Criticizing Models as a Strategy to Help Students Understand Hemodynamics and Develop Their Critical Abilities

In education, models and analogies are developed to help in making it easier to understand physiological concepts. The effectiveness of the chosen model depends to a great extent on the capacity of the analogy to transfer understanding from frames that are familiar to the student to the new concept (3). Analogies may also have shortcomings and may give rise to misconceptions in the student’s mind (2); however, these shortcomings can be turned to an advantage when they are used with the intention of provoking an active reaction from the student, thereby increasing the students’ interest in the subject. The method of critically studying an analogy is described here with the aforementioned considerations and pursues two objectives: 1) to help in learning physiological concepts and 2) to try to develop the ability in the student’s mind to use “a critical view.” The example studied here is the basic laws governing hemodynamics. Common analogies used to explain hemodynamics are Ohm’s electric law or hydraulic circuits (2, 3). A different analogy is presented here, which we have found easier for the students to criticize. The analogy is based on the supposed behavior of the students coming into the classroom as if this flow were a fluid.

Scope of the application and materials used. We use this strategy during the course together with other active learning strategies to encourage participation by the students (1). There is no requirement for sophisticated media to present the information to the students, as the main tool for visualizing the analogy is their own imagination, but some graphic aids may be helpful in engaging their attention.

Methods. The session begins with a brief description of the objectives and a presentation of the formal laws we are going to study. The analogy is then explained in detail. In the next step, the formal law is revisited, but it is now explained with its meaning and limitations, providing the students with hints for finding the faults and comments that they will use in the last step of the strategy. This part, which follows on without loss of continuity, is where students are asked to make a critical assessment of the analogy. They describe and discuss what discrepancies they find and what misconceptions, in their opinion, the analogy may provoke compared with the law. If we have enough time, we introduce traditional analogies (Ohm’s law and hydraulics) at this point to compare their strengths and failings.

STEP 1: OBJECTIVES AND DEFINITIONS. The objectives are as follows: 1) to learn the physical and physiological basis of blood circulation and 2) to acquire a minimal ability to make a critical assessment of an analogy.

Hemodynamics is defined as the study of the relationships among pressure (P), viscous resistance to flow (R), and blood flow (Q) in the cardiovascular system (2). In the first approach, the bulk flow law is defined as \( Q = \Delta P/R \), where \( \Delta P \) is the pressure gradient in the circuit. The viscous resistance of the blood is defined as \( R = 8\eta L/r^4 \), where \( r \) is the radius of the tube, \( \eta \) is the viscosity of the blood, and \( L \) is the length of the circuit. When the equations are combined, we have Poiseuille’s law: \( Q = \Delta P/r^4/8\eta L \).

STEP 2: THE ANALOGY. The flow of students coming into the classroom depends on the behavior of the whole group of students, as if it were a fluid composed of students. They are then able to imagine that the “pressure” exerted over a given student to come to the classroom to hear this lecture is psychological and depends on the motivation to come. On the other hand, the resistance that the student feels as s/he moves along this path is merely physical and depends on the physical route to the class. The initial pressure of the fluid can be explained as follows: students at home feel a strong motivation to come to class, as they know how motivating our physiology lectures are. As the students approach the classroom, they come up against more and more distractions, and some of them will feel less compelled to come to the lecture. Thus, the driving force for them will be the difference between the greater initial motivation and the effect of the distractions. Now, we turn to the resistance, which physically hinders the flow into the classroom. They have to imagine the physical path to the classroom as though it were a corridor. The resistance opposing the flow of students through the corridor depends basically on three factors: the viscosity of the fluid and the length and radius of the tube or corridor. To visualize how viscosity can change in a moment, we ask them to imagine themselves inside the corridor walking normally as part of the fluid. Suddenly, all of them raise their arms to shoulder level at the sides; at that instant, the viscosity of the fluid is increased, and the fluid proceeds with difficulty. Physical dimensions also influence resistance: the longer the path, the harder it is for people to reach the classroom. Conversely, the wider the corridor, the easier it is for a given quantity of people to go through, and minor changes in the width will greatly modify the flow (\( r \) is raised to the fourth power).

STEP 3: THE LAWS REVISITED. The parameters and usual assumptions and limitations of the law are described at this point: i.e., Poiseuille’s law is valid for straight, rigid tubes that contain a fluid with constant viscosity circulating with constant flow rate. We stress what presumably will guide the students to the key aspects of the analogy.

STEP 4: DISCUSSION OF THE ANALOGY. The last step is to find discrepancies, misconceptions, or concepts that are difficult to understand when the formal theory and analogy are compared. Among the questions raised by students we have selected some, and in case of less active classrooms, we try to conduct the discussions through those questions:

- In which circumstances could the circulation of the “fluid” in the analogy be considered open and in which closed?
- How will the nature of the “circuit” (open or closed) affect the functioning of the system?
- The different natures of pressure and resistance in the analogy may be puzzling, but the students accept it easily as an artifact of the analogy.
- In connection with the previous point, we ask them to try to find alternative sources of pressure.
- A concept that is difficult to understand is the concordance of units. If pressure is expressed as N/m² instead of the usual units (mmHg), it is far easier to accommodate concordance of units (this difficulty is not dependent on this particular analogy).

Modifications and improvements in the analogy. One of the greatest objections one could pose to the analogy is the different natures of the pressure and resistance found by the student forming part of the fluid flow. This disturbing effect is what we wanted; however, if the teacher is not comfortable with it, it
would be better to substitute the psychological pressure with another force. For instance, the students are on the top of a hill, where they have the greatest potential gravitational energy, and are pushed off so that they run downhill inside the corridor to the school that lies some distance away from the base of the hill, so that in this last segment of the path the force over the student is minimal.

Other possible analogies are different fluid circuits. Additional situations could also be incorporated into the analogy, such as nonlaminar flow (i.e., if panic breaks out in the corridor), pathological situations such as an embolus (if the students hold hands with the other students), or how the flow will be affected if we change the density of students inside the corridor (analogous to variations in hematocrit).

In summary, this method of criticizing an analogy has proved a useful tool, and one that motivates the students. They develop an interest in using the same technique for other “classic” physiological analogies using a critical view. The simplicity of the analogy and the simplicity of finding its defects was also seen to be of value, as this makes it easy to “play the game” from the very beginning. Nothing has ever gratified us more than unsolicited comments from former students over the years, thanking us for presenting them this approach to learn physiology and scientific methods.

REFERENCES


Angel Agis-Torres
Elvira López-Oliva
Secc. Dep. Fisiología
Facultad de Farmacia
Universidad Complutense de Madrid
Madrid 28040, Spain
E-mail: aagisto@farm.ucm.es
doi:10.1152/advan.00072.2006