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What determines the physiology that students learn?

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Macknight ADC. What determines the physiology that students learn? Adv Physiol Educ 43: 172–174, 2019; doi:10.1152/advan.00035.2019.—Modern technologies enable us to engage students in learning in innovative ways. This article discusses ideas about how we can use these technologies to provide efficient, effective, everlasting, and exciting learning—the 4 E’s of tomorrow’s education.

INTRODUCTION

When asked the question that is the title of this talk, the immediate response from any teacher will be, “The exam questions.” How many times have we been asked at the end of a lecture, where we think we’ve told the students something really interesting, “Will it be in the exam?” So, undoubtedly, the exam, and passing it, dominate student’s thinking.

But there is another aspect too, that influences what students learn, and that is the content and how and where we present it. Modern technologies are providing us with tools to revolutionize learning, and the student today is equipped to use these technologies and eager to do so.

To deal with content first. We are lucky in physiology that, for students starting the study of our subject, there is really not a lot of debate about what the content should be. In a brief and subjective evaluation of the content of some standard physiology textbooks, I found that all cover the same topics. Whether it is a 300-page book or a 1,200-page one, the proportion of the space devoted to the different topics is very similar, and the variations appear to reflect more the interests of the authors than any fundamental disagreements about the importance of the topics. Not surprisingly, the two biggest areas covered in these textbooks are cardiovascular system and the central nervous system (CNS). The greatest variation is in the space devoted to endocrinology that, in one instance, is greater than the space allocated to the CNS. So it seems safe to conclude that there is general agreement on the material that should be included in a first-year physiology course, and we won’t discuss content further.

Much more important then, is how and where we present the content. We should have four goals in mind, the 4 E’s of learning. First, learning must be “efficient,” both for students and for teachers. Students don’t appreciate having to spend what for them seems unnecessary time, trying to sort out muddled presentations, and teachers don’t want to spend additional time repeating what they have already presented.

Second, learning must be “effective.” By which I mean that it should lead to an understanding of the material and the ability to use it to solve problems, rather than simply rote learning to pass exams.

Third, it should be “everlasting.” The understanding of the subject should remain with the students long after the course has finished. So again, we need to provide learning opportunities that focus on concepts and principles, not the regurgitation of “facts.” “Facts” are all around us now. Making sense of these “facts” is the challenge that we face.

And fourthly and last, learning must be seen to be “exciting.” Unless students actually want to learn and enjoy the learning, nothing else we do will be successful in achieving our first 3 E’s.

So let’s explore now how we can generate efficient, effective, everlasting, and exciting learning. To provide a quality education, what we deliver must be engaging and authentic.

By engaging, we mean that the students must be engaged in the learning process and not viewed simply as “receptacles” for knowledge—there must be “active learning.” Active learning is very much in vogue at the moment, and one could be forgiven for thinking that it is a relatively new idea. But rather it is being rediscovered as this quote from Sophocles, Trachiniae (5th century BC) attests, “One must learn by doing the thing, for, though you think you know it, you have no certainty until you try.”

By authentic, we mean that what the students are learning has to have meaning to them as individuals, as members of society, and in their future work: the learning must be “contextual.”

So how do we design our courses so that the students are engaged and have what is, for them, authentic experiences? We now understand better than ever how people actually learn, and we need to use that knowledge in designing the way we structure our courses and present material. We take material into our working memory and process it there, rehearse it, and link it to the knowledge that we already have in our long-term memory. We must provide the time and the material for these steps to occur. A key to designing our courses is the realization that working memory is very limited and easily overloaded. Sitting in a lecture and listening to someone talk for 50 min is guaranteed to overload our short-term memory and, if learning is our desired outcome, is counterproductive.

From what we now know about how people learn, the material we create should:

1. Motivate the students
2. Build on what they already know
3. Make them demonstrate their current knowledge before they see the instructor’s feedback
4. Provide instant, quality feedback
5. Provide repetition to rehearse the information they are learning
6. Provide contextual material
7. Allow students to learn at their own rate in their own time
8. Provide opportunities for group work

Let’s look at some of these points in more detail. First, motivation is essential: an unmotivated student will never learn efficiently or effectively and will certainly not gain everlasting knowledge or find the learning exciting. Motivation comes back to this idea of authenticity. Students need to believe that what they are learning is important to them, not simply to us.

Second, building on what the student already knows is also essential. We are lucky in physiology in that students have got to know their own bodies and how they react and respond over years before we meet them. They may not be able to tell us things in the “correct, physiological jargon,” but they do know what happens when they exercise and eat and sleep, get a fever, and breathe. It’s important that we build on this knowledge and give them opportunities to tell us these things before we tell them (point 3 above).

Our fourth point relates to feedback. We’ve all had the experience of taking a test, wondering how we did and what the answers to questions 3 and 5 were as we finish the test. But, by the time we get our results back a week (or more) later, our thoughts have moved to other things, and the learning that we might have achieved, had there been prompt feedback, is lost.

Our fifth point recognizes the importance of repetition and rehearsal when we take information into our short-term memory and process it there. It’s important to reinforce the learning by additional questions that allow the students to use what they are learning as they study it.

Our sixth point we have already considered. We must learn in the context in which we will use the material. Otherwise, when we do need it in the future, we won’t be able to retrieve it from our long-term memory.

The last two points are very important, but in the past often ignored. Every one learns at a different pace. People need to be free to learn when they want to and where they want to. And learning together with your peers is one of the most effective ways we have for students to sort out any difficulties in their knowledge and understanding.

Many of us would say that most students when they first arrive at tertiary institutions don’t know how to study. Opening a book after dinner and falling asleep while reading it is unlikely to be either efficient or effective. And doing the same every evening in the hope that, if you do it enough times, magically you will know enough to regurgitate in the exam is not guaranteed to give you your desired outcome.

So, one task we have is to change the way that students learn. To do this, we first have to trust the students. By this, I mean that we have to create a partnership with them in which instructors and students both understand exactly why the course is different from what they are probably used to, and a recognition by them that learning in this way will actually be more efficient and effective, as well as everlasting and exciting.

And in this, we have to provide the right motivation for learning, showing the students how they will use what they are learning in their future lives and careers.

Fortunately, all this is much easier now, for the new technologies we have are allowing us to revolutionize the way we deliver material to our students. In particular, it is now so much easier using these new technologies to make their interactions with all material we give them truly active learning.

However, much of the use of these new technologies is ineffective. Let’s look at what is now available online. The textbook I used to read is now there. But does reading it from the screen really help me to learn better than reading from the printed page? I used to get up and attend lectures. Now my university has said that all lectures must be recorded and put in the University Learning Management System (LMS), so, of course, I don’t attend lectures any more. Instead, I play the lecture at double speed on my computer, maybe several times if I’m a rote learner. Is this more effective than sitting in the lecture theater with pen and paper making notes as the lecture progresses? In fact, in my “revolutionary course,” there’d be no lectures of this type anyway. Then there is the question of illustrations and diagrams. Do you learn the information you need from simply looking at a diagram? And are complex diagrams actually useful for learning anyway? There is certainly no shortage of complex diagrams on the internet, as Google Image is readily able to demonstrate on any topic you care to name. And all of the above is passive learning. So simply putting a video of my lecture and my PowerPoint slides on the University LMS is not facilitating active learning.

So what would I do differently now? If I were now designing a course in any subject, these are the things that I would do. My course would be a blended learning course build around cases or problems. The initial presentation of the case or problem would be to small groups and designed to motivate and excite the students. “Let’s find out together what is really going on here in the physiology that can explain the person’s problem.”

I’d decide what material was best studied online so that the precious contact time with the students was used to maximal effect. The focus would always be to provide understanding of the important concepts, not simply providing facts. Having made that decision, I would deliver this online part of the course using a flexible platform that allowed material to be presented as questions.

Here’s an example. I could give students this to read:

“Chemoreceptors are sensory organs that are stimulated by specific chemicals in their environment.

“They are responsible for the sense of taste, or gustation, and smell, or olfaction. Besides those involved with taste and smell, other chemoreceptors are distributed throughout the mucous membranes, the gut where they respond to products of digestion, and the upper respiratory system, where they detect the presence of certain irritating substances.

“The chemoreceptors for gustation and olfaction are similar in that they both are able to sense the identity and concentration of molecules to which they are sensitive, and both transduce this information into nerve action potentials that travel to the CNS and reach consciousness.”

But, increasingly, student are averse to lots of text to read, and, however well written, simply reading anything instructional is inherently boring to them.

So instead, I would give them this to do.

For each of these statements, decide which are correct and which are incorrect.

“Chemoreceptors are sensory organs that are stimulated by specific chemicals in their environment.”
“Information received by chemoreceptors is transduced into a chemical signal.” “They are responsible for the sense of taste, or gustation, and smell, or olfaction.” “They are found in mucus membranes.”

“They are found in the gut and upper respiratory tract.”

“They detect the presence of certain irritating substances.”

“They sense the identity and concentration of chemicals in general.”

So now the student reads and thinks about each of these short statements to decide which are correct and which are incorrect. Having made their decisions, the platform gives them immediate feedback about which they got right and which they got wrong and then, as part of the answer, gives them the text to read that is reproduced above. But now, the student reads this text in a very different way. Without the question, it is just a series of words that we try to visualize, understand, and remember. But, after attempting to answer the question, we read it looking to see if our ideas were correct or not. We are reading it now with a purpose. Note also that we read the major points twice: once to answer the question, and a second time to see how our ideas matched with the answer provided. So we are reinforcing our learning through repetition.

Now what about images? Conventionally, our textbooks and lectures contain images that the student may or may not look at. But how do you “learn” an image? Well, with our new technologies, it’s simple. You interact with it in some way. Maybe you have to label it, or you have to circle a particular part, or you have to place a “pin” on the structure you are asked to identify. And images are particularly good in helping students to retrieve from their long-term memory information they already possess. So, in my new course, students would be given lots of images that they had to interact with. And never any images that they did not do something with.

So, in summary, my approach here to the online component of the course would be:

• Keep text to a minimum on the page.
• Wherever possible, turn every important point into a question.
• Use a wide variety of question types.
• Provide the essential information in the feedback to the question.
• Never use a diagram that students do not actively interact with.
• Only provide information that leads to better understanding of an important concept.
• Break down every lesson into a logical progression: don’t leave out steps.
• Say the same thing different ways (if possible) several times.
• Test understanding on each page with more questions.

So that’s the online component that I’d encourage students to do, not alone, but working in a small group with their friends. Obviously, this online component would be designed to allow the students to obtain knowledge of the fundamental physiological concepts and principles that they need for an understanding of the case or problem.

Then, having completed this online component, I’d have the students together again, in what used to be lecture time, for group activities and discussions, the “flipped classroom” approach. Finally, it would be back to the small groups to wrap up the case and, at that time, to make physiological measurements on themselves, where possible, of exactly the same parameters that were measured in the case or problem. So students would record their ECGs or respiratory variables or autonomic nervous system parameters, etc., and compare their results with the findings in the case.

In summary, the new technologies made possible by computers, the internet, and the cloud are revolutionizing how we can facilitate student learning. The opportunities we now have to enhance learning and understanding free us from the conventional model of tertiary education that evolved over the last 600 yr and make this the most exciting time in education since the invention of the printing press.

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AUTHOR CONTRIBUTIONS

A.D.C.M. conceived and designed research; drafted manuscript; edited and revised manuscript; approved final version of manuscript.