progression, and (iii) determine effective treatment options. However, for complex, heterogeneous diseases, these classifiers are limited by not being able to capture varying combinations of genes that lead to the same phenotype. Advancement to this is pathway-based classification. This overcomes these challenges by using robust, aggregate features to represent biological mechanisms. A recent work has used a novel pathway-based approach, PRObabilistic Pathway Score. It has been used successful to differentiate the two types of inflammatory bowel disease, ulcerative colitis (UC) and Crohn's disease (CD).[57] Future appears exciting for many more complexities, for diagnostic, prognostic, and therapeutic precision.

Competency Tip

Sayings of the great continue to inspire and motivate highest professional standards. Sir Stanley Davidson, the renowned educator and a particularly gifted teacher at the bedside, remains an inspiration. At the bedside he taught

> Everything has to be questioned and explained.[58]

We have done exactly the same, questioned and explained the use of technology, at bedside and beyond. Overall, professional standards may be attained with

> Practice, analyse, labour, improve, learn, advance, & perfect.

Medical Institutions Worldwide

Medical institutions, public and statutory, play an important role. The General Medical Council (GMC) UK helps protect patients and improve UK medical education and practice by supporting students, doctors, educators and healthcare providers. The Medical Council of India (MCI), now National Medical Commission of India, establishes uniform and high standards of medical education in India.

WHO along with World Federation of Medical Education (WFME) had importantly highlighted, way back in 2004, in its report on technical meeting on "Accreditation of medical education institutions":

> Training in the new information technologies in order to help doctors cope with the explosion in medical and scientific knowledge and technology, is expected to be ensured.[35]

Now, definitely with many advantageous and meritorious advancements, time has come to take definitive steps with "Technology proficiency" made an essential clinical competency worldwide.

MCI India has been proactive in training on technology. The MCI Competency-based Undergraduate curriculum for the Indian medical graduates requires the following core competency:

> Demonstrate adequate knowledge and use of information technology that permits appropriate patient care and continued learning.[36]

The GMC UK views are to keep up to date, with medical education keeping up with developments in the technologies used to diagnose, treat and manage illness. It specifies UGs to have professional skills to be able to (i) use technology-enabled communication platforms as part of "Communication and interpersonal skills" outcome and (ii) use the different technologies used to support prescribing as part of "Prescribing medications safely" outcome.[37] For PGs, it recommends in its "Generic professional capabilities framework" in information and technology domains for only learning and research.[38] For both UGs & PGs in the "Promoting excellence: standards for medical education and training", it recommends

> The opportunity to develop their clinical, medical and practical skills and generic professional capabilities through technology enhanced learning opportunities, with the support of teachers, before using skills in a clinical situation.[39]

Soon, GMC UK should be including technology proficiency in actual practice, in its proven aspects, with all its advanced professional abilities, as an essential professional capability. Informatics applications should also be boosted, broadening its applications to evidence-based healthcare practices.

CanMEDS 2015 Physician Competency Framework has recommendations for use of digital technology for effective communication and IT for leadership. It envisions integrating eHealth throughout in all competencies.[40] However, we recommend introducing "Technology proficiency" as a distinct competency based on the findings of this study.

The Liaison Committee on Medical Education (LCME) of the United States and Canada Element 1.1 requires medical schools to engage in strategic planning and continuous quality improvement (CQI).[41] We suggest including "Technology proficiency" as a distinct strategic plan for continuous quality improvements.

Curriculum Development for Medical Education

Our positive findings should contribute to modern curriculum development, incorporating "Technology Proficiency". Medical educators "benefit from learning a practical, generic, and timeless approach to curriculum development that can address today's as well as tomorrow's needs"[59]

The six-step approach to curriculum development proposed by Kern et al is very useful and the best.[9] It represents a model comprising a series of components that were derived overall from systems theory applied to curriculum development.[11] The detailed application based on this for "Technology Proficiency" is given in Table 7.

Limitations

New interventions and technologies are constantly being developed and refined. Their impacts on health, and implications for health systems, are not always clear. This is an important limitation. However, the solution is also there, as health technology assessment (HTA). A systematic and multidisciplinary evaluation of the properties of health technologies and interventions covering both their direct and indirect consequences is done in HTA.[64] This includes 1) Safety, 2) Clinical effectiveness, 3) Economic considerations, 4) Budget impact analysis, 5) Organization impact, 6) Equity issues, 7) Ethical issues, 8) Feasibility considerations, 9) Acceptability to health care providers, and 10) Acceptability to patients. Evidence-based medicine is best, and similarly HTA evidence-based use of technology needs to be promoted. Also, the World Health Assembly had resolved in

Table 7 Six-Step Approach to Curriculum Development

The Steps	The Details
Problem identification	Technology-driven health solutions have an immense scope and training needs to keep pace.
Needs assessment of the learners	WHO and World Federation of Medical Education (WFME) highlight: "Training in the new information technologies in order to help doctors cope with the explosion in medical and scientific knowledge and technology, is expected to be ensured".[35]
Educational goals and objectives	Attainment of proficiency for practice: 1. Technology for proper assessment 2. Technology for pertinent treatment 3. Technology for progress monitoring 4. Technology for prevention applications 5. Technology for professional standards
Instructional strategies	Medical schools to engage in strategic planning and continuous quality improvement (CQI).[41] Structured strategy as 'Five Bs' proposed as per Simpson's classification[60] (i) Basics and applications - 'Teaching' (ii) Best comprehensive incorporation details and applications of all five categories of Technology Proficiency model – 'Curriculum development' (iii) Betterment with guidance – 'Mentoring' (iv) Bellwether for best directions - 'Leadership/administration' (v) Boosting aims with appraisal of knowledge, skills, and attitude – 'Learner assessment'
Implementation	Technology proficiency in actual practice, in its proven aspects, with all its advanced professional abilities, as an essential professional capability. Informatics applications with implementation of evidence-based healthcare practices. All this can be based on Ericsson et al's 'Theory of Expertise'. The learning task should aim at developing expertise as 'Five Ms': • Motivated the learner through improvement in real-life, final performance; • Measured expertise development takes into account the learner's pre-existing knowledge (learning curve); • Multiple experiences with repetition of the skills many times; • Modulated with immediate feedback; and • Multi-faceted with varied experiences across content areas.[61,62]
Evaluation and feedback	Important principles to guide educational practice[63] • Learners should be given supported opportunities for practice. These are accompanied by self-assessment and constructive feedback from their teachers and peers. • Learners are given opportunities to reflect on their practice. This is done by analysing and critiquing own performance for developing new perspectives and options.

2014 for the promotion of HTA within national frameworks, including health professional education.[65] Also, health professional education for "Technology proficiency" should include only those which have passed HTA.

Physicians have an important role to play in ensuring that the powerful technologies and sources of new information, like epigenetics, microbiomics, metagenomics, metabolomics, exposomics, etc, are applied judiciously to patient care.[1] "Technology proficiency" will ensure weighing pros and cons of advances judiciously.

In Lighter Vein

The philosophical dilemma "which came first: the chicken or the egg?" Progressive perspective is education for practice, practice for experience, and all for excellence.

A systematic review for "Factors determining the success and failure of eHealth interventions" has importantly pointed that for eHealth interventions to be successful, future research must ensure a positive impact in the quality of care, with particular attention given to improved diagnosis, clinical management, and patient-centered care.[66] All these three attributes should be essential components of "Technology proficiency".

It is important to recognize that while technology and innovations can enhance health service capabilities, human interaction remains a key element to patients' well-being.[67]

Conclusion

"Technology proficiency" is need of the hour with technology progress in healthcare at a fast pace and pertinently found fruitful. Our proposed model of "Technology Proficiency" for Modern medical curricula for modern health care covers all aspects comprehensively. Results of systematic reviews and meta-analysis have provided the necessary evidence for excellence. It should be made a recommended requirement as a distinct strategic plan by all statutory Medical Institutions worldwide.

Fast pace technology progress, Present & future perfect favourable Technology proficiency for success.

Worldwide competency sophistication worth fullness is summarised as

Better competency standards, better technology proficiency, best care,

Futuristic & favourable.

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