THE DEVELOPMENT AND VALIDATION OF DIGITAL MEDICAL EDUCATION ENVIRONMENT (DigiMEE) INSTRUMENT IN MEASURING ONLINE LEARNING ENVIRONMENT FOR UNDERGRADUATE MEDICAL STUDENTS

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TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
AMOS	Analysis of a Moment
AR	Augmented Reality
BL	Blended Learning
COLLES	Constructivist online learning environment survey
CAL	Computer assisted learning
CFA	Confirmatory Factor Analysis
CVI	Content Validity Index
Digi-MEE	Digital Medical Education Environment
DELES	Distance Education Learning Environment Survey
DREEEM	Dundee Ready Education Environment Measure
EEAM	E-learning educational atmosphere measure
EFAC	Exploratory Factor Analysis
FVI	Face Validity Index
I-CVI	Item Content Validity Index
I-FVI	Item Face Validity Index
LA	Learning Analytics
LMS	Learning Management System
ML	Maximum Likelihood
MOOCs	Massive Open Online Courses
OLLES	Online Learning Environment Survey
PAF	Principal Axis Factoring
PCA	Principal Component Analysis
PHEEM	Postgraduate hospital Education Environment Measure
SALG	Student Assessment for their learning gains
SDE	Synchronous distance education
S-CVI	Scale Content Validity Index
S-FVI	Scale Face Validity Index
SPSS	Statistical Package for the Social Sciences
	Technology Enhanced Learning
TELEMED	Technology Enhanced Learning Environment in Medical Education

TROFLEI	Technology-Rich Outcomes-Focused Learning Environment Inventory
USE	Usefulness, Satisfaction, and Ease of Use Questionnaire
USM	Universiti Sains Malaysia
VR	Virtual reality
WFME	World Federation for Medical Education
WHO	World Health Organization

LIST OF APPENDICES

PEMBANGUNAN DAN PENGESAHAN INSTRUMEN DIGITAL MEDICAL EDUCATION ENVIRONMENT (DigiMEE) UNTUK MENGUKUR PERSEKITARAN PEMBELAJARAN DALAM TALIAN BAGI PELAJAR PERUBATAN PRASISWAZAH

ABSTRAK

Memandangkan peranan yang diakui teknologi dalam pembelajaran perubatan, terdapat keperluan untuk pendekatan penilaian yang khusus untuk persekitaran pembelajaran dalam talian dalam bidang ini. Kekurangan kaedah penilaian yang khusus menekankan keperluan untuk mengenal pasti komponen utama dalam persekitaran pembelajaran dalam talian untuk pendidikan perubatan. Sebagai tindak balas kepada keperluan mendesak ini, kajian ini bertujuan untuk membangunkan dan mengesahkan Instrumen Persekitaran Pendidikan Perubatan Digital (Digi-MEE), mengakui peranannya yang penting dalam menangani jurang yang sedia ada dan meningkatkan kualiti pengalaman pembelajaran dalam talian dalam pendidikan perubatan. Kajian ini direka sebagai projek penyelidikan campuran pelbagai fasa yang dilakukan dalam persekitaran dalam talian melibatkan kumpulan pakar, guru, dan pereka pengajaran yang pelbagai serta beberapa kolej perubatan di Pakistan (Fasa 2 dan 3), selama 18 bulan. Dalam Fasa 1, pakar dalam pendidikan perubatan dan pembelajaran yang dipertingkatkan teknologi mengenal pasti dan memvalidasi komponen persekitaran pembelajaran dalam talian melalui kajian skop dan kajian e-Delphi yang diubah suai. Fasa 2 melibatkan pelajar perubatan pra-siswazah dan ahli fakulti untuk validasi kandungan, validasi proses respons, dan penyempurnaan versi instrumen Digi-MEE v.1.0 dan v.2.0. Kesahan kandungan item soal selidik dinilai melalui ulasan pakar (S-CVI/Ave: 0.98), dan kesahan proses respons melalui maklum balas peserta (S-FVI/Ave: 0.87). EFA bagi Digi-MEE v.3.0 mendedahkan 9 komponen

dengan 46 item, menerangkan 57.18% varians, dengan konsistensi dalaman yang tinggi. Bilangan item per komponen adalah seperti berikut: Peningkatan Kognitif (5 item), Penataan Kandungan (6 item), Amalan Cybergogical (6 item), Ciri-ciri Pelajar (7 item), Keupayaan Digital (4 item), Kebolehcapaian Platform (4 item), Dinamik Fasilitasi (5 item), Interaksi Sosial (4 item), dan Sokongan Institusi (5 item). Konsistensi dalaman untuk komponen ini adalah tinggi, dengan Cronbach's alpha 0.952. Beban faktor berkisar dari 0.404 hingga 0.721 untuk setiap komponen, menunjukkan hubungan yang kuat dalam setiap faktor. CFA bagi instrumen Digi-MEE akhir yang mengandungi 28 item menunjukkan indeks model yang baik, konsistensi dalaman yang cemerlang (Cronbach's alpha: 0.952), dan kebolehpercayaan komposit yang boleh diterima (0.7). Indeks utama termasuk nisbah chi-square/df 2.4, RMR 0.03, dan GFI 0.902. CFI dan TLI adalah kukuh pada 0.926 dan 0.91, masing-masing, manakala RMSEA adalah 0.057, menunjukkan kecocokan yang rapat. Dalam Fasa 3, kajian kebolehlaksanaan melibatkan tinjauan rentas dan kajian fenomenologi mengesahkan kegunaan praktikal instrumen Digi-MEE. Dalam Fasa 3, kebolehlaksanaan instrumen Digi-MEE dinilai melalui tinjauan dan kajian fenomenologi, dengan peserta menilai persekitaran pembelajaran dalam talian mereka pada 2.95 ± 0.84 daripada 4. Penemuan menekankan isu dengan kualiti kandungan, penglibatan, dan interaktiviti. Cadangan termasuk meningkatkan latihan kemahiran digital, maklum balas peribadi, dan komunikasi platform, bersama dengan sokongan pengaturan diri yang lebih baik dan aplikasi yang lebih berkesan. Pandangan ini menghasilkan senarai cadangan untuk universiti. Penemuan mengesahkan bahawa instrumen Digi-MEE adalah alat yang berguna dan mudah untuk menilai persekitaran pembelajaran dalam talian dalam pendidikan perubatan, memandu penambahbaikan dalam pelbagai komponen berdasarkan hasilnya.

THE DEVELOPMENT AND VALIDATION OF DIGITAL MEDICAL EDUCATION ENVIRONMENT (DigiMEE) INSTRUMENT IN MEASURING ONLINE LEARNING ENVIRONMENTS FOR UNDERGRADUATE MEDICAL STUDENTS

ABSTRACT

Given the acknowledged role of technology-enhanced learning in medical education, there is a need for a focused evaluation approach for online learning environments specific to this field. The current lack of dedicated evaluation methods underscores the necessity for identifying key components in online learning environments for medical education. In response to this pressing need, this study seeks to develop and validate the Digital Medical Education Environment (Digi-MEE) Instrument, recognizing its pivotal role in addressing the existing gap and enhancing the quality of online learning experiences in medical education. The study was designed as a multi-phase mixed-methods research project conducted in online settings involving a diverse group of experts, teachers, and instructional designers and multiple medical colleges in Pakistan (Phase 2 and 3), spanning 18 months. In Phase 1, experts in medical education and technology-enhanced learning identified and validated components of online learning environments through a scoping review and a modified e-Delphi study. Phase 2 involved undergraduate medical students and faculty members for content validation, response process validation, and refinement of Digi-MEE instrument versions v.1.0 and v.2.0. Content validity of the questionnaire items as assessed through expert reviews (S-CVI/Ave: 0.98), and response process validity through participant feedback, (S-FVI/Ave: 0.87). EFA of Digi-MEE v.3.0 revealed 9 components with 46 items, explaining 57.18% of the variance, with high internal consistency. The number of items per component were as follows: Cognitive Enhancement (5 items), Content

Curation (6 items), Cybergogical Practices (6 items), Learner Characteristics (7 items), Digital Capability (4 items), Platform Usability (4 items), Facilitation Dynamics (5 items), Social Interactions (4 items), and Institutional Support (5 items). The internal consistency for these components was high, with a Cronbach's alpha of 0.952. Factor loadings ranged from 0.404 to 0.721 for each component, indicating strong associations within each factor.CFA of the final 28-item Digi-MEE instrument showed good model fit indices, excellent internal consistency (Cronbach's alpha: 0.952), and acceptable composite reliability (0.7). Key indices include a chi-square/df ratio of 2.4, RMR of 0.03, and GFI of 0.902. CFI and TLI are strong at 0.926 and 0.91, respectively, while RMSEA is 0.057, indicating a close fit. In Phase 3, a usability study involving a cross-sectional survey and phenomenology study validated the practical utility of the Digi-MEE instrument. In Phase 3 of the study, the usability of the Digi-MEE instrument was evaluated using a cross-sectional survey and phenomenological study, validating its practical utility. In Phase 3, the usability of the Digi-MEE instrument was validated through a survey and phenomenology study, with participants rating their online learning environment at 2.95 ± 0.84 out of 4. Findings highlighted issues with content quality, engagement, and interactivity. Recommendations included improving digital skills training, personalized feedback, and platform communication, alongside better self-regulation support and more effective applications.These insights led to a list of recommendations for the university. The findings confirmed that the Digi-MEE instrument is a useful and straightforward tool for evaluating online learning environments in medical education, guiding improvements in various components based on the results.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter outlines the research background, problem statement, and significance of the study. This is followed by a list of general and specific objectives along with research question(s).At the end of the chapter, the section of operational definitions provides of the key terms

1.2 Research Background

Online learning in health professions education has experienced remarkable growth due to the widespread use of technology and the availability of the internet. The use of technology has enabled health professionals to access education and training outside of traditional classroom settings (Adams et al., 2013). Many medical schools have been utilizing various technologies for teaching and learning purposes as an additional or supplementary tool. The COVID-19 epidemic has brought about a significant shift in the perception and adoption of online learning in medical education. The outbreak has necessitated the rapid implementation of online learning platforms to ensure the continuity of education during lockdowns and social distancing measures. The COVID-19 pandemic has accelerated the integration of online learning as a primary mode of education in medical schools, highlighting its importance and potential for future use (Ferrel & Ryan, 2020).

Overall, the COVID-19 epidemic has acted as a catalyst for the integration of educational technology into mainstream education, particularly in the field of medical education. It has accelerated the adoption of online learning platforms and highlighted the potential of technology in enhancing and transforming medical education

(Ketchell, 2020). This has led to adaptation of web-based learning by medical educators to deliver content followed by assessment all over the world. On the other hand, many issues arose regarding the quality of education being provided to the medical students through digital learning platforms. Evaluation of the quality of medical education involves examining the school's learning environment as one of the key parameters. (Khursheed I & Baig L, 2014).

A learning environment is seen as a setting where students engage in learning and interaction with faculty, staff, and peers, encompassing physical, social, and psychological contexts. Genn provides a definition for educational environment as the manifestation of its curriculum (Genn, 2001a). Rothman and Ayoade (A I Rothman & F Ayoade, 1970) considered the learning environment as "*a manifestation of the effects on students of the various parts of the curriculum*". Multiple factors influence the learning environment forming the basis upon which the curriculum is implemented in a medical school (Haron et al., 2019).

An institution's learning environment can play a role in influencing the academic performance of the students along with their wellbeing making learning environment an important factor for quality of life of medical students (Genn, 2001b). Learning environment is in turn influences the student's perception of the environment which leads to student's participation in academic activities in the learning environment. Hence it has been proven that an institution's learning driver is one of the key influential factors for academic success of the students (Genn, 2001c). Li et al (2023) reported the impact of the learning environment on the competence and identity development of students in competency-based clinical education. Given the importance of learning environments in medical students' academic success, the World Federation for Medical Education (WFME) (World Federation for Medical Education,

2015) considers learning environment as one of the targets for the evaluation of medical education programmes. Based on the above reasons, a study of the environment should become an inseparable part of the evaluation of a medical school's curriculum.

This relationship between medical student's perception of their learning atmosphere and their satisfaction, achievement and success in academics has brought up the need to evaluate the school's learning environment. For the same purpose, multiple tools have been developed to obtain students' perceptions regarding their educational environments. Dundee Ready Education Environment Measure (DREEM) (Roff et al., 1997a) and Postgraduate hospital education environment measure (PHEEM) (Vieira, 2008) are just of the few tools that allow meaningful of traditional educational environment in undergraduate and postgraduate medical education programs respectively. This highlights the fact that different educational settings may require a separate educational environment instrument, which is suitable for that specific situation of the institution. The same is true for a need to develop an instrument for measuring online environment in medical education.

1.3 Problem Statement

Research documents a various validated instruments for measuring quality in online learning environments in general education over the past twenty years. Developed in 2006, the Constructivist online learning environment survey (COLLES) (Baker, 2006) evaluated the perceptions of university student in the areas of affective support, cognitive demand, interactivity, interpretation of meaning, professional relevance and reflective thinking. Earlier to COLLES, Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI) (J. M. Aldridge & Fraser, 2003) was introduced in 2003, which had eighty items evaluating the ten domains in high

school classroom environments using technology including computer usage, cooperation, differentiation, equity, investigation, involvement, task orientation, teacher support , student cohesiveness and interpretation. By technology here, the authors meant using computers for learning activities (e.g. email, the Internet and forums), and not a complete e-learning system.

The Distance Education Learning Environment Survey (DELES) evaluated the learning environment in post-secondary distance education in its six defined dimensions i.e. authentic learning, active learning, instructor support, student interaction and collaboration, personal relevance, and student autonomy. On the other hand, the Online Learning Environment Survey (OLLES) (J. F. Clayton, 2007) focused on active learning, computer competence, information design and appeal, material environment, tutor support, , student collaboration and reflective thinking among students of tertiary educational institutions. All the above instruments were developed for a particular level of education (primary, secondary or tertiary).

Recently, E-learning educational atmosphere measure (EEAM) (Mousavi, Mohammadi, Mojtahedzadeh, et al., 2020) measured the online learning environment in university settings in terms of evaluating dimensions of learner support, evaluation, teaching skills, professionalism and professional ethics, self-efficacy and virtual education. However, the study included a mixture of students from varied educational backgrounds, without any regard to the contextual background of the programs the students are enrolled on (24 out of 185 participants were from medical education). It is already discussed that such inventories are highly contextual to their educational environment. Hence it is required that online medical learning environment has its own tool for measurement instead of relying on the general instruments above.

The above tools have overlapping markers of measurement but also fail to develop consensus towards what constitutes an effective online educational environment. These tools were developed during the early phases of technology integration in education and do not reflect the recent advancements in online learning technologies. Given the significant updates in technology and the changing profile of learners—particularly millennials who are more technologically adept—there is a critical need for an updated inventory that accurately measures technology-enhanced learning environments.

Developing a new instrument will provide several benefits: it will offer a more accurate assessment of online learning environments, ensuring that educational quality aligns with current technological and learner trends. Solving this problem will prevent continued reliance on outdated measures, which could lead to ineffective teaching strategies and diminished educational outcomes. The research will address this gap by creating a tool that incorporates modern technological advancements and reflects the competencies of today's learners. This new tool will directly benefit universities by improving the evaluation and enhancement of their online learning environments, while indirectly supporting students through better-designed educational experiences. The instrument’s applicability extends to other institutions and organizations, providing a broader impact on online education. Additionally, this research aligns with current educational policies that advocate for updated and effective quality assurance mechanisms in technology-enhanced learning.

Expanding upon the provided introduction and identified gaps, this research was carried out in three distinct phases:

i. In the first phase, researcher carried out a scoping review to identify the main components and functional elements of virtual learning environments in

medical education. This was followed by a mixed-method study employing sequential exploratory method to explore the enablers and barriers of online learning in online learning environment as perceived by medical students and medical teachers. Finally, researcher conducted a modified e-Delphi study for achieving consensus on relevance of identified components and subcomponents for online learning environment in medical education along with proposed definitions. Based on the above results, the researcher developed Digi-MEE instrument version.

ii. In the second phase, the researcher investigated the content validity evidence for Digi-MEE instrument through content expert ratings followed by response process validity evidence through ratings given by medical students. Based on the suggestions, researcher revised Digi-MEE instrument. Next, the researcher determined the factorial structure of revised Digi-MEE instrument by exploratory and confirmatory factor analysis following determination in internal consistency and reliability.

iii. In the third phase, researcher evaluated the usability of validated Digi-MEE instrument in a cross-sectional survey in a medical school to measure its online learning environment as perceived by medical students, following focus group interviews to triangulate findings of cross-sectional survey.

1.4 Significance of the study

This study is significant because it addresses the factors influencing the online learning environments in undergraduate medical education in the current scenario when there has been transformation of online education in the field of medical education. Thus, a part of the work done in this study focuses on the current trends and practices of teachers and students on online learning environments in medical

education. A few of previous research have focused on tools and techniques used in general online education as such and have not directly tackled the contextual nature of undergraduate medical education, Thus, this study evaluated the role of various online tools used in teaching and learning, which can offer valuable insights to the policy makers and other relevant stakeholders in virtual medical education.

This study involved a development and validation of an instrument aimed for measuring digital learning environment in the context undergraduate medical education. It produced a well validated and reliable instrument to understand the scope of elements that influence cyberspaces in medical education. Additionally, inclusion of new factors like digital civility associated with digital ethics and e-professionalism has enriched the questionnaire. Further the questionnaire elaborated on evaluating the 'processes' involved in online teaching and learning instead of evaluating mere presence of certain elements like computer competence. What the questionnaire focused on the processes that made a student computer-competent e.g., how he behaves and interacts in online learning environments or uses the online platform? This questionnaire can later be used by future researchers to describe such phenomena and make the necessary recommendations for their institutions of students and staff training in respective domains.

1.5 General Objective

To develop and validate an instrument measuring technology-enhanced learning environment in medical education.

1.6 Specific Objectives

Phase 1

To finalise a set of functional components and elements of an effective online learning environment in medical education.

i. To identify components and elements can be identified from scoping review of recent literature.
ii. To explore the perspectives of medical students and teachers regarding functional components and elements of an effective online learning environment in medical education.
iii. To achieve consensus regarding functional components and elements of an effective online learning environment in medical education

Phase 2

To investigate the evidence of validity of developed Digi-MEE instrument.

i. To investigate the content validity evidence of developed Digi-MEE instrument.
ii. To investigate the response process validity evidence of developed Digi-MEE instrument
iii. To investigate the internal structure evidence of developed Digi-MEE instrument.
    (1) To explore the factor structure and distinct dimensions of the Digi-MEE instrument in assessing online learning environments in medical education as revealed through Exploratory Factor Analysis (EFA).
    (2) To determine the extent to which proposed factor model of the Digi-MEE instrument align with the observed data, providing evidence of construct validity, when assessed through Confirmatory Factor Analysis (CFA).

(3) To assess the internal consistency (e.g., using Cronbach's alpha) of the dimensions or factors identified through factor analysis.

Phase 3

To evaluate the usability of developed and validated Digi-MEE instrument for measuring technology enhanced learning environments in medical education (TELEMED).

1.7 Research Questions

Phase 1

What are the functional components and elements of an effective online learning environment in medical education?

i. What components and elements can be identified from scoping review of recent literature?
ii. What are the perspectives of medical students and teachers regarding functional components and elements of an effective online learning environment in medical education?
iii. What consensus can be achieved regarding functional components and elements of an effective online learning environment in medical education?

Phase 2

What is the evidence of validity of developed Digi-MEE instrument?

i. What is the content validity evidence of developed Digi-MEE instrument?
ii. What is the response process validity evidence of developed Digi-MEE instrument?
iii. What is the internal structure evidence of developed Digi-MEE instrument?

iv. What are the underlying factor structure and distinct dimensions of the Digi-MEE instrument in assessing online learning environments in medical education as revealed through Exploratory Factor Analysis (EFA)?

v. To what extent does the proposed factor model of the Digi-MEE instrument align with the observed data, providing evidence of construct validity, when assessed through Confirmatory Factor Analysis (CFA)?

Phase 3

What is the evidence usability of developed and validated Digi-MEE instrument for measuring technology enhanced learning environments in medical education (TELEMED)?

1.8 Operational Definitions

i. Learning Environment

A learning environment is considered as a milieu for students influencing their success and determining the quality of life of medical students (Genn, 2001b)

ii. Technology enhanced Learning Environment

Educational environment utilizing and embedding technology for a meaningful learning experience and encompasses any online, virtual, or digital integration in face-to-face, blended, or fully online courses (Baker, 2006). Similar words used are Online learning Environment, Virtual Learning Environment, digital / cyber space.

iii. Evidence for Validity of a questionnaire

Validity can be defined as "*an interpretive argument to which evidence is collected in the support of the proposed inference*." Evidence of validity can stem from five sources: content, response process, internal structure, relational,

and consequential. (Cook & Beckman, 2006a). In this study, three validity aspects that are relevant to instrument development are assessed: content and response process and internal structure. Content validity pertains to assessing the representativeness or relevance of the elements within an instrument's measurement of content. (Yusoff, 2019). Content validity pertains to assessing the representativeness or relevance of the elements within an instrument's measurement of content. (Yusoff, 2019). Internal structure refers to the examination of the relationships and organization of elements within an assessment instrument, assessing factors such as reliability and factor structure (Cook & Beckman, 2006a).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter begins by presenting an overview of evolution of online learning in the context of medical education and discusses the need of having effective online learning environments to achieve successful student outcomes. Further section describes how these online learning environments have evolved with time with their key features. Theories that explain online learning environments include theoretical concepts from behaviourism, cognitivism, constructivism, humanism and connectivism. As the researcher intends to develop and validate an evaluation tool for online learning environments in medical education covering various aspects from the above theories, the review gives overview of these theories in the light of online education. The chapter then introduces various methods of evaluation of such online learning environments, especially the quantitative methods of evaluation. This is followed by introducing concepts of developed and validation. Next the chapter throws light on the already existing tools that are available for evaluating online learning environments in general as well as medical education. The chapter concludes by presenting a conceptual framework that serves to link the key findings from the literature review and highlights the existing gaps in our comprehension of evaluating online learning environments in medical education.

2.2. Online learning in medical education

Online learning has revolutionized teaching by allowing accessibility that is not limited by time zones or global frontiers (Gaupp et al., 2016). The integration of e-learning into various levels of undergraduate, graduate, and continuing medical education has allowed healthcare professionals to keep up with increased demands of

competency secondary to competency-based curricula , changes in health care delivery, complex medical education content and advances in medicine (Zehry et al., 2011). Many educationists are certain that what was once was just an add-on assistance tool for boosting the learning process outcomes, has now become an essential modality in medical education(De Leeuw et al., 2016). The following chronological overview highlights the significant milestones in the evolution of online learning within the context of medical education.

2.2.1 Evolution of Online Medical Education

Seventy yeas ago, the doubling time of medical knowledge was estimated to be half a century which changed to 7 years in the 1980s and 3.5 years in 2010. In 2020, with the advent of e-learning as the principal teaching method, it was estimated to be just 73 days (Densen, 2011). Barton et al (2021) discuss about a strong tendency for students to supplement university materials with online resources in their recent study . There is clear-cut evidence to show that traditional learning methodologies like face-to-face learning are losing ground as emphasis on self-directed learning has paved it's way following the availability of remote e-learning resources (Franklin et al., 2011). To accelerate this evolution, complex learning algorithms have been developed to optimize the success of online learning (Tabibian et al., 2019). As the new generation of learners have been termed as 'digital natives', their proficiency in multitasking and dependence on technological advances warrants a thorough understanding of the e-learning evolutionary process and policies to make the paradigm of medical education more suitable to their nature(Prensky, 2001).

2.2.2 1990s: Emergence of Online Resources

In the 1990s, use of online medical education began with the emergence of basic online resources, such as medical websites and digital databases. These resources provided students and professionals with easy access to medical information. The need for distance education seemed to become more apparent in wake of increased aspirations for higher education being faced with geographic, financial and social limitations making traditional university attendance less feasible(Kentnor, 2015a). Even though distance learning was not an unknown concept in the late 1800s, its rapid growth began in the late 1990s – hand-in-hand with technological revolution (Kentnor, 2015b). Earlier in the decade, there was widespread commercial availability of computer-based learning multimedia as evident by the presence of CD-ROMs in schools (Hammond, 1995). In 1991, the World Wide Web was unveiled followed by adoption of online internet-based education by many reputable institutions as well as not-for-profit colleges and universities (Shale, 2003) However, many fledging online educational programs started during this time did not survive. The most significant factors leading to their demise were lack of understanding of online pedagogy and online learning styles, as well as the lack of faculty buy-in for online education as many teachers could not accept methods contrasting with the traditional classroom process (Marcus, 2004).In retrospect, faculty struggled with not just with poor understanding of online technicalities but also lack of institutional support and fear of educational quality decrement (Gordin, 2007). Thus it becomes evident that in the 1990s, pedagogical practices were driven principally by behaviourist perspectives – in other words, learning was largely derived from responses to external stimuli and curricula was aimed to influence behaviour and as online learning could not entirely keep up with this, it was perceived with doubt (K. V. Mann, 2011a) .

2.2.3 Early 2000s: Introduction of E-Learning Platforms

The early 2000s witnessed the introduction of e-learning platforms tailored for medical education. These platforms incorporated multimedia elements, making it possible to deliver lectures, simulations, and interactive content online. The theory of cognitivism gradually started to replace behaviourism as the individual mind's ability to process and organize knowledge and possess memory skills was appreciated (K. V. Mann, 2011b). Subsequently, as there was appreciation of individual differences in the learning process, online systems hoped to integrate methods and tools that suited multiple learning strategies like auditory narration with animation (Moreno & Mayer, 1999). Computer assisted learning (CAL) in a dermatological training program in the year 2000 successfully equipped trainees with better diagnostic problem solving and concluded that the implementation of CAL in medical curricula could contribute to reformations of medical education (Roesch et al., 2003). Learning Management Systems (LMS) started to gain popularity which were being used by schools and universities to maintain attendance records, monitor academic performances, manage finances and issue fee vouchers (Bach et al., 2013). Via LMS, learners could efficiently introduce the most relevant material into their assignments, have group discussions and up-to-date knowledge and carry out their self-assessment (Noreen, 2020). Kamin et al (Kamin et al., 2006) surveyed on presence of educational technology services in medical schools and demonstrated that in 2004, around 80% of schools reported having used "*computer-based simulations for teaching and/or assessment*". Over 1.6 million students in the United States were reported to access online learning systems in 2002, whereas the number of students have tripled in a short span of six years(Allen & Seaman, 2013).

2.2.4 Mid-2000s: Growth of Virtual Patient Simulations

Apart from learning management system (LMS) being an e-learning tool as web browsers, many other tools like email programs, media players, video camera for conferencing, microphone for online conversations emerged as promising supplements to the learning process(W. Horton & Horton, 2018). During the mid-2000s, virtual patient simulations became increasingly prevalent. As medical students were rather marginalized than involved in the clinical decision-making process under traditional learning environment, these simulations were vital in facilitating students to experience clinical decision-making in a safe and controlled digital environment (Nutter & Whitcomb, 2001). The use of these virtual patient simulations is not just limited to portrayal of various clinical presentations but also in their employment in teaching communication skills (Bearman et al., 2001) and bioterrorism response(Henderson, 2005). However, at the time, the impact of virtual patient simulation remained limited due to the requirement of complex programming and multimedia being extremely resource and time intensive (G. Huang et al., 2007a).

2.2.5 Late 2000s: Integration of Learning Management Systems (LMS)

Towards the late 2000s, the integration of Learning Management Systems (LMS) became a standard practice. These systems facilitated content delivery, assessment, and tracking of student progress, enhancing the efficiency of online medical education. Owing to this, assignment submission time was reduced from weeks to days and learners were provided flexible learning opportunity as both synchronous and asynchronous access to the LMS was possible (Bartolomé & Steffens, 2015). A variety of LMS found their way into the international market among which some prominent names include BlackBoard (proprietary environment), Moodle (which has a public license), Breeze, plus dotLRN and the Sakai Project(Oliveira et al., 2015). The modern

Learning Management Systems (LMS) are predominantly web-based, facilitating the hosting and delivery of diverse learning content. This includes, but is not limited to, reading materials, video and audio resources, wikis, web conferencing, chats, forums, blogs, learning games, as well as testing and grading functionalities (Bezhovski & Poorani, 2016). Later in the 2000s studies on LMS operability established that just like other profound aspects of university functioning, effective administration of institutional LMSs depends on creating and executing productive strategies governing their use (Naveh et al., 2010). Following its integration, the prominent advantages of LMS employment were noted to be time and resource saving, advanced progress monitoring features and openness to communication and discussion(Shurygin et al., 2021). On the other hand, educationists gradually became aware of its challenges as well which included absence of student self-discipline and the malalignement between LMS functionalities and specific academic programs requirements (Snoussi, 2019). Kanuka 2006) discussed accessibility as one of the prevaialing issues by reporting the frequency of continual print media as medium of instruction owning to lack of proper access to online educational services by learners dispersed in rural areas especially. However, even at the time the role of LMS was promising as its increasing popularity worldwide irrespective of borders and consumer styles made it seem unrestrained by creative boundaries(Mohd Nasir et al., 2021).

2.2.6 2010s: Rise of Massive Open Online Courses (MOOCs)

The 2010s saw the rise of Massive Open Online Courses (MOOCs) in medical education. These open-access platforms offered a wide range of medical courses, making high-quality education accessible to a global audience. MOOCs emerged as a soaring paradigm of knowledge distribution as they tackled previously laid concerns pertinent to digital education in terms of pedagogy, strategies and finances (Sancho-

Vinuesa et al., 2015). The content of MOOCs was not just easily available, accessible, easy to download and easy to store for future use but also affordable to all thus breaking through the shackles of financial and geographical constraints which would otherwise hinder learning (Kumari, 2021). Studies pointed out that MOOCs caused an increment in number of students per teacher by cultivating interest and making the discipline more appealing simply by serving as a fresh means of studying (Feitosa de Moura et al., 2021). However, by the middle of the decade, a pool of research publications started to point out that these MOOCs would cause damage to the quality of higher education, some attributing it to the fact that research is entirely different from teaching and that even though MOOCs allow progress in research, teaching online requires expertise and resources otherwise unexplored by the institutions (Chen, 2014; Giasiranis & Sofos, 2020). Also, compared with traditional education systems, MOOCs suffered significantly high dropout rates as approximately only 10% of enrolled students in the most prominent MOOCs actually completed their courses (Daniel, 2012). Scholars attributed this to the inevitability of lack of interest and commitment fuelled by the low to none cost of the program and openness, rather than limitations, in the least selective admission process (Clow, 2013). Later in the decade, as more MOOCs were integrated into the higher education curricula, the belief that this online learning modality will have a prominent place in the future academic world became stronger, especially in the form of MOOC-based blended (BL) learning (Littenberg-Tobias & Reich, 2020).By 2018, interest in exploring how MOOCs can augment traditionally taught courses was blossoming as a series of pedagogical and technical questions pertaining to its full potential remained unaddressed and meagre literature was present regarding construction of an effective MOOC-BL model (Bralić & Divjak, 2018).

2.2.7 2020s: COVID-19 Accelerates Digital Transformation

The COVID-19 pandemic in the early 2020s accelerated the digital transformation of medical education. In wake of the pandemic, medical colleges all over the world made the then unheard-of decision to suspend clinical rotations and in-person classroom learning as ways of minimizing patient contact and curb the spread of COVID-19 (Qarajeh et al., 2020). Virtual classrooms, telemedicine training, and remote simulations became essential components of medical learning as an effort to prevent disruption of the educational process (Dedeilia et al., 2020). Apart from asynchronous learning via recorded videos and podcasts, following the COVID-19 spread synchronous distance education (SDE) became widely by students worldwide, also being accepted by medical students (He et al., 2021). The concept of 'flipped classroom' became commonplace as this blended type of learning mode with an asynchronous component allowed medical students to have more schedule flexibility, and a synchronous component offered interaction between medical students and faculty members (Mukhtar et al., 2020). Another disruption caused by the COVID-19 pandemic was the examinations of medical students which were delayed, cancelled and replaced by online tools of assessment (O'Byrne et al., 2020). Many universities adopted an open-book examination (OBE) approach which was shown to help curb student anxiety, something much needed at a time of heightened apprehension such as a pandemic (Stowell & Bennett, 2010). Overall, during the COVID-19 pandemic the deliverance of lectures via online webinar platforms like Zoom was well received with high levels of engagement (D. Kay & Pasarica, 2019a).

2.2.8 Present and Beyond: Personalized Adaptive Learning

In the present and beyond, personalized adaptive learning is a growing trend in online medical education. AI-driven systems enhance the effectiveness of education in this field by tailoring individual content to learners placed at the center of education (Layng & Redding, 2016). The core of personalized adaptive learning lies the premise of smart learning environment (SLE) which is a refined form of online learning and broadly consists of two type of technologies: (1) smart devices technologies that exhibit some properties of universal computing (such as wearable gadgets, Internet of Things) and (2) intelligent technologies via which learning data can be captured, analysed and directed towards boosting learning and teaching (such as cloud computing and learning analysis) (Peng et al., 2019). The most striking feature of an ideal personalized smart learning system is that it will be capable of predicting learner needs, which would prove revolutionary with respect to allowing individuals to learn within context of the real world(Gros, 2016). Some ambiguity remains attached to adaptive learning at present due to lack of homogenous nomenclature needed to define it for subsequent implementation (Cavanagh et al., 2020). Needless to say, with this paradigm shift to student-centred education, more effective learning is seen as students feel more empowered when making decisions in their learning (Dockterman, 2018). The future of personalized learning looks promising as it has been identified as one of the six developments of educational technologies that will have the greatest impact in institutions of higher education (Adams Becker et al., 2017).

2.3 Benefits and Challenges of online learning in medical education

This section explores the various benefits and challenges associated with the integration of online learning in the field of medical education, shedding light on the complexities and opportunities it presents for both students and educators.

2.3.1 Benefits of online medical education

Online instruction and learning are pivotal in medical education and are acknowledged for their numerous advantages in promoting student learning (Dergham et al., 2023). Online education can furnish students with fundamental knowledge and bolster their confidence prior to encountering actual or standardized patients (Ellman & Schwartz, 2016). It has also demonstrated its strength in training evidence-based medicine and in enabling interprofessional education (Maggio et al., 2013). Some recurring themes highlighting the benefits of modern online medical education have been seen in various studies. A broad categorization is ensembled in Figure 2.1.

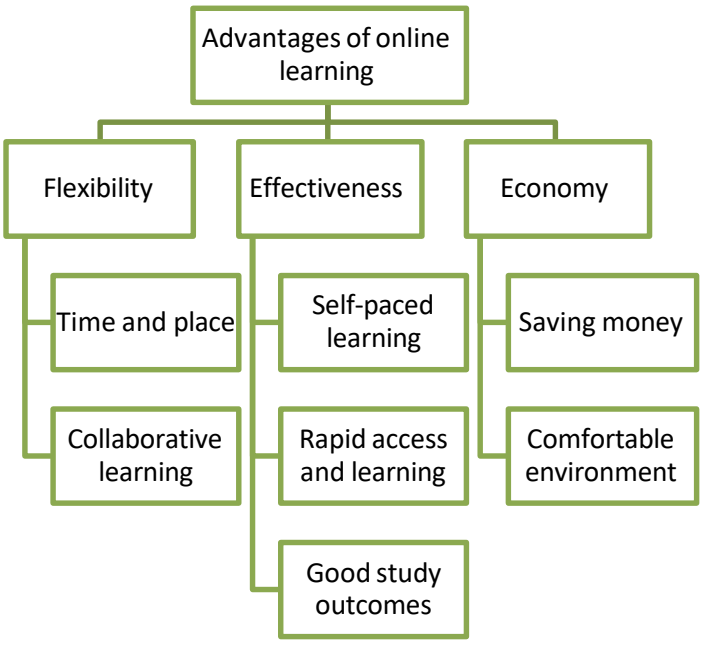

Figure 2.1 Advantages of e-learning. Adapted from (Talal, 2021a)

Flexibility and Accessibility

Flexibility in online learning allows individuals with busy schedules, including working professionals, to conveniently access educational materials and pursue medical education at their preferred times and locations. Teachers and student agree alike that this flexibility and accessibility saves them resources and time (Mukhtar et al., 2020). This flexibility allowed students to maintain social distancing in the COVID-19 pandemic era and can still do so as well and proved extremely cost-efficient and comfortable while preserving learning outcomes (D. Kay & Pasarica, 2019b). Studies on student perception show that these advantages are more evident in online learning when compared with face-to-face learning as the obligation to be physically present according to a fixed schedule requires a higher degree of commitment (Keis et al., 2017). Thus, keeping up with the demands of the digital society, online learning rightly claims to not only refine classroom learning but also to introduce more freedom in the learning space by being flexible and accessible(Smith & Hill, 2019). One study on information-seeking behaviour of medical students pointed out that it is the rapid accessibility rather than quality and quantity of resources that influences their usage of online learning platforms (O'Carroll et al., 2015). Positive perception of students concerning online learning has been seen in study comprising Polish students, such as the possibility to stay at home, the possibility to have access to online materials and learning in friendly environment at home (Bączek et al., 2021a). This malleability of course design has another advantage: it can help researchers and educationists to create study designs catering the needs of certain pools of students including those who are working, cannot afford to study in another city or are unable to attend courses. (Gherheș et al., 2021).

Diverse Learning Resources

Online learning platforms provide a wealth of diverse learning resources, including videos, engaging simulations, and e-textbooks, enhancing the learning experience for medical students. Keeping up with the rapid growth of technologically enhanced learning, variety of up-to-date information in online learning platforms is expanding and a need for creating a source of global information and universal educational space is increasingly being felt (Kononenko & Nedospasova, 2021).One study showed that while previous generation of medical students heavily relied on textbooks, lecture notes and physical access to libraries, the revision and study dynamic has changed dramatically over the past 20 years as online learning resources have seen both quantitative and qualitative improvement (Judd & Elliott, 2017a). Modern online education consists of certain learning elements like information transmission medium (internet), tools for organizing remote interaction and storage of remote content (LMS, webinars, etc.) and resources and methods of learning which include seminars, consultations and all types of lectures with text or video/audio-based content(Konopko et al., 2021). While commenting on the ability of modern online learning systems to offer knowledge in numerous ways, earlier research has shown that using various types of learning materials can significantly benefit student learning. For instance, worked examples, which provide step-by-step solutions, can result in swifter and more impactful learning compared to attempting to solve problems without guidance(Shareghi Najar et al., 2014). Judd & Elliott (Judd & Elliott, 2017) explored selection and use of various types of online learning resources by first-year medical students as shown in Table 2.1, proposing how online learning platforms can have diverse information sources.

Table 2.1. Variety of online curriculum resources Adapted from (Judd & Elliott, 2017b)

Type	Description
Lecture notes	PDF notes created from lecture presentations
Lecture recordings	Video and/or audio capture files of lecture presentations
Journal article	Full text journal articles
Textbooks (pdf)	Electronic versions of key textbooks
Website	Consumer, practitioner and researcher-oriented websites
Image	Image files (often used to support clinical cases)
Clinical case notes	PDF notes containing details of clinical cases
Clinical case videos	Video clips designed to contextualize clinical
Clinical roleplay notes	Notes designed to support clinical roleplay exercises
Clinical practice video	Videos of physical examination and medical interview techniques
Tutorial notes	PDF notes containing details of basic clinical science tutorials
Reading	Notes designed to be read before specified lecture or tutorial activities
Extras	Collection of minor resource types

In summary, modern online learning systems offer students a wide range of learning resources, including readings, video lectures, assignments, quizzes, and discussions. Interacting with diverse materials, such as worked examples, has been shown to enhance learning compared to unsupported problem solving. These systems aim to make learning more effective and engaging, with multimedia elements playing a crucial role. Additionally, they provide assessment tools to measure and apply knowledge (Feroz et al., 2022).

Global Collaboration

Online environments enable medical students from around the world to collaborate, share experiences, and learn from a diverse range of perspectives, fostering a global healthcare perspective. Collaborative online learning is an educational approach in which students work together on learning tasks and projects using online platforms and tools and emphasis is placed on group interaction, communication, and cooperation among learners, often facilitated by technology(Haugland et al., 2022). Many research

studies have indicated that collaborative online learning has the potential to complement traditional teaching methods, creating a more captivating and efficient learning atmosphere for both educators and students (Reeves et al., 2017). This advantage of online learning also promotes active engagement and enriches the learning experience by facilitating connections and forbearing the generation of knowledge at both individual and collective levels (Altowairiki, 2021). Indeed, this positive aspect of online learning fosters a sense of belonging among students within a supportive community where they can freely exchange pertinent knowledge, offer valuable feedback, seek assistance when needed, receive support during challenging phases, derive motivation from peers facing similar challenges, and collectively strive toward a shared objective (Saqr et al., 2018). In one Australian study, the targeted use of micro-blogging platforms like Twitter received favourable endorsement from students as this could enhance interaction by fostering a continuous academic dialogue (Diug et al., 2016) thus showing that students indeed valued the collaborative aspect of online learning.

Self-Paced Learning

One of the main advantages of online learning is allowing self-paced learning, accommodating varying learning styles and the ability to review complex medical topics as needed. The asynchronous and virtual characteristics of online education require learners to shoulder the responsibility for their own learning which entails taking on a more significant role in organizing, overseeing, and overseeing their learning procedures(Si, 2022). In self-paced learning, an individual proactively takes the lead, either with or without external support, in identifying their learning requirements, establishing learning objectives, pinpointing learning materials and applying suitable learning approaches (Kemp et al., 2022). An effectively structured