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ENHANCING PHYSIOLOGY EDUCATION THROUGH INTERACTIVE COMPUTER-BASED LEARNING

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Abstract: Effective understanding of acid–base balance is essential for the formation of clinical thinking in medical students. However, traditional lecture-based instruction often provides limited opportunities for active engagement with this complex topic. The present study introduces an alternative educational approach based on interactive digital learning for teaching acid–base physiology to first-year medical students. Mobile-oriented computer modules were developed to facilitate step-by-step exploration of buffering mechanisms, regulation of blood pH, and the pathophysiology of acid–base disorders. The instructional design emphasizes visual representation, learner control, and integration of basic physiological principles with clinical scenarios. This approach aims to enhance conceptual understanding, promote independent learning, and improve the ability of students to apply theoretical knowledge to clinical situations.Traditionally, this topic includes an explanation of the CO_2–bicarbonate buffer system under normal physiological conditions, an overview of other major buffering systems of the body, and a physiological classification of acid–base disorders. These disturbances are commonly demonstrated using clinical examples. In the present project, the conventional lecture-based approach to teaching acid–base physiology for first-year medical students was replaced with interactive computer-based instruction designed mainly for iPads and other mobile devices. Three educational modules were created, each consisting of 20 information screens, covering the CO_2–bicarbonate buffer system, alternative physiological buffer systems, and acid–base disorders.

Key words: active learning, teaching methods, bicarbonate buffer system, training modules, students.

The developed training modules were based on interactive and active learning principles. Students were able to control the explanation of complex physiological concepts step by step, with most information presented in graphical form. In clinical scenarios, active learning was achieved primarily through question-and-answer tasks that connected clinical findings with core concepts of basic physiology. Student feedback was highly positive, and the interactive nature of the modules was highlighted as their most valuable feature. In recent years, medical education has increasingly emphasized active learning [1] and independent study [2]. Moreover, accreditation standards for undergraduate medical education require the incorporation of active and self-directed learning activities [3].The growing incorporation of digital technologies into medical education has fundamentally changed the ways in which theoretical and clinical knowledge are delivered to students. Electronic learning environments provide flexibility, accessibility, and opportunities for individualized pacing, making them particularly suitable for supporting modern educational paradigms that emphasize student-centered and self-directed learning. Despite these advantages, a substantial proportion of digital educational materials used in medical training continue to reflect traditional didactic models. In most cases, learners remain passive recipients of information presented through prerecorded video lectures, static slide presentations, electronic textbooks, and text-based instructional resources, offering minimal opportunities for interaction or critical engagement.

In recent years, several educational initiatives have sought to move beyond this passive framework by incorporating multimedia and interactive components into physiology teaching. Some of these efforts have focused on complex topics such as electrolyte balance and acid–base regulation, aiming to facilitate deeper conceptual understanding through visual and interactive representations. However, the scope and availability of such resources remain limited, and their integration into formal curricula is often inconsistent. As a result, the potential of digital technologies to promote active learning in medical physiology has not yet been fully realized.Advances in mobile and portable computing technologies have created new possibilities for enhancing the teaching of physiological processes. Modern tablets and laptops are capable of delivering sophisticated multimedia content, including animations, interactive diagrams, and real-time feedback, which can significantly improve the visualization of dynamic physiological mechanisms. These tools are particularly valuable for subjects such as acid–base physiology, where abstract concepts and regulatory processes can be challenging for students to grasp through traditional teaching methods alone.

Historically, the development of truly interactive educational materials required specialized programming knowledge and substantial technical resources, limiting such innovations to institutions with dedicated support teams. This constraint has represented a major barrier to widespread adoption of interactive e-learning solutions. Recently, however, the emergence of user-friendly instructional design software featuring graphical interfaces, modular templates, and menu-driven navigation has markedly reduced the technical complexity of creating multimedia educational content. These platforms enable individual educators to design, customize, and implement interactive learning modules independently, without the need for extensive programming expertise or costly technical assistance. Consequently, the integration of active, interactive e-learning resources into medical education has become increasingly feasible within routine academic practice.This paper outlines the development and implementation of interactive multimedia modules on acid–base physiology for first-year medical students. The entire project was independently designed and programmed by the author. Overall, the modules were very well received. Students identified interactivity and active engagement as the most significant strengths of this learning format. The modules were introduced during a 20-minute session in a lecture hall as part of a lecture on respiratory physiology, specifically focusing on CO_2 as a blood gas. Students were also introduced to the principles of e-learning and instructed on how to access the online acid–base materials via the university's electronic educational environment.The presentation was delivered three weeks prior to the final examination, which included topics on respiratory, renal, and acid–base physiology. Students were informed that the previously scheduled traditional lectures on acid–base physiology were canceled and that this material should be studied exclusively online. Acid–base physiology accounted for 14% of the final examination score. Each training module contributed three points, while each clinical case was worth one point. The questions related to clinical cases were intentionally straightforward and aimed to confirm whether students had engaged with the material. Module usage was monitored by tracking daily access requests. During the first week after introduction, no module usage was recorded, while increased activity was observed approximately one week before the examination. Students consistently identified interactivity as the most important advantage of online instruction in acid–base physiology. Therefore, it is essential for educators to understand the various forms and degrees of interactivity achievable in multimedia learning environments. A commonly cited framework is provided by the U.S. Department of Defense, which defines four levels of multimedia interactivity [5]. Level 1 corresponds to passive learning, where learners

simply receive information. Level 2 involves limited interactivity, requiring learners to respond to basic prompts. Level 3 represents more advanced interactivity, where learner responses influence the progression of content. Level 4 consists of real-time simulations with complex instructional pathways and learner responses.
At present, most online educational resources remain at Level 1 interactivity, including video lectures, presentation slides, text-based materials, PDF documents, and electronic textbooks. Student control is usually limited to basic navigation functions. In the described implementation, most interactions fell under Level 2 interactivity, incorporating direct prompts and responses. The author's software enabled a wide variety of interactive features, such as selecting specific areas on graphs, sequentially revealing information under student control, branching to supplementary screens, and flexible navigation throughout each module. Additionally, diverse question formats were incorporated, including true/false items, image and graph identification tasks, single and multiple-choice questions, dropdown selections, and open-text responses.
Detailed explanations and feedback were provided following each student response.
A more comprehensive interpretation of active learning emphasizes critical thinking and the application of knowledge to problem-solving. Although problem-solving was not a primary component of the introductory learning modules—since students were still acquiring foundational concepts—it was a central feature of the clinical case sections. In these cases, students were actively engaged in correlating clinical data with fundamental physiological principles related to the respiratory system, renal function, and acid–base balance.

Literature

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