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Teaching Article

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Vision on the internationalization of physiology education: Trends and prospects

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Abstract: Rapid advancement of physiology education has occurred since the twentieth century due to the emergence of new pedagogies and collaborative effort of physiologists worldwide. Physiological organizations and institutions contribute to the teaching of physiology through international congresses, education symposia, teaching workshops, exchange programs, and journal publications. The Internet and information technologies play a crucial role in the promotion and improvement of computer-based physiology education across

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different countries. Interactive teaching practices and problem-based learning have also become globally applied strategies to enhance students' motivation and facilitate learning effectiveness. In this article, we review the global development and implementation of pedagogical approaches to the teaching of physiology, as well as the emerging trends and practices for physiology education in the future.

Key words: physiology education; pedagogy; internationalization; innovative teaching methods

生理学教育国际化前瞻：趋势和展望

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摘 要：伴随教学法的变革和世界各地生理学家的共同努力，生理学教育自二十世纪以来在全球得到多元化发展。在国际及地区层面，生理学组织和机构持续通过学术大会、教育专题讨论会、教学讲习班、交流计划和出版相关期刊文章等不断地为生理学教育作出贡献。近年来互联网和信息技术的突破发展，对于促进和改善运用计算机辅助教学于生理学教育上起着关键作用。同样，互动式教学和问题导向的学习模式亦已成为全球普遍应用的教与学策略，以增强学习动机，提高学习果效。本文回顾生理学教学法的全球发展和实施，并展望未来生理学教育的新趋势。

关键词：生理学教育；教学法；国际化；创新教学方式
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1 Timeline and milestones of physiology education in the world: contributions by international networks

International and regional organizations, provide a platform of exchange for teaching practices and pedagogical development across institutions. National societies of physiology further contribute to nurturing the next generation of physiologists by offering additional impetus for the growth and advancement of physiology teaching.

1.1 International level

At the international level, the International Union of Physiological Sciences (IUPS) has been organizing international congresses to share advances in physiology research and physiology education since 1889. During his term as President of IUPS (1994–1997), Professor Masao Ito broadened the activities of IUPS Commissions to "open the new field of physiology" [1] by fully integrating education symposia and keynote lectures into the programs of the IUPS Congresses [2, 3]. In the Claude Bernard Distinguished Lecture (IUPS 35th Congress, 2005) entitled "*Charting a global future for education in physiology*" [4], the "*aim to find ways of expanding the range of our activities in collaboration with the education committees of related international groups*" was announced as one of the directives of the IUPS.

Apart from fostering collaboration and providing insight in the future of physiology education, the IUPS has been organizing education-related workshops for over 40 years since its first one held in 1977 [5–10]. These Physiology Teaching Workshops continue to attract physiology teachers from over 20 countries worldwide [11].

1.2 Regional level

Regional societies for physiology have also worked with IUPS and national level societies to facilitate mutual support for physiologists in different continents over the world. These include the Federation of European Physiological Societies (FEPS), the Federation of the Asian and Oceanian Physiological Societies (FAOPS), and the Latin American Association of Physiological Science (ALACF).

Apart from workshops on physiology education, the FEPS also has a Task Force Group for education in physiology, which plays an active role in supporting physiology education. In particular, the FEPS Visiting Program for Physiology Teachers aims to support the exchange of experienced physiology teachers between member countries to facilitate planning and implementation of teaching of physiological sciences.

In Latin American, there have been plentiful activities related to physiology education. These include the UNIBE Workshop held in Costa Rica (2000) focusing

on the modern approaches to physiology teaching such as collaborative learning and problem-based learning (PBL) [12], the IUPS Physiology Teaching Workshop held in Brazil (2017) focusing on "*Improving physiology learning and understanding by adding outreach activities to the teaching*" [9], and the 2nd Pan American Congress of Physiological Sciences held in Cuba (2019) with two symposia, a workshop, and a poster session on miscellaneous topics in physiology education [12].

In the Asian and Oceanian region, the FAOPS has been regularly organizing scientific congresses in physiology every 4 years. In the 5th Congress (2002), the first round-table discussion on teaching of physiology was conducted [13]. By the 8th Congress (2015), a series of sessions were devoted to presentations and discussion on physiology education. Between the congresses, FAOPS also supports regional conferences on physiology and physiology teaching [14].

1.3 National level

At the level of national societies, The Physiological Society (TPS), the American Physiological Society (APS), and the Chinese Association for Physiological Sciences (CAPS) have played cardinal roles in the implementation of initiatives at the national level. Founded in 1876, TPS promotes physiology by organizing scientific conferences, workshops [15–21] and symposia along with journals such as *the Journal of Physiology* (since 1925), *Experimental Physiology* (since 1981) and *Physiological Reports* (since 2013). In addition, grants are provided for teaching and research in physiology. In particular, TPS Education & Teaching Theme covers 23 specialties across various biological systems. It promotes innovative physiology teaching through the sharing of best practices, and plays a key role in creating a positive teaching environment by developing teaching and learning resources and informing the public about physiology through outreach activities [22].

In 1887, the APS was founded to promote the advancement of physiology and facilitate interaction among American physiologists. Today, the APS continues to work at the frontiers of physiological sciences in the world, leading to significant advancement in our understanding of life and health, as well as insights on treatments for various diseases. In 2014, with the support of the APS Education and Meetings Services Offices, the APS Teaching Section developed the first biennial Institute on Teaching and Learning (ITLs). The ITLs significantly enhance collaborations that stimulate ideas for educational research and provide information on the best practices of physiology teaching. With a growing number of participants, the ITLs also assist in the establishment of new friendships and consultations among physiology educators [23].

In 1926, the CAPS held the inaugural meeting in Beijing [24]. The teaching of physiology is conducted as distinct discipline by over 200 academic departments in China. The CAPS has contributed to numerous meetings and workshops on the teaching of physiology around different cities in China [25–27]. Following the establishment of an education committee in 2002, the CAPS has organized symposia on physiology education in every national conference, as well as special physiology education conferences biennially [28, 29]. Examples of recent initiatives focused on PBL at Hangzhou in 2012 [30] and on physiology teaching materials at Changsha in 2018 [31]. In 2020, with the COVID-19 pandemic, the CAPS has embraced information technology by organizing an online education workshop in June, followed by a virtual physiological education symposium as part of its first online annual conference in August.

2 How is physiology taught from the global perspectives?

New teaching strategies have been continuously developed and applied in different parts of the world. Reviewing the reports of educational initiatives by scholars from different countries, we can find many successful examples of pedagogical approaches to the teaching of physiology.

2.1 Active learning in the classroom

Traditionally, didactic method is employed in classroom teaching through lectures and tutorials. With teacher-led learning and rote learning as the main mode of education, physiology education in the past mostly centered on knowledge delivery, instructional guidance, homogenous learning, congestion, target, destination, assessment, and grades.

After the Millennium, however, the concept of flipped classroom as a modified instructional strategy has gained interest amongst teachers and institutions worldwide. With the transition towards flipped learning, knowledge traditionally taught in the classroom can be delivered at home instead of occupying valuable time at school where teachers and students

meet physically. As such, class time can be spent on interactive activities. In the last few decades, some teachers also started to adopt an inquiry-based approach instead of step-by-step instructions. The inquiry-based approach has been shown to benefit learning outcomes of physiology courses [32].

To enrich the learning process, many physiology teachers are interested in designing more active ways of learning. Examples include the combined use of educational games and quizzes in physiology teaching, animation of textbook images [33], flashcards, theater presentation, and models of people or biological structures [9]. Role playing, personalized learning [12], and intercultural learning [34] have also been reported to be beneficial to physiology education. Recently, mobile phone applications also became an option to improve students' learning [9]. These interactive teaching practices effectively motivate students to study physiology.

2.2 Inclusion of clinical aspects

Pathophysiology explains the functional changes of the body in disease states. The teaching of pathophysiology as an independent discipline was introduced by physiologist Viktor Pashutin at the University of Kazan, Russia in 1874 [35]. Nowadays, it is popular for educators to integrate pathophysiology into the curriculum to facilitate students' understanding of the adaptive powers of the human body to maintain the steady state, as failure to maintain homeostasis is the basis of pathophysiological mechanisms. Some physiology teachers are keen to explore how physiology can be linked to clinical sciences in basic medical physiology course [5] and how clinical cases can be used to encourage students to study physiology [12]. Since medical students highly value physiology as a preparation for success in clinical studies and future practice, physiology instructions that emphasize clinical relevance enhance students' satisfaction in learning physiology [12].

2.3 PBL

PBL is a learning approach based on group discussion of clinical or scientific problems under the guidance of tutor/facilitator, who can be a non-expert with special training in PBL tutoring. In contrast to rote learning, PBL brings the mode of education towards independent self-learning as a life-long process.

As early as the 1920s, the concept of PBL appeared. A primary school teacher, who was too weak to speak due to an injury in World War I, created a new system of learning in which the students manage their own progress of study and cooperate with peers [36]. In medical education, PBL was first used in 1965 at McMaster University Medical School in Canada [37]. Since then, PBL has infiltrated to many medical schools across different countries. In 1978, PBL was pioneered in Australia at the University of Newcastle Medical School [38]. In the 1980s, this mode of learning became even more widely adopted. For example, PBL was first implemented in the UK at Manchester Medical School in 1984. Soon, Harvard Medical School established a "New Pathway" curriculum based on PBL in 1985, followed by a New Integrated Curriculum in 2006 [39]. In 2015, Harvard Medical School launched the redesigned Pathways curriculum, which has shifted almost exclusively towards a PBL preclinical curriculum to encourage critical analysis of ideas and stances [40].

Despite many years of research and debate, there is no definitive conclusion on the best way for the elements of a PBL environment to be optimized. Furthermore, it is essential to develop assessment systems that accurately evaluate students' problem-solving competencies in an environment aligned with the PBL environment. It is hoped that further educational research will overcome the challenges with PBL [41, 42]. Nevertheless, PBL clearly reflects a commitment to a student-centered approach in which students work together to identify the issues, brainstorm hypothesis, and find solutions to the problems presented to them. Through these sessions students also learn to work in a team and develop interpersonal skills. PBL encourages scientific and clinical reasoning, as well as the use of biomedical language in an appropriate way [43]. In physiology education, it is evident that PBL is significantly more effective than traditional instruction to increase motivation and promote long-term retention of knowledge and problem-solving skills [44–46]. Self-learning skills acquired through PBL sessions will further equip students with the necessary tools for life-long learning that is essential in the rapidly advancing field of physiology.

2.4 Computer and information technology

Since the 1990s, computer technology has been evolving at an accelerated pace. Accordingly, the applications of computers in education expanded quickly. In physiology discipline, a lot of educational research focused on how computers can be effectively used to improve teaching and learning. Towards the end of the

twentieth century, the ideas of group learning in computer-supported human physiology projects and teaching physiology by distance education were already emerging, especially in the UK and USA [5, 47].

Since the mid-80s, the computer-based data-acquisition and analysis system *PowerLab* was available as tool for physiology teachers in the international arena. *PowerLab* software is designed for teaching and research particularly in physiological and pharmacological sciences. It can be customized to suit different levels and types of physiological experiments where recording and display are needed. *Biopac Student Lab* is another commercially available system that provides similar functions. In the classroom, teachers can also provide students with clear illustrations of experiments that are normally conducted in the laboratory [43]. Other computer-based strategies in physiology education include on-campus collaborative computer aided learning [11, 43], multimodality learning via the implementation of 3D technologies, and audience response systems [33]. Recently, innovative techniques such as augmented reality (AR) [48] and virtual reality (VR) [49] have initiated a trend of new teaching strategy.

The Internet and information technologies have also played a crucial role in the advancement of physiology education since the beginning of this century [6, 50]. Since the Millennium, there has been a growing trend for open access. Universities across the globe have provided free online courses as OpenCourseWare (OCW) or Massive Open Online Courses (MOOCs) [51, 52], while many leading academic journals now offer open access for articles. These open a great opportunity to promote knowledge exchange and communications not only among students and teachers, but also to members of the general public [43]. On the one hand, students can have online access to learning materials, receive information about the courses, participate in interactive discussion forums, and work on online questions for self-assessment. On the other hand, teachers can obtain high-quality online resources of updated physiological knowledge and educational strategies [4]. Public access to learning materials and the latest breakthroughs in physiology will no doubt generate widespread interest in the subject and promote physiology education in popular science.

Given the rise of digital literacy for online learning, the foci of physiology education will undoubtedly shift to flexibility, individuality, reliability, and cross-discipline self-directed learning experiences. Nowadays, the vast majority of institutions in the world support online learning management systems for curriculum delivery. With the outbreak of COVID-19 and associated social distancing measures, it is expected that online learning will continue to gain precedence over traditional teaching techniques.

3 Incorporation of international pedagogical approaches in HKUMed

Physiology is a core subject of medical education. In the Li Ka Shing Faculty of Medicine, the University of Hong Kong (HKUMed), international pedagogical approaches are incorporated into physiology teaching to enhance the learning effectiveness since first implementation of PBL teaching in 1997.

Since 2018, the Bachelor of Medicine and Bachelor of Surgery (MBBS) curriculum at HKUMed has been undergoing modernization in which information technology is amalgamated into teaching. Through a blended innovative approach associated with conventional classes, students at HKUMed enjoy a range of E-learning resources. The COVID-19 pandemic further acts as a "catalyst" for E-learning.

In the 2020/21 term, over 60% of physiology lectures will be conducted via online learning formats, with teaching materials no longer restricted to PowerPoint slides. Each one-hour online lecture consists of 3 to 4 video clips, each with its highlights, captions and take-home messages. Each lecture is supplemented by multiple-choice questions or 10 to 15 minutes of interactive session whereby students have plenty of opportunities to discuss the lecture content, thereby strengthening their learning for the applications of physiological sciences.

For practical sessions, physiological experiments enriched with AR and VR technologies are being developed to create an immersive learning environment in which students learn by doing. According to Edgar Dale's Cone of Experience theory, people remember what they do much better than what they read, see, or hear. At the same time, students are provided with in-person guidance to maintain the standard of skills.

PBL tutorials at HKUMed have shifted to the online mode, particularly during the pandemic of COVID-19. Students participate in small-group tutorials via video conferencing software to discuss clinical scenarios

involving physiological functions and other biomedical issues. Students learn by experience so as to recognize and resolve gaps in knowledge. Although conducted online, these tutorials provide a good context to motivate active learning, help students with decision-making, and further develop the communication skills of students.

Online PBL is not without disadvantages. Learning through virtual environments may fall short of building up real-life relationship, friendship and trust. Relying too much on electronic devices, students may face a lack of social and emotional learning. How to encourage every student to participate and enhance team-building of students in a group during online PBL tutorials is an interesting topic for teachers to explore. Is it useful for group members to interact with WeChat or WhatsApp? Can "chat room" benefit the introvert students? Obviously, PBL tutors need to walk an extra mile for students.

Recently, HKUMed further initiated inter-professional team-based learning (IPTBL), an innovative teaching approach that promotes peer-to-peer learning and inter-professional education across healthcare disciplines both within HKU and in collaboration with other local universities. IPTBL integrates team-based learning, flipped learning, and E-learning. Hundreds of students from different universities can be served in a single session through a large-scale flipped classroom, greatly enhancing collaborative learning.

In HKUMed, physiology teachers review the validity and utility of different forms of assessment including continuous assessment, such as in-class tests and online quizzes, as well as end-of-course examinations. Questions are mapped to pre-defined learning outcomes that are tagged to each learning activity. Over the past few years, essay questions have been progressively replaced by non-essay questions, such as short questions or structured-answer questions. With the modified question format, the assessment items become more focused and specific, thus reflecting the students' performance more accurately. The teaching team in HKUMed aims to provide debriefing to students within one month of every major exam and a personalized report.

Since the COVID-19 pandemic, online assessment became more widely adopted in different curricula. Some examinations in HKUMed have been conducted online. With the advancement of technology, it is expected that the mode of online examinations will be improved by computer systems that allow instantaneous monitoring by an offsite invigilator. For example, *OnVUE* online proctoring platform from *Pearson* protects the integrity of the examination content, deliver, and data with high security. Nevertheless, some drawbacks, such as the lack of opportunity for the candidates to take physiological break, still need to be resolved. As the trend for online learning continues globally, we will gain a more accurate assessment of its faults and merits, and develop ways to improve the effectiveness of these new teaching methods.

Altogether, HKUMed is actively enriching basic paradigms of teaching to open up new perspectives in physiology education.

4 Physiology education in the future

Physiology has generally been taught by division of whole body function into ten physiological organ systems [53, 54]. Indeed, the majority of leading medical schools in China adopt an organ system-based curriculum model [55]. While different lectures focus on individual disciplines, there has always been an undercurrent of integration of knowledge from different disciplines, such as anatomy, biochemistry, pharmacology, pathology, microbiology, and medical humanities. This kind of presentation has the advantage of giving students a clear concept about the specific disciplines in clinical practice, while providing a constant reminder that different organ systems do not stand alone, but rather support bodily function through interaction. Phenomenon-based learning (PhenoBL) which stresses a multidisciplinary, learner-based, holistic approach to understanding real-world problems [56] was officially incorporated into the Finnish National Curriculum in 2016 [57].

While large-scale PhenoBL has only been implemented at the secondary school level, it is easy to appreciate how this approach is well suited for physiology education. In fact, students already tackle real-world clinical problems using self-guided multidisciplinary approaches in PBL sessions. In this light, the organ system-based approach serves the essential function of equipping students with solid ground knowledge, easing their learning curve towards acquiring self-learning skills in physiology.

Similar ideas of multidisciplinary teaching and research have led to a trend of agglomerating depart-

ments of physiology, anatomy, biochemistry, pharmacology, etc. into schools of biomedical science in universities in Australia, UK and US. This poses a challenge for the training of physiologists. In the past, research students and staff joining the department of physiology would be required to study physiology comprehensively. In effect, this practice contributed to nurturing the next generation of physiologists and identifying individuals with the potential, ability or interest to become physiology teachers. Upon the vanishing of physiology departments, a gradual decline in the availability of physiology teachers seems to be inevitable. While novel big-data and omics approaches in physiology research have highlighted the importance of understanding bodily functions as a whole, finding a balance between nurturing expertise in particular aspects of physiology versus a broad understanding of interaction between organ systems is a dilemma that will require resolving for the education of physiology to prosper into the 21st century.

Apart from new curriculum structures, advancement in AR and VR technology have provided new platforms in education. While some limitations related to technical issues exist [58], the ability to supply multimedia information in real time by AR or to provide students with interactive and immersive learning experiences through VR has a great potential in promoting medical and physiology education [48, 49].

Since the beginning, physiology education has remained relevant through constant evolution with the advancement of knowledge, pedagogy and technology [59]. Personal feedback, comprehensive guidance, and activities that reinforce problem-solving skills with the ability to apply physiological knowledge [60], together with a good balance between depth and breadth of learning will be major considerations in curriculum design. Additionally, it will be important to develop students' awareness of their understanding and learning processes. By recognizing their own difficulties in studying physiology, students can implement more effective learning strategies to overcome them [60]. With the advancement of new technologies, particularly online education, learning has become more flexible and accessible. More diversified modes of learning can be achieved through better combinations of online learning with traditional teaching methods [61]. Physiology education which classically was restricted to medical students may well experience a boom in interest from the general public with the advent of online learning and MOOCs. Whether we, as physiologists, can continually innovate and perfect physiology education will decide if this discipline surfs the tide of time or gets swept away.

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