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Revisiting Michael's Framework for Physiology Education in the Age of Generative AI

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Abstract

Physiology remains challenging because students must integrate knowledge across multiple levels of biological organization and use mechanistic reasoning to explain body function. Nearly two decades ago, Michael's framework identified factors that make physiology difficult to learn. Since then, digital learning and generative artificial intelligence (AI) have changed the educational environment. This perspective revisits Michael's framework to examine which challenges remain, which have changed, and which new difficulties have emerged. Generative AI has lowered the barrier to obtaining explanations, feedback, and learning support, but it has not reduced the cognitive demand of constructing causal explanations. Factual recall remains necessary but insufficient. Students still need to develop mechanistic understanding and apply physiological principles. Artificial intelligence also creates new challenges in evaluating generated information, maintaining higher order thinking, and using AI responsibly. Three priorities emerge for physiology education. These are preserving mechanistic reasoning, developing AI literacy, and aligning learning and assessment with deep conceptual understanding.

Keywords: Generative artificial intelligence, mechanistic reasoning, medical education, physiology education

1. Introduction

Nearly two decades ago, Michael's perspective, *What Makes Physiology Hard for Students to Learn?* provided an influential framework for understanding difficulties in physiology learning. It identified factors related to the nature of physiology, teaching approaches, student characteristics, and influences beyond the classroom. The framework highlighted causal or mechanistic reasoning, integration across levels of biological organization, dynamic systems, graphical and mathematical representation, and the tendency to equate learning with memorization^{1,2}.

The educational environment has changed substantially since then. Digital learning, online resources, and generative artificial intelligence (AI) have changed how students access, generate, evaluate, and use information. Generative AI has also created new opportunities for personalized learning, feedback, teaching support, and assessment, while introducing challenges that were not part of Michael's original framework³⁻⁷.

This raises an important question. Has AI changed why physiology is difficult to learn, or has it mainly changed the environment in which students encounter these difficulties?

These changes are considered across the major areas identified by Michael. This perspective examines which challenges remain unchanged, which have been amplified, diminished, or transformed, and which new difficulties have emerged with generative AI. It also considers whether AI can make some existing challenges more manageable and what these changes mean for physiology educators.

2. Which of Michael's Challenges Remain Unchanged?

Two areas of Michael's framework remain particularly relevant. The nature of the discipline still requires causal or mechanistic reasoning, understanding of dynamic systems, and integration across multiple levels of biological organization. What students bring to learning also remains important, particularly their tendency to rely on memorization and their difficulty integrating physiological concepts across systems¹.

3. Which Have Been Amplified by Digital Learning?

Michael identified influences beyond the classroom as an important part

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of physiology learning. These influences have expanded considerably with digital learning, as students now have rapid and continuous access to large volumes of online and AI generated information. The challenge has therefore shifted from limited access to information toward selecting, evaluating, and using information appropriately^{1,5}.

4. Which Have Been Diminished?

Michael identified dependence on teachers and conventional learning resources as part of the learning environment. Digital learning has reduced this dependence by giving students access to explanations and feedback outside scheduled teaching. The limitation is therefore less about access to basic information and more about how students use and evaluate it^{1,5}.

5. Which Have Been Transformed?

The nature of teaching and learning beyond the classroom has changed substantially. Generative AI allows students to interact directly with learning content, receive personalized responses, and obtain continuous support, while the teacher's role increasingly involves facilitating, guiding, and verifying learning^{1,5,6,7}.

6. Which New Challenges Have Arisen Due to AI?

Generative AI introduces new challenges that were not present in Michael's original framework. These include judging the reliability of AI generated explanations, managing possible cognitive offloading, maintaining assessment validity, and developing the AI literacy needed for critical and responsible use of these technologies^{1,5,6,8,9}.

7. Can the Original Problems be Better Managed by AI?

Some difficulties identified in Michael's framework may now be more manageable with additional learning support. AI can provide personalized explanations, immediate feedback, language support, and opportunities for practice, potentially helping students understand and apply physiological concepts. For students learning physiology in a non-native language, AI can provide simpler explanations, translation, and repeated clarification, potentially improving access to learning support. However, these benefits do not remove the intrinsic cognitive demands of physiology or the need to develop mechanistic understanding^{1,6,7}.

8. Does AI Fundamentally Alter the Relationship Between Learner, Teacher, Content, and Assessment?

Generative AI has redistributed specific educational functions across learner, teacher, content, and assessment. For the learner, AI can provide explanations, generate practice questions, give immediate feedback, and support self-assessment. For the teacher, AI can assist with generating learning materials, questions, and formative feedback, while increasing the need for teachers to interpret, verify, and contextualize AI generated content. For content, information is no longer limited to teacher selected or textbook material because students can interact with AI to generate explanations, examples, comparisons, and alternative representations. For assessment, AI can generate responses to conventional tasks, while students can use it to check and refine their work, increasing the need for assessments that demonstrate independent reasoning, application, and justification. Thus, AI has not replaced any of these educational elements. It has redistributed some functions previously concentrated within the teacher, learning resources, and assessment toward greater interaction among the learner, AI, content, teacher, and

assessment^{1,5,10}.

9. How Should Physiology Educators Respond?

The continuing relevance of Michael's framework suggests that the primary goal of physiology education remains unchanged. Students must develop mechanistic reasoning, integrate concepts across physiological systems, and apply their knowledge to explain normal and altered body function. AI should therefore be adopted when it strengthens these educational outcomes rather than simply improving efficiency or expanding access to information^{3,4}.

Revisiting Michael's framework highlights three priorities for physiology education in the AI era. First, mechanistic reasoning should remain the central learning outcome. Meaningful understanding depends on explaining physiological processes rather than recalling isolated facts. AI should support this reasoning rather than replace it.

Second, AI literacy should become an essential graduate attribute. Students should learn to evaluate AI generated explanations, verify information using reliable scientific sources, recognize the limitations of AI systems, and use these technologies responsibly. These competencies will become increasingly important as AI becomes integrated into healthcare and biomedical practice⁵.

Third, learning and assessment should emphasize understanding, integration, and application rather than factual recall alone. Learning activities should encourage students to use AI for exploration, reflection, and self-assessment rather than as a source of final answers. Assessment should place greater emphasis on authentic tasks that evaluate mechanistic reasoning, integration of physiological concepts, clinical application, and justification of decisions. Although AI can support learning and formative assessment, summative assessment should continue to evaluate competencies that require human understanding and professional judgement⁶.

Teachers remain central to achieving these priorities. AI can strengthen educational practice, but its use should remain guided by human judgment and educational goals. Together, these priorities provide a practical framework for integrating AI while preserving the fundamental principles of physiology education¹¹.

10. Conclusion

Nearly two decades after Michael's perspective, the educational environment in which physiology is learned has changed substantially. Students can now obtain, generate, and evaluate information through digital resources and generative AI. Artificial intelligence has also changed how students interact with learning content, receiving feedback, and engaging with educational activities.

What has not changed is the fundamental intellectual task of physiology. Students still need to explain biological function through integrated causal mechanisms, connect processes across physiological systems, and apply physiological knowledge to unfamiliar situations. AI has changed how students access and work with knowledge, but it has not reduced the need to understand physiology.

Revisiting Michael's framework therefore shows continuity within change. AI has changed the epistemic environment of physiology education, but it has not changed the fundamental intellectual task of physiology.

Disclosure of AI Use

During preparation of the manuscript, ChatGPT (OpenAI, GPT-5.5) was used to assist with language editing and to improve clarity, grammar, and readability. The author critically reviewed, revised, and verified all content generated with the assistance of the AI tool and accept full responsibility for the accuracy, interpretation, and originality of the final manuscript.

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