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Construction of Digital Literacy Training System for Medical Students in the Age of Healthcare 4.0: Perspective of Educational Ecology

Li Lixia[1] & He Jun[2] & Yao Wenhao[3] & Nasir Ali[4]

[1] Northwest Normal University, China & Ningxia Medical University, China
[2] Ningxia Police Vocational College, China & Shaanxi Normal University, China
[3] Shaanxi Normal University, China
[4] Shaanxi Normal University, China
Correspondence: He Jun, Ningxia Police Vocational College, China & Shaanxi Normal University, China
Email: 249745128@qq.com

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Abstract

In the age of Healthcare 4.0, the deep integration of digital intelligent technology and medicine has put forward higher requirements for the digital literacy of medical students. Based on the literature review, this paper analyzes the current situation and deficiencies of digital literacy training in medical education: although most medical colleges have begun to attach great importance to digital technology education, there is a lack of systematic training programs and practice platforms. Based on this, guided by the theory of ecology of education, this paper focuses on four aspects of Collaboration between Hospitals and Universities, Policy support, Smart campus and Smart hospital at the macro level, five aspects of the training concept, Training mode, Evaluation mechanism, Teachers' digital literacy and Curriculum system at the meso level. At the micro level, there are mainly three functional entities, including the guidance and guarantee group, the transmission and development group, and the inheritance and pioneering group. These three entities, based on the macro and meso systems, promote the process of comprehensive improvement of medical students' digital literacy through the transmission of material flow, energy flow, and information flow (knowledge flow).

Keywords: Healthcare 4.0, Ecology of Education, Medical Students, Digital Literacy, Training System

Introduction

The advancement of Industry 4.0 technologies, encompassing artificial intelligence, the Internet of Things, big data, and 5G, is profoundly transforming the healthcare sector, ushering in the era of Healthcare 4.0 (Aceto et al., 2020; Paul et al., 2021). These advancements are propelling a move towards preventive care, earlier

diagnosis, and enhanced life quality (Papulová et al., 2022). Healthcare 4.0, marked by intelligent and interconnected care, represents a groundbreaking change in the healthcare industry (Li & Carayon, 2021). This transformation is facilitated by the incorporation of emerging technologies such as artificial intelligence, electronic medical record management, and genetic data analysis (Haleem et al., 2022). These innovations, falling under the broader Industry 4.0 framework, are reshaping the healthcare landscape by enhancing patient care and alleviating pressure on healthcare systems (Paul et al., 2021). The progression from Healthcare 1.0 to 4.0 underscores the growing influence of technology, especially artificial intelligence, in defining the future of healthcare (Chen et al., 2019). Doctors, as an important role in the medical field, play a pivotal role in the integration effect. In the future, doctors will work in an environment that relies on digital technology, and their work content and work form will be transformed accordingly. The medical sector's digital transformation is imposing new requirements on physicians, necessitating that they continually enhance their digital competencies.

As future medical students, they must continuously improve their digital literacy to effectively cope with the transformation of future medical services under the guidance of technology. The cultivation of digital literacy in medical students will be the top priority in medical education. At the same time, "new medicine" requires future medical students not only to have excellent medical skills but also to have the ability to deeply integrate emerging digital technologies such as big data and artificial intelligence with professional knowledge, which points out the direction for the training of medical students and indicates the necessity and urgency of the cultivation of digital literacy of medical students.

Clarifying the development goals of future doctors' digital literacy and improving the training system of medical students' digital literacy have become the key issues that need to be solved urgently. Therefore, strengthening the digital literacy of medical students is not only vital to their personal career development but also an inevitable requirement to adapt to the medical 4.0 era and improve the quality of future medical services. Only when medical students can skillfully use digital medical technology can the medical industry in the future better serve the public and provide better quality and efficient medical services. Medical schools and educators need to recognize this and actively take action to integrate education and training in digital health technology into their curricula to ensure that students can make a smooth transition to this digital healthcare environment after graduation.

Literature Review

Healthcare 4.0

Healthcare 4.0 refers to the application of the ideas and technologies of the fourth Industrial Revolution in the field of health care, to realize the digital and intelligent transformation of medical services. It covers a series of technologies such as cloud

computing, big data, Internet of Things (IoT), artificial intelligence (AI), 5G network and blockchain (Paul et al., 2021 and Aceto et al., 2020), aiming to improve the quality and efficiency of medical services and provide personalized and precise medical experience.

Digital Literacy

Digital literacy is a complex concept that includes various skills, knowledge, and attitudes required for the efficient and ethical use of digital information (Julien, 2019). It extends beyond mere technical ability to involve cognitive, motor, sociological, and emotional competencies (Eshet-Alkalai, 2004). Nevertheless, the absence of a clear, universally accepted definition of digital literacy continues to be an obstacle (Bieza, 2020). The concept is shaped by numerous disciplines and its application varies across different settings, with challenges such as cross-cultural digital literacy and the digital divide presenting significant hurdles (Ray, 2019).

Digital literacy has been highly valued by the international community, but its name and definition have not been unified globally. The expression of its connotation varies according to national conditions and personal opinions of different countries. The concept of Digital Literacy was first put forward by Israeli scholar Yoram in 1994 (Eshet-Alkalai, 2004). He identified digital literacy as the ability to use or operate digital devices (software), a variety of complex cognitive, motor, sociological and emotional skills. In addition, he also proposed the framework of digital literacy for the first time, which includes five aspects: image recognition and understanding literacy, re-creation literacy, branch literacy, information literacy and social-emotional literacy. Later, Paul Glister simplified the term "digital literacy" in his 1997 book "Digital Literacy", describing digital literacy as the use and understanding of information in the digital age, and emphasizing the importance of digital technology as a "fundamental life skill".

Digital Literacy refers to the ability to access, understand, evaluate and use information in a digital environment. China's "Digital literacy of teachers" defines it as The awareness, ability and responsibility of teachers to acquire, process, use, manage and evaluate digital information and resources by appropriate use of digital technology, to discover, analyze, and solve educational and teaching problems, and to optimize, innovate and transform educational and teaching activities (Jiacheng, 2023) believes that given the particularity of medical education, the digital literacy of medical students is reflected in four dimensions: digital awareness, digital knowledge, digital ability and digital ethics.

Research Design

Theoretical Basis: Ecology of Education

The ecological system of education is the highest and most complex level of education ecology. The whole human being constitutes the global education ecosystem. In

this large system of education ecology, it can be divided into several sub-systems, such as the basic education system, higher education system, vocational education system, adult education system, etc. These are macro education ecosystems. They include both the system of education itself and the environmental system. Within these macroscopic educational ecosystems, several sub-systems can continue to be divided. For example, a university in a higher education system is a microscopic educational ecosystem. Each education ecosystem, whether macro or micro, has its specific components and structure. Its external environment includes not only the natural environmental factors but also the social and normative environmental factors. All kinds of factors influence each other and are intricate. The education ecosystem takes education and its structural level (or the teaching level in the school) as the main body, takes the three functional groups of guiding, guaranteeing, conducting, developing, inheriting and developing groups as the ties, and takes talents and results as the center, forming a multi-dimensional complex network with comprehensive influence and interaction of multiple factors around several ecological environment circles. In the network system, through the material flow, energy flow and knowledge flow (information flow), the development of education at all levels and the ecological succession of education are promoted and the level of education is transformed from a low level to a high level, from simple to complex, and the training of talents is developed from basic to specialized depth (Wu & Zhu, 1990).

The ecological system of education has three characteristics: openness, purpose and order. Openness is reflected in the educational objectives, educational content, teaching methods, etc. should be adjusted accordingly with the development of science and technology, the changes of The Times and the changes of social demand for talent. The purpose is reflected in that education must be aimed at cultivating talents needed by society at the present stage and for the future. Order from the macro point of view of the social demand for talents is stratified, from the micro point of view of the differences between students, cannot one-sided pursuit of "large-scale harvest".

The educational ecosystem has dual ecological functions of internal and external nature. In school education, there are various ecological factors, which is the basis and condition for the normal play of the internal function of education ecology. Of course, various ecological factors in education are the result of the internalization of external ecological environment factors. In the educational ecosystem, under the influence and action of various ecological factors, the three functional groups are connected and penetrated by energy flow, material flow, information flow (including knowledge flow, and ability flow), and value flow. They are interrelated, interact and influence each other, promote the operation and evolution of the whole system, and promote the "reproduction of talents" and "reproduction of knowledge". In this way, the internal function of education ecology (educating people) is realized, and a large number of well-developed talents are cultivated. Moreover, it has laid a good foundation for exerting the external ecological

function of education -- social function. The external function of education -- the social function is mainly reflected in the service function of education to politics, the foundation function of the economy, the "dual" function of science and technology, and the selection function of culture.

System Construction

Based on the theory of ecology of education, this paper analyzes the various components of the training system and their relationships and mechanisms from the macro, meso and micro levels, and constructs the digital literacy training system for medical students. This training system focuses on the comprehensive improvement of medical students' digital literacy, revolves around the three layers of macro, meso and micro, and takes the three functional groups as the link to form a multi-dimensional composite training system with comprehensive influence and interaction of multiple factors. To maintain the virtuous cycle and dynamic balance of the training system, the relevant elements of the system will be adjusted accordingly with the development of technology and the changes in the demand for talent in the medical field. This is shown in Figure 1.

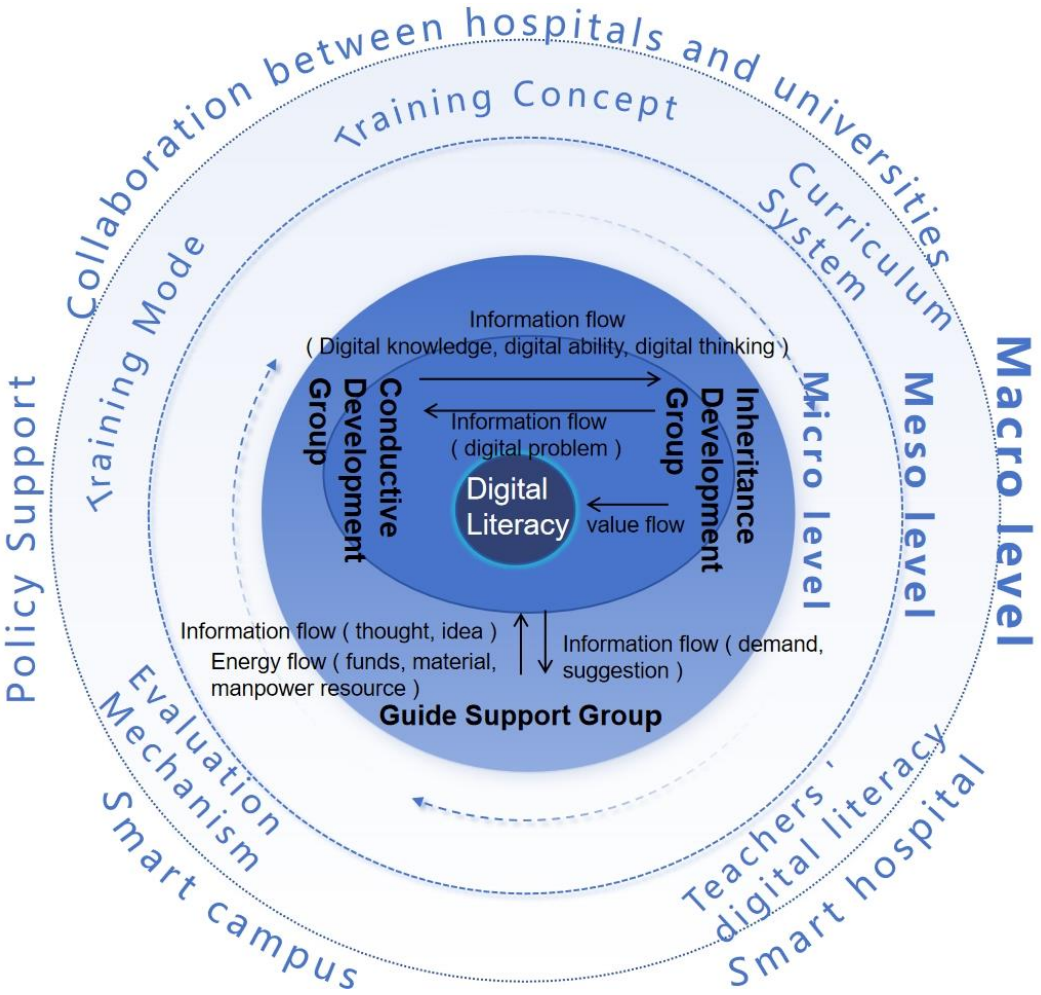

Figure 1: Digital literacy training system for medical students

Macro Level

According to the theory of ecology of education, from a macro perspective, the macro factors affecting talent training mainly include collaboration between hospitals and universities, policy support, smart campus and smart hospital.

Collaboration between hospitals and universities: open up the education channel between hospitals, enterprises and universities, and build an integrated training model. Provide students with a digital learning and practice environment. Through the virtual simulation experiment platform, students can carry out experimental operations in a highly simulated virtual environment to consolidate theoretical knowledge and skills.

Telemedicine system and intelligent diagnosis system provide advanced medical learning resources for students. Cui underscores the significance of blending diverse disciplines and industrial resources within education (Cui et al., 2022).Tao further advances this concept by integrating AI and digital human technology into medical education, as well as by refining the network model algorithm in virtual simulation technology (Tao & Tao, 2024).It enables students to make use of the digital environment for situational learning and improve their adaptability to future careers.

Policy support: First of all, schools should formulate relevant policies to clarify the importance and urgency of digital literacy training for medical students and include it in the key tasks of medical education reform. Wu stress the need for policy and financial support, with Wu specifically calling for government intervention (Wu et al., 2024).Secondly, schools should increase funding input, provide necessary financial support for students' digital literacy, improve digital teaching facilities, and introduce high-quality digital education resources. Finally, interdisciplinary cooperation should be encouraged to promote the deep integration of medicine and information technology and other fields, to jointly promote the construction of a digital literacy training system for medical students.

Smart campus: The notion of a smart campus, which incorporates digital technology into education, is vital for fostering digital literacy among medical students (Yongbin, 2012). The smart campus provides a digital learning environment for the cultivation of digital literacy for medical students. The application of digital technology makes medical education more vivid and vivid. Abstract medical knowledge has become concrete and easy to understand through various forms of online teaching such as webcast teaching, videotape teaching, MOOCs and micro-classes. In terms of experimental practice, digital technology has given birth to a variety of new experimental teaching methods, such as experimental teaching based on ESP, digital experimental teaching equipped with wearable devices, virtual experimental teaching and so on. The use of digital technology in experimental practice can further enhance the learning experience (Yongbin, 2012). Through the online and offline collaborative education system, teachers and students can have more flexible and personalized teaching interaction.

Smart hospital: Smart hospital integrates advanced technologies such as artificial intelligence and big data, which have greatly improved the quality and efficiency of medical services (Huang et al., 2020). When building a digital literacy training system for medical students, Smart Hospital provides an ideal practice and learning platform. Through real-time data analysis and intelligent diagnosis and treatment support, medical students can quickly improve their technology application and clinical decision-making ability in practical work. Therefore, making use of the resources and environment of smart hospitals and designing courses and practical training programs in a targeted way is a key way to improve medical students' digital literacy and professional ability, so that they can

adapt to the development needs of the future medical field.

2. Meso Level

It emphasizes the people-oriented education concept, takes the learners as the core, and aims to improve the digital literacy of medical students. The meso level is constructed from five dimensions: training concept, curriculum system, training mode, evaluation mechanism and teachers' digital literacy.

Training concept: In the age of Healthcare 4.0, the development of medical students' digital literacy should be approached from the viewpoint of educational ecology, highlighting multifaceted interaction and holistic coordination (Kuhn et al., 2020). The training concept should focus on the integration of knowledge, skills and attitudes, and advocate the application of digital technology in real clinical scenarios to realize patient-centered medical services. Interdisciplinary cooperation should also be encouraged to cultivate medical students' critical thinking and lifelong learning skills to adapt to the rapidly evolving digital healthcare environment.

Curriculum system: In the digital literacy training system for medical students, the curriculum system is an important component. Under the guidance of the theory of ecology of education, the design of the curriculum system should take into account the interaction between students and the environment, and provide enough practical platforms (Meskó et al., 2015) such as simulation laboratories, online learning resources and telemedicine practical training systems, so that students can apply what they have learned in real or quasi-real clinical environments. At the same time, the curriculum system should be flexible and able to adjust and update according to the development of medical technology and the changing needs of students.

Training mode: In the age of Healthcare 4.0, the digital literacy training system for medical students should emphasize the combination of theory and practice (Kuhn et al., 2018). Through the curriculum, cutting-edge digital medical technologies and tools are introduced, so that students can master the ability of data collection, analysis and application. At the same time, emphasis is placed on strengthening practical links, and students can improve their digital literacy in practice through simulated cases and clinical practice. In addition, students are encouraged to participate in scientific research projects and communicate with industry experts to broaden their horizons and enhance the breadth and depth of digital literacy.

Evaluation mechanism: The evaluation mechanism should be diversified and effective. In addition to comprehensively evaluating students' digital skills and application ability through practical project assessment, online learning platform assessment, clinical application case analysis and other ways, the evaluation method of problem-oriented learning (PBL) should also be introduced to encourage students to explore real medical problems through teamwork, to exercise their digital literacy and problem-solving ability.

Alshamsan and Syed (2009) highlight the importance of student-centered evaluation systems in PBL and Chen specifically emphasizes the use of online evaluations to provide feedback to students and tutors (Chen et al., 2006). Through the performance of the PBL project, students' ability to apply digital technology and innovative thinking in complex medical scenarios can be more accurately evaluated, to cultivate medical talents with more practical ability and innovative spirit.

Teachers' digital literacy: Enhancing teachers' digital literacy is essential for advancing students' digital literacy (Zhang, 2024). The COVID-19 pandemic has further underscored the necessity for teachers to possess robust digital literacy, as they have been required to transition to online teaching approaches (Li, 2022). Teachers need to continuously improve their own digital technology mastery ability and understand the latest medical information tools and platforms to better guide students. In addition, teachers should have the ability to integrate and innovate digital education resources and design digital education courses that meet the needs of the Healthcare 4.0 era. By participating in professional training, practical application and reflection, teachers' digital literacy should be continuously improved, and strong support should be provided for the cultivation of medical students' digital literacy.

3. Micro Level

The micro level is mainly composed of three major functional subjects, including the process of promoting the comprehensive improvement of medical students' digital literacy through material flow, energy flow, and information flow (knowledge flow) based on the macro and meso systems among the guidance and support group, the transmission and development group and the inheritance and development group.

The guide support group is composed of the school's leadership and decision-making level, management and implementation level and service guarantee level, including leaders at all levels of medical colleges and universities, relevant administrative departments, libraries, network information centers and other teaching and auxiliary institutions personnel; The conductive development group includes teachers from medical colleges, practice teachers from hospitals and experimental technicians. The inheritance development group mainly refers to the medical students currently studying. The guide support group transfers training funds, infrastructure, information technology talents and training ideas to the conductive development group and inheritance development group through energy flow. Under the guidance of the training concept, the conductive development Group will transfer digital knowledge, digital ability and digital thinking to the inheritance development group through the information flow through the training mode to be constructed. At the same time, it will enhance its value flow through the professional development of teachers. The inheritance development group is immersed in the constructed macro and meso environment and generates its value flow

by accepting and actively exploring the information flow, which is the improvement of medical students' digital literacy.

Discussion

Based on the theory of ecology of education, this study constructs the digital literacy training system of medical students in the era of Healthcare 4.0 from the macro, meso and micro levels (Meskó et al., 2015), and creates an intelligent ecological system for the improvement of digital literacy of medical students (Tao et al., 2022).

The innovative point of this paper is that based on the full analysis of the future career of medical students in the era of Healthcare 4.0, combined with the analysis of a large number of literature, guided by the theory of ecology of education, the digital literacy training system of medical students is comprehensively constructed with a systematic view. The development of a digital literacy training system for medical students in the context of Healthcare 4.0 constitutes a vital component of their educational experience, as underscored by Chen (2019), Noskova (2020), Meskó (2015) and Srikong (2021). From three levels of macro, meso and micro, starting from four macro factors of Collaboration between hospitals and universities, policy support, smart campus and smart hospital, the support service construction is carried out from five dimensions of the training concept, curriculum system, training mode, evaluation mechanism and teachers' digital literacy. From the guide support group, the conductive development group and the inheritance development group, the paper emphasizes the subject of medical students' digital literacy training and the relationship between them. At the same time, starting from the actual needs of medical students' digital literacy training, this study highlights the practicability of collaboration between hospitals and universities, curriculum system, training subjects and other aspects, to build a digital literacy training system with strong operability and guidance.

The paper is innovative in theory construction and system design, but there are still some deficiencies. First of all, although the comprehensive training system of macro, meso and micro levels is proposed, the specific implementation strategy and operation steps are not detailed enough, which may lead to the disconnection between theory and practice (You et al., 2023 and Li, 2020). Secondly, the paper lacks clear indicators and methods on how to specifically evaluate and quantify the effect of digital literacy improvement on medical students (Wang, 2022 & Lu et al., 2019), which is crucial to verify the effectiveness of the training system. Third, the thesis rarely deals with potential obstacles and challenges, such as uneven allocation of resources and insufficient faculty, which are all practical problems to be faced in the implementation process. Finally, the constructed digital literacy training system for medical students is ideal but lacks empirical verification, and its effect needs to be further verified.

Conclusion

The development of science and technology promotes the deep integration of digital technology and medical education, and Healthcare 4.0 comes into being. Under this background, higher requirements are put forward for the digital literacy of medical students (Aydınlar et al., 2024). Medical students need to improve their digital literacy to adapt to the development of The Times. Based on this, with Healthcare 4.0 as the background and ecological theory of education as the guidance, this paper constructs the digital literacy training system for medical students with systematic thinking. The digital literacy training system of medical students in the era of Healthcare 4.0 is constructed from the macro, meso and micro levels respectively, and an intelligent ecological system is created for the improvement of the digital literacy of medical students.

At the macro level, it emphasizes the role of four major factors: collaboration between hospitals and universities, policy support, smart campuses and smart hospitals. Together, these factors build an integrated training model that provides medical students with a rich platform for digital learning and practice. In particular, the concept of smart hospital, which integrates artificial intelligence and big data technology, not only improves the quality of medical services but also provides an ideal learning environment for medical students (Tao et al., 2022), which is difficult to achieve in traditional medical education.

At the meso level analysis highlights the people-oriented education concept, constructed from five dimensions of training concept, curriculum system, training model, evaluation mechanism and teachers' digital literacy. In particular, this level emphasizes the flexible design of the curriculum system, which can be adjusted according to the development of science and technology and the changing needs of students, which is especially important for adapting to the rapidly changing medical environment. At the same time, the meso level also emphasizes diversified evaluation mechanisms, including the evaluation method of problem-based learning (PBL), which helps to comprehensively assess students' digital skills and applied abilities.

At the micro level, the analysis focuses on three major functional subject support groups, conductive development group and inheritance development group, which interact with each other through material flow, energy flow and information flow to jointly promote the improvement of medical students' digital literacy, revealing the dynamic interaction and multi-level interdependence in the medical education ecosystem, and highlighting the complexity and dynamic nature of education ecology.

In the future, artificial intelligence, big data, meta-universe and big language models will be further integrated with medical care. As a university training future professional doctors, it is necessary to adopt a systematic training system to meet the demand for talent training in the future, as stated that medical students face challenges in data reliability, relevance determination, and content augmentation (Farooq et al., 2023). Improving medical students' digital literacy is an important content to meet future

requirements.

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