CURRENT AND FUTURE IMPACT OF TECHNOLOGY ON PHYSIOLOGY EDUCATION

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There are at least three areas in which technology can impact education: teaching, learning, and assessment. Teaching, when viewed as communication of information, has been transformed by the technology revolution. Word processing, multimedia, distance learning, and access to the World Wide Web are some prominent examples. The impact of technology on learning, defined as knowledge or skill acquired by instruction or study, has been less dramatic, in part because of our limited understanding of cognitive processes. Some forms of assessment, the collection of evidence of learning, have benefited from technology, such as item analysis of multiple-choice questions. To be effective, the focus on instruction must start with the learner and, from there, consider what should be done to enhance learning. An emphasis on what is technologically appropriate, rather than what is technologically possible, will improve the quality of both teaching and learning.

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The process of education involves the acquisition of knowledge, skills, or attitudes by a learner. In formal settings, education is directed by an expert, who circumscribes the appropriate knowledge base. Physiology is generally taught in formal educational settings as part of a curriculum in a professional degree program. This paper will consider the evolving nature of physiology education and, in particular, the impact that technology promises for the future.

Formal education encompasses teaching, learning, and assessment. Teaching focuses on the activities of the instructor and is strongly influenced by the communications skill of the instructor. Technology can significantly impact instruction, improving the clarity of images presented, particularly with the developments in video and animation for showing time-dependent events. The impact of technology on learning, however, is more difficult to determine. Technology has improved aspects of assessment, particularly the item analysis of multiple-choice questions. Other aspects of assessment, such as oral or essay examinations, have not been altered by technology.

Cognitive research continues to expand our knowledge about the education process, mostly by examining the information processing and recall capabilities of the brain. This academic knowledge base, when combined with the more practice-driven educational models, has revealed a few generalities.

More is known than can be taught. One consequence of the information explosion in biomedical sciences is that our understanding of the workings of the body continues to be refined at an accelerating pace. Information management, an essential skill of the medical researcher, is equally important to the physiology student. Topics like microcirculation, which could be covered by a chapter or two in the early 20th century, are now in multiple-book volumes generated on an annual basis. It is not physically possible to teach all that is known about physiology, certainly not within one of the many courses in a professional program.

More is known than should be taught. Most research reports represent a refinement of our understanding of body function. Students, particularly those in professional programs, are better served by focusing on core concepts. Research should be introduced sporadically, mostly to communicate the fact that our understanding of physiology has resulted from experimental studies and that these studies are currently continuing to refine our knowledge. One essential role of a teacher, then, is to identify appropriate content. A benevolent viewpoint of this role identifies the teacher as a filter. A less charitable viewpoint of this action identifies the teacher as a barrier to learning.

IMPACT OF TECHNOLOGY

Technology allows the learner to circumvent the teacher and to access the information base directly. In prehistoric times (no, not before computers—before written history), the information base and the teacher were identical. Information was passed directly from an expert teacher to the novice learners, through demonstration or as part of an oral tradition.

The technology of written records, beginning with the cave wall writings during prehistory, created a paradigm shift. Information could now be separated from the expert, in both time and distance. Moreover, the information could be directly accessed (Fig. 1*B*), and the role of the teacher shifted to that of information creator and provider of the written records. This paradigm shift also expanded the role of teacher to include teaching students how to access the information—how to read and interpret the written records.

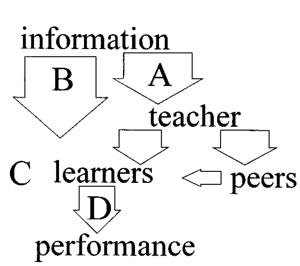

FIG. 1.
Impact of technology on teaching (*A*), information access (*B*), learning (*C*), and assessment (*D*).

As communications technology advanced, pictographs became letters or ideograms, collections of writing expanded into scrolls, and scrolls were gathered and stored in a central location, such as a library. The emergence of the Gutenberg printing press brought books into the hands of more people, and the information base continues to expand by typing, word processing, and electronic communication. Particularly in a university setting, information access is no longer a limiting aspect to learning.

Technology has dramatically improved our ability to communicate. The introduction of graphs improved written communication of complex topics. Photographs augmented the information presented in line drawings. Currently, the ability to store animations and movies on electronic ''texts'' allows communication of time-dependent events with greatly improved clarity and accuracy. The technological advances of the 20th century improved information transmission, and future improvements will likely provide additional incremental improvements.

To date, the impact of technology on learning (Fig. 1*C*) has been minimal. This may be partly because of our still-developing understanding of cognitive processes, such as how the brain sorts, stores, recalls, and interprets information. Until our understanding of cognition yields a technologically exploitable component, learning will continue relatively unchanged. One area that has provided useful insights about learning, however, has been the cognitive models.

BLOOM'S TAXONOMY

Cognitive models examine ways of ''knowing'' and provide a theoretical basis for educational approaches. In the 1950s, Bloom proposed an educational taxonomy, or a categorizing, of cognitive educational objectives (1). Bloom's taxonomy of educational objectives in the cognitive domain identifies six aspects of learning: knowledge, comprehension, application, analysis, synthesis, and evaluation. The impact of technology on teaching, learning, and assessment can be viewed within this framework.

Knowledge emphasizes factual recall, lists, and definitions. Teaching of factual material remains straightforward and has not been changed by technology. Technology can be used to facilitate learning through drill and practice, but the technology offers few advances over a flash card approach to memorization. Assessment of learning has been improved by the adoption of item analysis for multiple-choice questions, providing instructors with detailed information about the effectiveness of their assessment techniques (2, 3).

Comprehension requires an understanding of the relationship(s) between facts. Technology has improved our ability to communicate (teach) these relationships, particularly through the use of animations and video clips. The improved clarity of communication facilitates learning, but technology currently does not directly improve the ability of students to learn. Assessment using multiple-choice questions again has benefited from item analysis.

Application requires the use of general principles to solve a problem. In this instance, technology has improved learning rather than teaching. The technology of computer simulations allows students to apply their understanding to a new situation. The learning process is facilitated by having the students make predictions of outcomes before running the simulation, providing positive reinforcement if the predictions are correct and negative reinforcement and the opportunity for correction of the discrepancy if errors are uncovered (4). The ability of instructors to construct more sophisticated multiple-choice questions has opened the assessment of application to item analysis.

Analysis examines the ability to identify patterns of organization and relationships. The approaches to solving a problem differ between a novice and an expert and may form the basis for identifying improved analytical skills. Technology has had little impact on teaching or learning of analytical abilities, but improved testing in the future may allow the quantification of problem-solving abilities and the identification of expert problem solvers (5). Currently, assessment of analysis is better achieved through essay or oral examination formats.

Synthesis involves identifying novel relationships between objects or ideas. Again, technology has had little impact on the teaching or learning of this cognitive skill. The impact of technology on the execution, however, has been improved as a result of the use of data bases to search existing literature and to see whether the arrangement proposed by the learner is truly novel or duplicates existing work. Assessment of the outcomes is still best performed by the instructor (expert) evaluating the learner's product.

Evaluation is the judgment of worth based on external criteria. Technology has to date had little impact on the teaching, learning, or assessment of evaluation. This is in part because of the fact that the learner is assessed on the basis of the criteria the learner selects for evaluation as well as the application of those criteria.

CONCLUSION

The level of instruction for most general physiology courses emphasizes the first three of the cognitive domains: knowledge, comprehension, and application. Graduate research training emphasizes the analysis, synthesis, and evaluation cognitive domains.

The impact of technology on teaching centers on improved quality of information presentation. This is particularly notable for communicating time-dependent concepts using animation and video clips. The promotion of higher cognitive activity, however, remains unchanged by the current technological advances.

Technology impacts learning through greatly expanded information access and through structured exploration opportunities such as computer simulations.

Technology has allowed improvement in assessment by item analysis of multiple-choice examinations but has not impacted assessment of the higher cognitive skills associated with graduate-level education.

In summary, the role of instructor is no longer that of the sole source of information and has not been for many decades (if not centuries). Rather, the instructor must create an environment that enhances learning, must provide direction, and must model appropriate learning behaviors. The potential for technology to improve learning is significant, but few applications are on the horizon. As with most prognostication, only the future will tell whether the potential will be reached.

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