The future of physiology education: Igniting curiosity and innovation through modern teaching methods

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ABSTRACT

Since the 19th century the importance of physiology as a natural science emerged. There has been a great importance of physiology in the health sector, and thereby the immense expansion of the subject of physiology in education. But in recent eras due to the emergence of multiple branches in the healthcare sector and some other factors, the scope of physiology is getting narrowing. Moreover, the present arena is now considered the age of translational research. But simply by ignoring the basic or fundamental research, there can not be the emergence of a new translational field or even the success of translational research and, thereby, the betterment of our society. This article focuses on challenges and new scopes of the physiologist at this crucial juncture so that there can be a generation of curiosity among the learners to explore the basic or fundamental concept of physiology where there is an immense role of recent developments of teaching-learning methodologies in physiology education and subsequently research.

Keywords: Upcoming teaching learning methodologies in physiology education, Concepts building is a key of translational research, Challenges and Scope of Physiology as basic subject.

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INTRODUCTION

A. Physiology as a Basic Science – The Skeleton of Human Health: Past Journey in India's Perspective

The term "Physiology" is derived from the Greek word 'Physiologikos," which means the discourse of natural knowledge introduced by the French Physician Jean Fernel in 1552. So, it is a fundamental branch of biology that explores the functions and mechanisms of living organisms, with a particular focus on how various systems within the body operate. In the 19th century CE, under the influence of great Greek and Roman Civilizations, the idea to originate and develop 'Physiology' as an important branch of the then-modern science emerged. In India, the European system of medicine was first introduced during the British era and the teaching of physiology was first introduced in the Sanskrit School, Calcutta and Calcutta Madrasha in 1826, followed by the Medical College, Calcutta, where physiology was taught as an introductory subject of medicine in 1835.[1] The branch of physiology as a basic science beyond the medical faculties was introduced in the University of Calcutta in 1901 in Presidency College, the idea first conceived by Prof. S C Mahalanobis [1], the founder and president of 'the Physiological Society of India.' The postgraduate teaching was started later in 1911 under the faculty of Science of the University of Calcutta and in 1927, the PG department was shifted to Rashbehari Shiksha Prangan, popularly known as Rajabazar Science College in the Rajabazar area of Kolkata.[2] Later, realizing the importance of physiology as basic science, both undergraduate honors and postgraduate courses in physiology under the Faculty of Science were introduced at Tripura University (Bachelor's degree in 1961 and thereafter Master's in 2006), Burdwan University in 1997, Vidyasagar University (Masters course in 1990), Kalyani University in 2005 and PG in K N College, Berhampore in 2001, Barasat State University in 2008 and Gour Banga University recently. PG course is also started in Serampore College, Rammohon College, Midnapore College, and Raja N.L.Khan Women's College recently,[3] and etc.

Since then, there has been enormous growth of subject physiology and physiologists within the domain of medical and non-medical fraternity. As understanding normal physiology is the first step toward maintaining health and preventing diseases, the scope of physiology in the health sector is expansive and continually evolving. From understanding the intricacies of normal body function to diagnosing diseases, developing treatments, and advancing medical research, physiology is an indispensable pillar of modern healthcare. Its contributions extend to virtually every aspect of health and well-being, making it an essential discipline in the quest for improved health outcomes and a better quality of life for individuals and populations worldwide. As our understanding of physiology

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deepens, so too does our capacity to address the complex health challenges of the 21st century. Its contributions are multifaceted and essential in various aspects of the medical field. Here are some key roles (Figure 1) of physiology in the medical industry:

Diagnosis and monitoring

Physiological principles are integral to diagnostic medicine. Healthcare professionals use physiological measurements and tests to diagnose and monitor a wide range of medical conditions. For example, electrocardiograms (ECGs) assess cardiac function, spirometry measures lung function, and blood pressure monitoring helps detect hypertension.

Treatment planning

Physicians and healthcare providers rely on their knowledge of physiology to develop treatment plans tailored to individual patients. Understanding how different drugs and therapies affect the body's physiological processes is crucial in prescribing effective treatments.

Surgery and interventional procedures

Surgeons and interventionalists use their understanding of physiology to perform complex procedures safely and effectively. Procedures like open-heart surgery, organ transplants, and minimally invasive surgeries all require a deep knowledge of anatomical and physiological principles.

Medication development

Pharmacologists and pharmaceutical researchers depend on an understanding of physiological processes to develop medications. They study how drugs interact with the body's systems to target specific diseases and conditions. This knowledge is essential for drug design and testing.

Disease understanding

Physiology helps in unraveling the underlying mechanisms of diseases. Researchers and clinicians use physiological knowledge to understand how diseases disrupt normal bodily functions. This insight is crucial for disease prevention, early detection, and the development of targeted therapies.

Genomics and precision medicine

Advances in genomics have made it possible to personalize medical treatments based on an individual's genetic makeup.

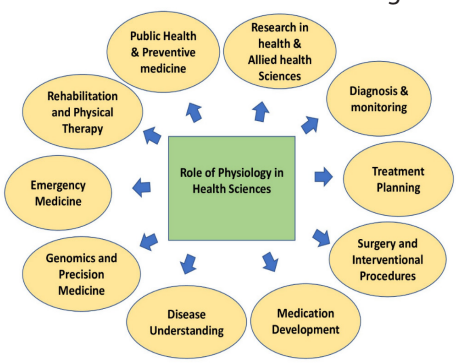

Figure 1: Uses of physiology in health sector

Physiology plays a significant role in interpreting genetic data and tailoring treatments to a patient's unique physiological profile.

Emergency medicine

In emergencies, healthcare providers must make rapid decisions based on a patient's physiological status. Understanding the body's response to trauma, shock, and acute illnesses is critical in emergency medicine.

Rehabilitation and physical therapy

Physiological principles guide rehabilitation programs and physical therapy. Therapists use their knowledge of muscle and joint physiology to help patients recover from injuries, surgeries, or chronic conditions.

Medical education

Physiology is a fundamental subject in medical education. Medical students learn about the body's systems and functions, providing them with the essential knowledge needed to become competent healthcare professionals.

Public health

Physiological insights contribute to public health initiatives and health policy decisions. Epidemiologists and public health experts use physiological data to understand disease patterns, assess risk factors, and design interventions.

Preventive medicine

Physiology plays a role in preventive medicine by helping identify risk factors for various diseases. Understanding how lifestyle choices and environmental factors affect physiological processes is crucial in promoting health and preventing illnesses.

Medical research

Physiological research is a cornerstone of medical advances. Scientists study physiological processes to uncover new insights into health and disease, driving innovation in medical science and technology.

Physiology as a basic subject: Today's perspective

This is the age of translational science and translational research in which the thirst area of both Govt. and private sectors are research and education both in the direction of bench to bedside where the practical implications of the research and education in the society have got the pivotal importance. Keeping this objective in mind there is a paradigm shift of the policy makers in both govt. and private sector to bring new and multiple courses that can fulfill both the researcher's interest and students' interest towards providing the betterment of society and better job opportunities.

Emergence of New Courses

As physiology is the mother of medicine the value of physiology in the health and allied health sector was

tremendously developed, for which there was tremendous growth of basic physiology in both academics and research fields until recently. But the irony is that with the advent of these newer courses like PG courses in Medical physiology, the scope of basic physiology is reduced to a greater extent. This marginalization of basic physiology courses started with the inception of regulations adopted by MCI, Govt. of India in 1998 [4] in which the role of basic physiologist from the faculty of science is stopped as a faculty in the Dept of Physiology under any medical colleges. Thus, with the emergence of newer courses in biological sciences, health sciences, and allied health sciences, the scope of physiology as an academic subject and research opportunities are restricted. The situation was further aggravated when the Govt. of India itself started to change its education policies to focus on meeting the deficiencies of allied healthcare professionals. A study undertaken by the Public Health Foundation of India (PHFI) for the Ministry of Health and Family Welfare (MoHFW) has indicated a supply-demand gap of about 65 lakh allied health professionals [4]. In 2007, the government of India proposed setting up separate councils for medical laboratory technicians, radiology technicians, and physiotherapists/ occupational therapists to solve this problem. These councils would be responsible for the maintenance of uniform standards of education in the respective disciplines and the registration of qualified personnel to practice the profession [4]. A number of councils, such as the National Medical Council (Formerly known as the Medical Council of India or MCI), the Dental Council of India (DCI), the Pharmacy Council of India (PCI), and the Indian Nursing Council (INC) have already been established by Government of India for regulating the standards of education and training, as well as the registration of practitioners in these fields. The aim is to prevent unqualified people from practicing and also to maintain the standards of these professions. However, there is no central regulatory mechanism for AHPs. This is why India's health sector underwent major policy reforms during the 12th Five-Year Plan (2012–2017).[5] This time is ideal for comprehensive, targeted interventions to address the demand-supply mismatch that plagues the allied health system in the country, which was absent until recently in our country except Madhya Pradesh, Himachal Pradesh, and Kerala, which have a statutory paramedical council to regulate education, recognize courses, and maintaining the registers. For education and training of AHPs, there are a number of courses ranging from short-term (up to 3 months), certificate, diploma, and graduation. Therefore now attempts are being made to create a regulatory council for paramedical courses just like MCI and DCI. In view of the desperate need for a comprehensive regulatory framework to ensure uniform training, employment, and standardization for allied health services staff, the Paramedical Council Bill, 2007[6] was drafted and subsequently proposed in Parliament. This Bill aimed to set up three councils to regulate physiotherapists and occupational therapists, medical laboratory technicians, and radiology technicians, with minimum educational and professional standards for each. It mandated that every practicing AHP be registered with the council. It was also proposed that all clinical establishments can only appoint those AHPs who are registered with their respective councils. A proposal was put forward in May 2010 [7] to the Cabinet for its decision to augment the supply of skilled paramedical (allied health) human resources and to promote the quality of paramedical (allied health) training through standardization of such education/ courses across the country. It was decided to support human resource development through support to state government medical colleges in the form of a one-time grant, by the establishment of a National Institute of Paramedical Sciences (NIPS) and National Institute of Allied Health Sciences (NIAHS); and by the establishment of eight regional institutes of paramedical sciences (RIPS) or regional institutes of allied health sciences (RIAHS). In this light, the National Commission for Allied and Healthcare Professions (NCAHP) is an upcoming Indian regulatory body of Allied and Healthcare Professionals.[8,9] It covers all allied and healthcare professions that were not covered under the National Medical Commission, Dental Council of India, Indian Nursing Council, Pharmacy Council of India, etc till 2021.[10] Recently this council has come up with the proposal in detail and will be effective throughout the country within a couple of years.

Limited job Opportunities in Basic Physiology

Besides the emergence of newer courses in different biological sciences like molecular Biology, Biotechnology, Nanoscience, and Allied Health Sciences etc the scope of physiologists in academics has also been restricted due to some other reasons as follows:

Job market saturation

With an increasing number of graduates in physiology, the job market has become highly competitive. Many traditional physiology jobs, like academia or research, might have fewer openings compared to other fields. This saturation can make it difficult for new entrants to find suitable positions.

Technological advancements

While technology has significantly enhanced research capabilities, it also demands physiologists to constantly update their skills. Staying abreast of new technologies and methodologies becomes crucial to remain competitive.

Interdisciplinary skill

The modern landscape often requires physiologists to possess interdisciplinary skills. For instance, expertise in data analysis, computational biology, or bioinformatics might be necessary to complement traditional physiological knowledge.

Funding challenges

In research-oriented roles, securing funding for projects is a perpetual challenge. Cutbacks in research budgets or

increased competition for grants can hinder the progress of physiological research.

Public understanding

Educating the public about the importance of physiology and its implications on health can be challenging. Bridging the gap between scientific research and public understanding is essential but often difficult.

Remote work challenges

While remote work has become more prevalent, certain aspects of physiological research might require physical presence in laboratories or fieldwork, posing challenges in adapting to remote work models.

Change of thirst area of Research

The present arena is now considered the science of translational research (TR) and therefore, the policy of both govt and private concerns in the field of research is exclusively towards translational research (TR) and limited funds are available for basic research. The main vision of TR is to communicate with different stakeholders and help them to promote 'bench-to-bedside and bedside-to-community' research effectively. The mission of TR is to hasten the processes involved in discovery and innovations for the ultimate benefit of the community.[11,12] Therefore, the primary aim is to bring all interdisciplinary stakeholders on a common platform and introduce new products/technologies into the market and medical advancements in a cost-efficient manner for social benefits [13]. As a result, health policies are being reformed at the government level, while workforce training and development are being initiated at various levels and awareness programs at academia and industry levels.[14] India, being a signatory of the United Nations Mission for Sustainable Development Goals till 2030,[13] is actively participating in improving health research in the country on macro and micro levels. Under the Ministry of Health and Family Welfare, the Department of Health Research (DHR) has initiated many programs, including Standard Treatment Workflow (STW) and Health Technology Assessment (HTA) in India as a part of TR to evaluate new cost-effective health technologies and medical devices which can be included in the National Health Programmes.[13] ICMR (Indian Council of Medical Research), New Delhi, initiated one such type of TR program under DHR in 2008. The Department of Biotechnology (DBT), Ministry of Science and Technology (MoST), GoI, took the initiative to establish an autonomous institution named Translational Health Science and Technology Institute in 2010 [15]. So the ultimate goal of this TR is to make the fundamental basic research evidence-based, validated, and target-oriented, which will facilitate the identification of potential leads for translational discoveries.[16]

Physiology as a basic subject: future perspectives (Figure 2)

TR has indeed got its immense importance as any research without any social impact is not advisable, but simultaneously it can be said that TR is like a roof on which different strata of society are built. However, this roof (TR) stands on multiple pillars, which are basically fundamental research. For example, once William Harvey discovered the existence of blood vessels through which blood from the heart flows in the body, it was basic research. When W. Frossman did one experiment in his own body to pass the catheter through his vein to the heart by taking his life risk also was fundamental research, but all this research led down the steps towards the invention of the modern *Cath lab* through translational research. Similarly, Watson & Crick won the Noble Prize for their discovery of the DNA model, which was again fundamental research, but when it was discovered, even they probably had no idea about what evolutionary field of research they created that ultimately led to the birth of a new field, i.e., genetic engineering, a type of translational research. This means that simply by ignoring the basic or fundamental research, there can not be the emergence of a new translational field or even the success of translational research and, thereby the betterment of our society. At the same time, it is also true that there are numerous aspects of the human body and human function (fundamental) that are yet to be explored. For example; We all know that our fingerprints are so unique that no two people have the same ones, not even identical twins. But why do humans have these swirly patterns on their fingers in the first place? Similarly, How can a person be a prodigious savant like Suborno 'Isaac' Bari? To explore such types of unexplored events or phenomena, basic research should go hand in hand and then only our society will be more benefitted through translational research. So policymakers should think on this line without ignoring the fundamental basic research.

Simultaneously, there is the utmost duty for teachers of basic physiology to make the subject very interesting and generate curiosity among the learners to explore the subject for which they have to think beyond the C*halk and Talk* and *PowerPoint Presentation* of the teaching-learning methodologies.

Importance of new Teaching-learning Methodology

Physiology is regarded as vital in all biomedical fields. In spite of that, some alarming views on a potential decline of physiology evoked justified concerns about how teaching-learning and research might be affected in the coming years.[17-21] This concern related to the "Future of Physiology" has been addressed by reference science organizations in recent years [21-23]. It was also mentioned [21-23] that the fame of Physiology has been progressively blurred by more applied and trendy themes [21,24] while research has become progressively absent in high-rank journals, even if physiology-related. These impact early career students, scholars, funding agencies, and scientific editors and are noticed in the general public culture as likely some loss of character and identity. To address this problem, during the 4th meeting of P-MIG in Minneapolis, Minnesota (United States), a workshop on "Future of Physiology" was organized in 2019 [25]. Although principally based in North America, P-MIG

conferences involve experienced international physiologists the motivation behind this focus group was to better understand current concerns to identify major trends for the future of Physiology beyond 2030. An additional goal was to contribute to the development of reliable strategic scenarios for physiological teaching practices, learning, and innovation for the future so that the understanding or concept of basic physiology among the learners becomes crystal clear and comprehensive. This is only possible by igniting interest in students' minds, innovative teaching-learning tools, and motivating students to quest for knowledge and interdisciplinary integration. To achieve this goal it is the utmost duty of the teacher to ignite the young mind toward their curiosity on fundamental research that can turn into translational one later.

Recent Developments in Physiology Education

Emerging technologies enable a personalized, adaptable, and differentiated focus on learning needs and pedagogy [26]. There are numerous advanced learning methodologies have come up and the most appropriate in the field of basic physiology education are cited here.

Virtual and augmented reality

Virtual reality (VR) and augmented reality (AR) have emerged as powerful tools in physiology education. The idea of virtual reality as we know it today was developed in the 1960s [27]. This educational mode of VR technology has become a unique tool of learning that enhances the conventional approach to learning. This innovative approach increases students' interest in learning with the help of multiple sensory inputs. A more accurate display of functioning or activities can be achieved with virtual reality [28]. VR content will help students recognize and study abstract or difficult-to-observe knowledge in a risk-free environment, which is a crucial component of VR in education.[29,30] VR provides a fully immersive experience, allowing students to explore and interact with three-dimensional models of physiological systems. AR overlays digital information onto the real world, enabling learners to visualize internal structures and functions within a real-world context. These technologies facilitate a deeper understanding of complex physiological processes by allowing students to visualize and manipulate anatomical structures and dynamic physiological processes in ways that are not possible with traditional textbooks or static images. For example, VR can simulate the flow of blood through the cardiovascular system, while AR can enhance the study of human anatomy by projecting 3D models onto a physical body.

Online learning platforms

The rise of online learning platforms has made physiology education more accessible and flexible. Massive open online courses (MOOCs), webinars, and virtual classrooms provide students with access to high-quality educational resources from anywhere in the world. MOOCs are a form of online learning where online courses are accessible at little or no cost and without limits on participant numbers or prerequisites [30]. The first MOOC was set up by Stephen Downes and George Siemens at the University of Manitoba in 2008.[31] Platforms such as Coursera, edX, and Khan Academy offer courses on physiology and related subjects, often created by renowned institutions and educators. These platforms support various learning styles through multimedia content, interactive quizzes, and discussion forums, enabling learners to engage with the material at their own pace. Additionally, online learning facilitates lifelong learning and professional development for healthcare professionals who need to stay updated with the latest advancements in physiology.[32] The accessibility and flexibility of online learning platforms make physiology education available to a global audience, including students in low-resource settings. This democratization of education has the potential to address global health challenges by training a diverse and well-informed workforce capable of tackling health disparities and improving healthcare outcomes worldwide.

Simulation-based learning

Simulation-based learning has become increasingly prevalent in physiology education. Simulators, ranging from simple computer-based models to high-fidelity mannequins, allow students to practice and refine their skills in a controlled and safe environment. These simulations can mimic real-life scenarios, such as managing cardiac arrest or performing complex surgical procedures, providing hands-on experience without the risks associated with real patients. CPR technique can best be taught with the help of mannequins which is another example of simulation-based learning. Simulations also enable repeated practice, immediate feedback, and the development of critical thinking and decision-making skills. For instance, students can use physiology simulators to understand the impact of different variables on cardiac output or respiratory function, enhancing their ability to apply theoretical knowledge to practical situations.

Flipped class

The flipped classroom model, where traditional lectures are replaced with interactive, student-centered activities, has also become popular. The most common problem in a traditional classroom is that the teacher is teaching, but the students do not pay attention to the lecture. During the question-answer session, the topper and a few more students were involved, but the rest of the class remained silent. Here, we are using ICT-based techniques to change traditional classrooms into flipped classrooms. Also, by using the flipped classroom technique we can identify the ability of students with respect to completion of different tasks. The flipped classroom is a leaner-centric teaching process. In this, some activities are conducted inside the class and some are conducted outside the classroom. The activities that are conducted outside the classroom are done with the help of ICT tools.[33]

In this approach, students first engage with lecture materials,

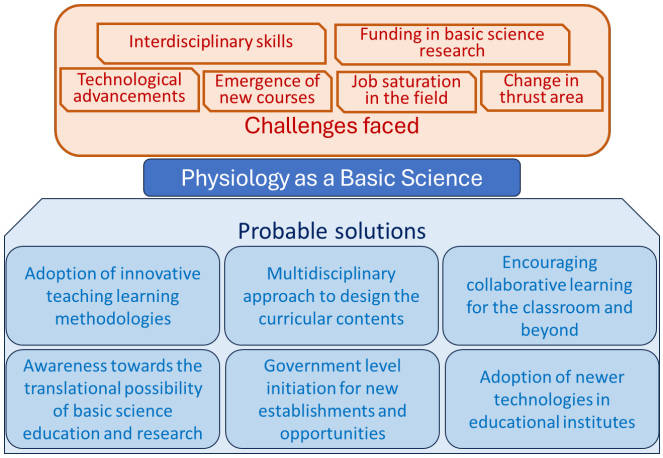

Figure 2: Challenges of physiology as a basic science and probable solutions

such as videos or readings, outside the classroom. Classroom time is then dedicated to active learning exercises, such as group discussions, problem-solving tasks, and hands-on experiments. This model fosters a more interactive and engaging learning environment, allowing students to apply and reinforce their knowledge collaboratively.

Active learning

This learning methodology has gained tremendous importance nowadays, especially in health care, physiology, law, etc, which involves engaging students in the learning process through activities and discussions. Techniques such as problem-based learning (PBL), case-based learning (CBL), and inquiry-based learning encourage students to apply their knowledge to real-world problems, promoting deeper understanding and retention.

Interprofessional education

Interprofessional education (IPE) involves training students from different healthcare disciplines together to promote collaborative practice and improve learning outcomes. This approach reflects the reality of modern healthcare, including the need for basic physiological knowledge in the healthcare systems, where teamwork and interdisciplinary collaboration are essential. In physiology education, IPE can involve joint sessions where medical, nursing, pharmacy, and allied health students learn about physiological concepts and their applications in a clinical context. This collaborative approach helps students appreciate the roles and expertise of different healthcare professionals, not only fostering a more holistic understanding of patient care but also igniting the young mind's curiosity to learn and explore.

Competency-based education

Competency-based education (CBE) focuses on the acquisition and demonstration of specific skills and competencies rather than time spent in the classroom. This approach emphasizes the development of practical skills and the application of knowledge to real-world situations. In physiology education, CBE involves defining clear learning objectives and competencies that students must achieve, such as interpreting physiological data, conducting experiments, and applying physiological principles to clinical scenarios. Assessments are designed to evaluate these competencies, ensuring that students are prepared for professional practice.

Any other methods like live examples, storytelling, or any methods based on personal experience that can stimulate the students' minds to generate interest, curiosity, and motivation toward a better understanding of physiological concepts are always welcome.

Besides the implementation of the new teaching-learning methodologies, it is the need of the hour to think and implement other aspects like a multidisciplinary approach of curricular design, collaborative work, and awareness towards the importance of basic research/education for the translational outcome, pushing up the Govt., via different professional bodies like The Physiological Society of India and alumni associations of the concerned subjects under different Universities/Colleges undergoing Physiology courses to open new establishments and also to adapt to the new technology.

CONCLUSION

Physiology serves as the bedrock of medical knowledge and practice. Its role in the medical industry extends across diagnosis, treatment, surgery, research, and public health, contributing to improved patient care, better treatment outcomes, and advancements in medical science. The integration of physiological principles into healthcare is essential for enhancing our understanding of the human body and improving overall health and well-being. Recent developments in physiology education have transformed the way we teach and learn about the functions and mechanisms of living systems. Technological innovations, such as VR, AR, and online learning platforms, have enhanced the accessibility and interactivity of educational resources. Pedagogical advancements, including active learning,

interprofessional education, and competency-based approaches, have improved student engagement and clinical competence. The integration of interdisciplinary knowledge has enriched the understanding of complex physiological processes and their applications in healthcare and research. These advancements have significant implications for the future of education and healthcare, promoting lifelong learning, enhancing clinical competence, advancing research and innovation, and addressing global health challenges. As physiology education continues to evolve, it will play a crucial role in training the next generation of healthcare professionals and researchers, ultimately contributing to the improvement of health and well-being worldwide.

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