Information Technology and Its Use in Medical Vocational Education: Present Practice and Future Prospects

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Abstract. Information technology (IT) is booming in the recent years, which has been changing our world and our lives style broadly. With the development of the new generation of IT and internet, medical education has entered a new era of intelligentization, networking and digitalization. The new-generation IT, including virtual reality (VR), augmented reality (AR), three-dimensional (3D) printing and artificial intelligence (AI), has been applied in medical education and evolved as pedagogical strategies to promote the learner-centered teaching method. In this paper, we review the current applications of VR, AR, 3D printing and AI in the medical education, and further discuss the future prospects of their applications in the medical vocational education.

Keywords: Information technology · Vocational education · Medicine

1 Introduction

Information technology (IT) is booming in the recent years, which has been changing our world and our lives style broadly. Ministry of Education of China has placed great emphasis on vocational education which is in close contact with the social and economic development. A series of policies has proposed that IT application in vocational education, contributing to reform teaching method and talent training mode, should be promoted actively.

With the release of Healthy China 2030, medical vocational education has been placed in a very important position. With the development of the new generation of IT and internet, medical education has entered a new era of intelligentization, networking and digitalization. The new-generation IT, including virtual reality (VR), augmented reality (AR), three-dimensional (3D) printing and artificial intelligence (AI), has been applied in medical education and evolved as pedagogical strategies to promote the learner-centered teaching method [1]. From this perspective, integrating IT with medical vocational education will bring a bright future to the training of health technical personnel.

In this article, we review the current applications of the new-generation IT in medical education and discuss the future perspectives and challenges for the applications in medical vocational education.

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2 Current Applications of IT in Medical Education

A great deal of practice and the following accumulation of experience play a crucial role in medical learning. For centuries, the medical educators have employed simulation training type models, ranging from animals to cadaveric dissections. There is no denying that those models offer realism during the training of operation and provide good practice in managing the mimic complications. However, some limitations of using those models are existed, including consuming large amount of money, having different anatomy from the human body and confronting with the concerns of morality and ethics [2]. With the advances in IT, VR, AR, 3D printing and AI have been used in medical education, which attempts to reappear the real scenarios, situations and procedures with the absence of patients [1]. Those applications could break through the limitations of time and space, compensate for the shortage of experimental resources and avoid dangers in the real scenarios.

2.1 Application of VR/AR in Medical Education

By using immersive, highly visual, 3D characteristics, VR provides opportunities for users to observe, feel and operate in virtual environments resembling real-world objects and events [3]. The immersive simulation is provided by physical or other interfaces such as motion sensors, a head-mounted display, haptic devices, computer keyboard, mouse, voice recognition and speech [4]. Take the head-mounted display for example, users receive sensory input from the displayer instead of the real world [5]. With the immersive simulation, users interact as if they were in the real world, whereas the focus of the interaction is still in the digital environment [4]. Different from VR, AR overlays digital information on objects or places in the real world to make users place themselves in the real world instead of a completely virtual environment [4–6]. Users of AR can interact with virtual objects and the real world simultaneously via employing a head-mounted display, wearable computers, overlays of computer screens or displays projected onto humans and mannequins [4, 5].

With three characteristics of immersion, interaction and imagination, VR/AR is capable of integrating text, images, sound, animation and video into one, and exhibits considerable advantages in medical education. (1) VR/AR is conducive to visualize the abstract theoretical knowledge, bringing a more vivid and flexible teaching way. For example, applying 3D anatomical structure models designed with VR, teachers can zoom into or toggle the anatomical structures to show the relationship between structures in a stereoscopic way, which makes the teaching visualized and improves the teaching effect. (2) VR/AR enables learners to interact with a computer-generated realistic environment, offering a sense of a force feedback by some sensory information like sound and haptics. For example, using the simulator to create the realistic operating environment for learners, they can feel the operation in reality, in addition to theoretical learning, which makes a full combination of the theoretical teaching and practice. (3) By providing objective metrics, VR/AR can assess the performance of the learners with the absence of a teacher, which can even train the learners to make the right decision. For example, in the training program of knot-tying, a basic surgical skill, VR assesses the performance of the knot-tying via the number of hand movements and the time taken when the learners

tie a surgical knot. It can further provide information feedback about the security of the surgical knot to improve their performance [2].

Although the above advantages possessed, some limitations are still existing when VR/AR applied in medical education. First, VR still cannot make the virtual environment and real environment indistinguishable. Since the sense of touch, high realism and the opportunity to use real surgical instruments offered by cadavers, they are still considered as the gold standard for stimulation in the medical training, particularly in surgical training. Second, cybersickness, an adverse health effect, has been reported when using VR, which can lead to disorientation, nausea, headache, difficulty concentrating, fatigue and problems with vision [7, 8]. Third, several systematic reviews indicate that the studies of the application of VR/AR in medical education focused primarily on the outcomes of knowledge and skills improvement compared with traditional education. The poor quality and breadth of those studies make the recommendation of the application of VR/AR in medical education unconvincing to some extent [9–11].

2.2 Application of 3D Printing in Medical Education

3D printing, also known as additive manufacturing or rapid prototyping, is defined as the process of making the solid, 3D objects through collecting images in the manner of a digital file [12], printing the objects from flatland to spaceland. 3D printer is the requisite equipment to make the 3D objects. After a 3D model is designed with a computer program, it will be sent to the 3D printer to build the 3D model by depositing layers in a volumetric manner, with employing multiple materials such as plastic, gypsum powder, liquid resin, or even metal melted together with a laser. Current applications of 3D printing in medicine are broad, including developing prostheses, patient-specific implants, and anatomic models for medical education [12]. Among those applications, the most common 3D printing technologies are vat photopolymerization, binder jetting, material jetting, powder bed fusion and material extrusion [13].

Albeit 3D images can be obtained from VR/AR, the visualization of 3D content is limited to using the 2D flat screens, which is insufficient for the understanding of some complex anatomic details [14]. 3D printing performs as a feasible “bridge” to overcome the gap. This is the first advantage of applying 3D printing in medical education. Second, the lack of opportunity to use real surgical instruments in the 3D world results in the lack of tactile feedback and hands-on experience. With the 3D models created by 3D printer, medical learners can operate on them using the real surgical instruments, which can bring a sense of reality during their practice. Last but not the least, the high cost of some simulation models such as VR, AR and AI limits their applications in the teaching. 3D printing can produce low-cost simulation models, playing an integral role in medical education [13].

Several researchers have investigated the effect of applying 3D printing models in medical education [15–18]. In the application in congenital heart disease education, Su *et al.* demonstrated that the students achieved better structural conceptualization when using a 3D printing heart model [16]. Whereas, in a pilot randomized controlled study, Wang *et al.* found that a 3D printing model showed no significant superiority, when compared to a traditional model in hear disease education [15].When using 3D printing models for anatomy teaching, most students preferred the 3D printing models

to plastinates, and believed that the color prints improved their learning efficiency [19]. Despite interested in 3D printing models, students expressed that they would not abandon cadaveric specimens [17]. In general, there have been no conclusive results yet and more studies should be carried out to verify the real effect of applying 3D printing models in medical education.

2.3 Application of AI in Medical Education

A working definition of AI, proposed by Ken Masters, is the behaviors designed by computer software to mimic and further extend the rational thinking and actions of human being [20]. There are three main paradigms consisted in AI, including symbolic (logic based and knowledge based), subsymbolic (embodied intelligence and search) and statistical (probabilistic methods and machine learning). Several problem domains, including perception, knowledge, reasoning, planning and communication, are wrestled with those paradigms [21]. The current areas of AI applications are extensive, including finance and economics, automotive, medicine and education [21].

The development of AI in education is rapid and prominent in the twenty-first century. An advanced definition of the role that AI played in education, proposed by Sian Bayne, is a teaching assistant responsible for delivering content, providing feedback and supervising progress [21, 22]. Accordingly, the application of AI in medical education may exert it advancements in curriculum assessment, learning process and learning evaluation [21, 23]. In the curriculum assessment, the application of AI is conductive to solving nonlinear problems and building the relationships between variables. AI can be employed to review the effectiveness of the curriculum and the entire satisfaction with the program of the medical students, as which is critical in training future medical care personnel [21, 23]. In the learning process, the application of AI is conductive to providing learners with personalized educational content. With the feedback from learners, AI can help them to recognize the knowledge gaps [21, 23]. In the learning evaluation, the application of AI is conductive to providing an objective assessment of learners' work and immediate feedback on their assignments, which helps learners to reflect on their work. In addition, AI can make the learning evaluation more cost-effective and time-effective [21, 23].

There are mainly two groups of restrictions of application of AI in medical education, including limitations of AI perceiving the usefulness and the technical problems in the development of AI applications [21]. How to remove those restrictions accurately and effectively may open a new era of future medical education.

3 Future Prospects of Applications of IT in Medical Vocational Education

3.1 Future Prospects of Application of VR/AR in Medical Vocational Education

We have reviewed the advantages and limitations of application of VR/AR in medical education in Sect. 2.1. Where does the future of application of VR/AR in medical vocational education lie?

Before answering this question, we look back at our medical vocational college students. Compared to undergraduate students, students in medical vocational college possess a stronger image thinking rather than abstract thinking. From this perspective, VR/AR facilitates abstract theoretical knowledge visualization, which helps the students to interpret the abstract theoretical knowledge. A combination of learning with working play a crucial role in vocational education. The virtual working scenario like an operating room and clinical laboratories created by VR/AR can make students feel like they are working there. Excitingly, multiplayer VR/AR is becoming available, which allows many learners to see and talk to each other and even interact with the patient in the same scenario [24]. In consequence, VR/AR will be used routinely for medical vocational education in time.

A new concept named "mixed reality (MR)" has emerged recently. MR, combining VR with AR in 3D applications via cutting-edge devices for control, integrates virtual models into the real world and builds interactive feedback loop between the virtual and reality to augment users' sense of reality [6]. MR has been used in anatomy and surgery teaching [10, 25], and may perform as a more pragmatic technology than VR/AR in the future.

3.2 Future Prospects of Application of 3D Printing in Medical Vocational Education

To date, 3D printing has been employed mainly in the teaching of anatomy and surgery, as its advantages described above. Concerning the ability of 3D printing to produce specific and personalized models, 3D printing will be adopted more and more broadly in the future medical vocational education.

In medical field, 3D printing has been widely applied in the dentistry [26]. Little has been reported that the use of 3D printing in the teaching of dentistry yet. Actually, 3D printing is very suitable for applying in the teaching of stomatology technology, since it can produce almost any dental cast you want. In the same vein, 3D printing is also appropriate for the teaching of rehabilitation technology, for the lack of suitable teaching aids on the market. Although 3D printing possesses many advantages, its application in medical vocational education may be limited due to the factors such as production accuracy, preparation time and material cost. For the future application of 3D printing in teaching, it is required to strengthen the school-enterprise cooperation with 3D printing companies.

Nowadays, the novel concept of four-dimensional (4D), integrating a fourth dimension "time" on the basis of 3D printing, has emerged [27]. With the ability to change the configuration (such as shape, property and functionality) with the passage of time, 4D printing is deemed to be a suitable candidate for the use in the pharmacy to produce some personalized "smart drugs" [27]. By the time the technology matures, 4D printing will be used for the teaching of pharmacy and other disciplines in medical vocational colleges.

The concept of five-dimensional (5D) printing has arisen in 2016. Different from 3D printing, 5D printing can produce objects in multiple dimensions with the use of five-axis printing technique [28]. Although it hasn't been applied in medical education, we

believe that 5D printing will create disruptive innovation and provide excellent service to medical vocational education in the era of 6G.

3.3 Future Prospects of Application of AI in Medical Vocational Education

There is no doubt that theoretical knowledge and operating skills play a dominant role in medical education. AI possesses a huge advantage in facilitating the medical students with acquiring those knowledge and skills. In the future curriculum reform which integrating AI with, as suggested by Wartman *et al.* [29], the following 4 features we should emphasize: (1) Learning is knowledge capture rather than knowledge retention; (2) We need to collaborate with and manage AI applications; (3) We need to guide our students how to understand better the probabilities provided by AI and apply them accurately in making clinical decisions with patients and families; (4) We need to keep in mind the importance to cultivate the empathy and compassion of our students.

In the future, medical students will not only require to master data science, but also require to train them the nuanced comprehension and awareness of the ethical issues [30]. Accordingly, what we should highlight in the future medical vocational education is health AI ethics, which is defined as the 'application and analysis of ethics to contexts in health in which AI is involved' [30]. Consequently, a new curriculum that illustrates the ethical dimensions of health AI comprehensively will be necessary to be established in the future medical vocational education.

4 Challenges of Applications of IT in Medical Vocational Education

There is no doubt that applications of IT in medical vocational education help students' studies more targeted, more efficient and more convenient. However, there still exist some challenges that require educators to address.

With the booming development of IT, many medical vocational colleges have positioned "future classroom" and "intelligent and wise class" as their future development direction, and have carried out various reforms. The real intelligent and wise class is not to simply apply IT in the traditional teacher-centered teaching, but to conduct the student-centered personalized teaching with the help of IT. Therefore, the first challenge to educators is how to change their teaching concept from the traditional teacher-centered teaching to the student-centered personalized teaching. The second challenge to educators is how to incorporate a variety of IT into curricula, to instruct students to find the most trustworthy and pertinent information. It requires educators not only to have abundant professional knowledge, but also to master those new training techniques. The last but not the least, educators should balance the benefits of applications of IT in teaching with the downside of the social isolation brought by the excessive use of IT [1].

5 Conclusion

No matter what kind of IT applied for the future medical vocational education, what we should emphasize is how and when to use it in the education, but not whether to use it.

During the process of developing the effective application of IT in education, educators and IT developers should discuss and assess the instructional design that integrates IT well. That is to say, we use the advanced IT in medical vocational education only when it is refined.

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