HOW CAN WE HELP STUDENTS LEARN RESPIRATORY PHYSIOLOGY?

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Why should it be necessary to devote a whole morning’s session to teaching respiratory physiology? The general concepts underlying respiratory physiology are not new to students. They have encountered them many times in their lives in a variety of contexts. They encounter and have experience with elastic structures throughout their childhood, from using pacifiers as infants to playing with balloons as children and engaging in sports that use various types of balls (e.g., tennis, soccer, volleyball, basketball, football) to taking advantage of the recoil characteristics of rubber bands. Popular children’s books contain examples of reservoirs, illustrating steady-state mass balance relationships (5). All through their childhood, students encounter examples of pressure-flow relationships; they use garden hoses, blow horns, and squeeze toothpaste from a toothpaste tube. They also encounter numerous examples of control systems, and they learn about diffusion and chemical interactions long before they arrive in our classrooms.

In fact, students are often first introduced formally to ideas related specifically to respiratory physiology as early as the first grade. Figure 1 shows the report of a first-grade student whose classroom assignment was to tell what the class learned about the day before. The report indicates that the previous day’s discussion included aspects of pulmonary anatomy, gas exchange, and pulmonary mechanics. So students are well on their way toward developing a knowledge base in respiratory physiology at a very young age.

When students finally arrive in our classrooms, we have aids to help them organize their knowledge base into functional models of the respiratory system. In 1962, Comroe and his colleagues (1) presented simple pictorial representations of models of gas exchange and mechanics that were very helpful in conceptualizing the principles and relationships involved in respiratory physiology. These illustrations, examples of which are shown in Fig. 2, were so helpful that they are still used, some 35 years later, as the templates for many illustrations in current texts.

Despite all this prior knowledge and the clarity of our models, students have a very difficult time translating what we tell them into functional models that they can use for solving problems related to the respiratory system. Obviously we are doing something wrong when we teach respiratory physiology, or we are not doing something that we should be doing.

Why should we devote a session to teaching respiratory physiology? The answer is clear. Many students still seem to have more difficulty understanding the physiology of the respiratory system than they do any of the other organ systems, and until this situation is remedied, we must examine why our attempts to help students learn fall short of reaching our educational goals. In this communication, I would like to raise some relevant issues that, I suspect, some faculty may have reflected upon, but that most faculty have not yet considered regarding how we talk about respiratory physiology and how we approach the classroom.

The title of this presentation is “How can we help students learn respiratory physiology?” rather than “How can we best teach respiratory physiology?” In my mind, there is a critical difference between these two questions, and that difference is that, in the first question, the primary focus is on the student and his or her learning. Unfortunately, in most discussions of teaching among physiologists, the focus seems to be more on the presentation of information rather than the specific needs of the students. Let us explore some issues facing students in respiratory physiology, and then, I would like to propose an approach to dealing with these issues.
WHY IS RESPIRATORY PHYSIOLOGY DIFFICULT FOR STUDENTS?

Certainly the difficulties do not arise from the complexities of the underlying concepts. As we have already noted, most of these concepts are not new to students, and they have been able to deal successfully with them in other contexts. But we tend to obscure the familiarity of these concepts by introducing the concepts with an elaborate set of symbols and abbreviations. Upon opening any textbook of respiratory physiology or examining the respiratory section of a general physiology book, one of the first things that the student encounters is an extensive table of symbols and abbreviations. Most of these abbreviations and the conventions governing their use were adopted following a meeting of respiratory physiologists intended to establish standard terminology (4), but they are far from standard for the student who has not only never seen them before, but who, more than likely, just finished cardiovascular physiology, where many of the same words (e.g., blood flow, cardiac output, blood volume) are associated with a different set of symbols.

The problem gets worse for the student because, with the continuing trend toward use of acronyms and abbreviated speech, communication has been reduced to “buzz” words. For example, the student no longer reads about inspiratory and expiratory neurons, words that they can associate directly with an action. Instead, they read about the more abstract “I neurons” and “E neurons.” Furthermore, there are two types of I neurons, “I alpha” and “I beta” neurons. The authors have, of course, defined these terms the first time that they are used. However, when the student reads the text, the label is most likely read as a label rather than a concept (i.e., I neuron rather than inspiratory neuron). In addition, some of these abbreviations resemble different abbreviations used in other contexts. While this is not a source of confusion for the physiologist who is focused on his or her area of expertise, it confuses students who have recently been introduced to other areas of physiology and who, more than likely, have not really mastered any of them. For example, the student may wonder how these “I alpha” neurons relate to the “type Ia” nerve fibers that they were told about when they read about muscle spindles. After all, they are both neurons, and they are designated in the reading with the symbol “I.” At this point, students have several options. If they want to gain an understanding of the topic, they can continually revisit previous pages seeking the first use of the abbreviations, but this can become tedious and distracting as the number of abbreviations increases. Another option is to memorize the relationships involving the abbreviations without attaching any meaning to them. Yet another option is to stop reading altogether and adopt the attitude that, “If I wait until class, the instructor will tell me what I need to memorize to pass the exam.”

Another source of confusion and student stress related to respiration seems to be the quantitation associated with respiratory physiology. We want our students to
Static Relationships

Dead Space

Ventilation-Perfusion Maldistribution

FIG. 2.
Conceptual aids presented by Comroe et al. (1) that have become “standard” in presentations of respiratory physiology. (Reprinted with permission from Ref. 1.)
understand steady-state mass balance relationships. Yet, when we show relationships, we present equations without presenting the underlying concept (that is, in the steady state, the amount of mass entering a “compartment” per minute must equal the amount of mass leaving the compartment per minute). Furthermore, we show more abbreviations and symbols that lead to memorization and confusion rather than understanding. The mass balance equations applied to alveolar and mixed expired gas deal with the same concept, only the location of the “compartment” is different. However, the student interprets the different subscripts indicating the different compartments as constituting two very different sets of equations.

The first step to helping students understand respiratory physiology, then, is to explain the mechanisms in “everyday” English. In this way, students can draw on their previous understanding and vocabulary to build their mental models of the system in their own set of words. Having established an understanding in their own frame of reference, it is a small step to introduce our labels and jargon. However, most faculty will report that they are explaining mechanisms using everyday language and common analogies. For example, many faculty use balloons when they talk about elastic structures. Faculty will also report that taking this first step doesn’t remedy the apparent problems the students have understanding the simplest of concepts. Hence, while potentially helpful, minimizing jargon and trying to relate the physiology to the students’ previous knowledge and mental models do not solve the problem. So, what is the answer?

To solve the problem, we must gain a better understanding of the problem. To do this, we must have a better understanding of our students. Our students come to us with varied backgrounds and various levels of understanding. Some of this understanding is based on appropriate models of the system, but some is based on inappropriate models of the system. If we start with the first grader’s report shown in Fig. 1, we can see how the seeds of inappropriate models, that is, misconceptions, may be sown. The student said that she learned that, if you squeeze a sponge, all the water will come out and if you don’t squeeze the sponge, it will fill with water just like the lungs. Does this mean that when we breathe, we first force out gas, that is, squeeze the sponge, and then relax, don’t squeeze the sponge, to draw air into the system?

The first grade student also remembered that you breathe out corvindoxi. Later on in this young person’s education, she received clarification of this. She was taught that we eliminate carbon dioxide through the lungs. If we eliminate it, how can there still be carbon dioxide left in arterial blood? It has been eliminated, it’s gone!

The student was also taught that oxygen is delivered to the tissues by arterial blood. If the blood picks up the oxygen in the lungs and delivers it to the tissues, there must not be any oxygen left in venous blood.

**WHAT’S IN A WORD?**

Students learn that blood participates in gas exchange. “Exchange” is an essential word in the respiratory physiologist’s vocabulary. What does the word, exchange, mean to the student? The dictionary definition of “exchange” is to transfer one thing for another thing in return. We exchange currency, receiving an equivalent valued foreign currency for US currency. We exchange sweaters at the store, receiving a blue sweater in exchange for a green sweater or a large sweater in exchange for a medium sweater.

What model emerges from the use of the word “exchange”? We continually encounter students who, even after transport mechanisms involving hemoglobin have been discussed, believe that oxygen and carbon dioxide compete for the same binding site. Hemoglobin “exchanges” oxygen for carbon dioxide. Obviously this must involve the same carrying site. We continually encounter students who, even after discussing the gas exchange process, believe that if alveolar PO2 increases, alveolar PCO2 must decrease regardless of the mechanism by which the PO2 change came about. Ask these students what happens to alveolar PCO2 if the inspired gas is switched from room air to 100% oxygen. They will tell you that PCO2 decreases because “exchange” implies a coupling, and if something is exchanged for something else, they must move in opposite directions. So if oxygen goes up, carbon dioxide must go down.
AN EXPERIMENT

Consider another example. Show students (or colleagues, for that matter) a rubber tie-down strap, easily purchased at a home improvement or auto supply store, and a length of waistband (e.g., as found in underwear) material purchased from a fabric store. Ask which item is more elastic. The answer that is offered depends on interpretation of the word elastic. Is something that is "more elastic" more "stretchable" or less "stretchable"? According to the physicist, something that is elastic exhibits recoil. The more elastic something is, the more recoil it exhibits. The rubber strap is more elastic. However, according to the clerk at the fabric store, and according to most students (and some colleagues), something that is elastic is stretchable, and the more elastic something is, the easier it is to stretch. The waistband material is more elastic. Is it any wonder that students have a difficult time with respiratory mechanics?

All of these examples have, to one extent or another, depended on interpretation of language. They illustrate why it is important to choose language carefully and why it is critical that we interact with students to make sure that their interpretation of our language is the same as our interpretation.

OTHER SOURCES OF INAPPROPRIATE MENTAL MODELS

Are there other sources of potential misconceptions that students encounter before they come to our classrooms? The answer is, "Of course!", and the inappropriate models that they form are reinforced in their everyday lives. Figure 3 shows an excerpt from an article that appeared recently in The Seattle Times (3). The article clearly tells the reader that lung tissue is very elastic (easily stretched or exhibiting considerable recoil?) and that it stiffens as a result of emphysema (more recoil?). The article goes on to tell the reader that lung-reduction surgery allows the remaining lung to expand more, increasing its elasticity, but increased elasticity means increased recoil. What impact do this and other descriptions of physiological relationships encountered in the media have on the mental models that our students bring to our classrooms?

Before students arrive in our classrooms, they have formed very definite ideas about how the respiratory system works. They have formed these ideas from experiences in school, from exposure to information in the media, from experiences with friends and family, and from interpretation of language in all of these settings. Some of these models are appropriate, many are not. When students arrive in our classrooms, few of us recognize that these preexisting models exist, or we ignore them and assume that by telling students about the way things really are, they will correct their models.

How good is the assumption that students will correct their faulty models as a result of faculty lectures and course exams? Diane Halpern, chair of the Psychology Department at California State University at San Bernardino, addressed this problem in an article that appeared recently in the Chronicle of Higher Education (2). An excerpt from her article follows.

If you like horror stories, this one should terrify you: In a random telephone survey of more than 2,000 adults, conducted by the Public Opinion Laboratory at Northern Illinois University, 21 per cent of the respondents said...
they believed that the sun revolved around the earth; an additional 7 per cent said they did not know which revolved around which.

I have no doubt that virtually all of these adults were taught in school that the earth revolves around the sun; they may even have written it on a test. But, in fact, they never altered their incorrect mental models of planetary motion because their everyday observations didn’t support what their teachers told them: People see the sun “moving” across the sky as morning turns into night, and the earth seems stationary while that is happening.

Students can learn the right answers, even recite them in class, and yet never incorporate them into their working models of the world. The objectively correct answer that the professor accepts and the student’s personal understanding of the world can exist simultaneously, each unaffected by the other. Outside of class, the student continues to use the personal model because it has always worked well in that context. Unless professors address specific errors in their students’ naive models of the world, the students are not likely to replace their own models with the correct one promoted by the professor.

I would go a step further than Dr. Halpern and say that, unless we force students to test their models of the world, they will not recognize their errors and will not even attempt to correct them.

SOLVING THE PROBLEM

If we want to help students learn respiratory physiology, we must recognize that students have preconceived notions of how the respiratory system works and that many of these notions are based on a teleological view of the world. We must also recognize that the language that we use on an everyday basis may not have the same meaning to students as it does to us. So, how can we meet this challenge? How can we address the specific errors in our students’ naïve models of the respiratory system, and how can we address different interpretations of the language that we use?

The answer is that we must transform our classrooms into active learning environments. We must carry on a dialogue with our students. Normally, we wait until a student asks a question, and we answer the question based on our interpretation of the language that they use. But what we hear does not always reflect the student’s intent. We need to seek clarification from us. We need to ask questions, and we need to listen to the students’ answers. The interaction provides us with an opportunity to learn more about the student’s mental model. In this way, we can arrive at a common understanding, and the class, as well as the student asking the question, benefits from the interchange.

For example, I am responsible for the respiratory section of the physiology course that dental students and nursing graduate students take at the University of Washington. Early in the discussion, before we get to the topic of alveolar PCO₂, it is common for a student to ask what happens when we hyperventilate. Before I attempt to answer the question, I ask the student, “What does hyperventilation mean to you?” Last year, the questioning student told me that hyperventilation is when the body needs more oxygen (a teleologic view) and so your ventilation increases (a common, but erroneous interpretation of hyperventilation). This year, a student answered the question by saying that hyperventilation is when you breathe into a bag. By interacting with the student in this way, that is, asking him or her what the words mean to them, I learn more about the student’s misconceptions, and, to some extent, I can begin to address them. This also benefits other students who may hold a similar view or who do not have confidence in their mental models.

In addition to this questioning type of interaction, we must also encourage students to test their mental models. For it is only through this testing process that students can recognize the limitations of their models and correct them. There are many ways that we can do this in the classroom. We can present students with an observation and ask the student to explain what led to the current situation. Many people use clinical cases in this way. We can ask the students to make predictions about how the system will behave if it is perturbed. Another way of uncovering misconceptions is to ask students to explain aspects of familiar phenomena (e.g., exercise, going to altitude).

In each case, we, as facilitators of learning, must carry on a dialogue with students, we must listen to what our students are saying, and we must seek clarification so that we can better understand their needs with respect to learning. We are faced with a formidable challenge, and if we expect to help students learn...
respiratory physiology, or anything else for that matter, we must recognize that they have prior knowledge, that this prior knowledge may be faulty, and that communication is often limited by the language that we use. We must also learn from our students. We must learn how they interpret our language. We must learn about their mental models and how they apply them. In short, to help students learn, we must learn more about what kind of help they need. The only way we can do this is to carry on a dialogue with them.

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