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Conceptual Assessment of Physiology (CAP): development of a concept inventory for homeostasis

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Abstract

Homeostasis is an important core principle for undergraduate physiology students to understand and apply. Assessment of student conceptual understanding of homeostasis is important for teaching and learning, especially formative assessment to reveal students' incomplete understanding and 'misconceptions'. We engaged in a 3 step process to develop a Conceptual Assessment of Physiology (CAP) instrument for homeostasis. First, a conceptual framework for homeostasis that identifies component ideas appropriate for undergraduate physiology was developed and validated by a cohort of faculty at 2&4year colleges, universities & medical schools. Second, common student conceptions regarding homeostasis and its component ideas were identified (from physiology students and faculty). Third, multiple choice questions to assess important homeostasis component ideas were developed and tested in student interviews. These questions were then vetted by a cohort of faculty from diverse institutions and students in physiology courses. We will present the CAP questions on homeostasis, the physiology faculty data on the appropriateness of these questions for undergraduate students, and the results of initial testing with students. The questions will be linked to the conceptual framework and student conceptions & incomplete understandings. Supported by NSF DUE1043443.

Introduction:

We are developing a concept inventory for homeostasis based on our unpacking of the core principle of homeostasis[1,2]. Twenty multiple choice questions were written by our team. A group of physiology teachers across the country were surveyed and asked to (1) answer the questions, (2) tell us if there were any language issues that would affect their students ability to answer the question, and (3) tell us whether it was important that their students understand the concept being tested in the question. This feedback was used to edit and revise the questions in the inventory.

We then had students take the the inventory and after analyzing their responses, several interviews were conducted to better understand student thinking about the questions.

Methods:

SurveyMonkey™ was used to distribute the concept inventory to students at 7 colleges and universities across the country. A total of 244 students took the survey. Student responses were aggregated and the percentage of students picking each of the choices for each question was tabulated. One of our objective was to identify student misconceptions about homeostasis from the pattern of responses.

Comparisons of differences in percentages correct were analyzed by converting them to arcsines and then running two-tailed t-tests using Excel™.

Results:

The 20 questions have been categorized as either being "general model" questions (no specific physiological system is mention) or "application" questions (a specific physiological system is mentioned). A sample of each type of question is seen in Figure 1. Correct answer indicated with arrows.

4. A homeostatic control mechanism functions to maintain the concentration of X at a relatively constant level. This mechanism is functioning	% of students
A. when the concentration of X gets too high.	0.8
B. when the concentration of X gets too low.	0.8
C. when the concentration of X gets too high or too low.	46.5
D. at all concentrations of X. ←	51.0
9. Baroreceptors detect blood pressure. Blood pressure is maintained relatively constant even when the internal or external environment changes. Under what conditions do the baroreceptors send signals to the brain?	
A. when blood pressure is not at its normal value	34.2
B. when blood pressure is increasing	5.3
C. when blood pressure is constant	1.2
D. at all levels of blood pressure ←	58.0

Figure 1: two sample questions:
Q4 is a general model question, and Q9 is an application question

The degree of difficulty varied considerably across the 20 questions (see Figure 2). Five questions were apparently quite easy with performance ranging from 80-90%. At least four questions were quite difficult with scores ranging from less than 50% to less than 30%.

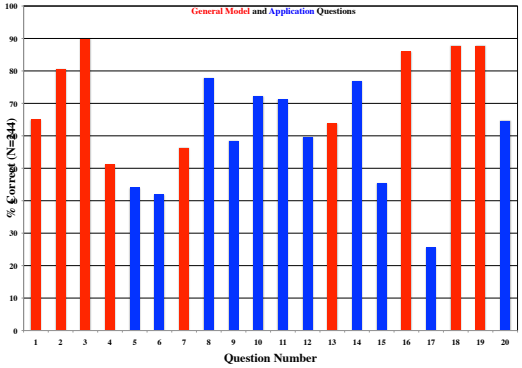

Figure 2: The degree of difficulty of the questions varied considerably and students performed better on the general model questions than on the application questions.

Student performance on geeral model questions was better than on application questions and this difference was significant at the p<0.05 level.

GENERAL MODEL		APPLICATION	
QUESTION #	% CORRECT	QUESTION #	% CORRECT
Q1	65.13	Q5	44.12
Q2	80.67	Q6	42.02
Q3	89.92	Q8	77.73
Q4	51.26	Q9	58.40
Q7	56.30	Q10	72.27
Q13	63.87	Q11	71.43
Q16	86.13	Q12	59.66
Q18	87.82	Q14	76.89
Q19	87.82	Q15	45.38
		Q17	25.63
		Q20	64.71
AVERAGE	74.32	AVERAGE	58.02

Figure 3: A comparison of student performance on general model and application questions.

The performance on questions 4 and 9 (see Figure 1) suggests that students have a faulty mental model about some important aspects of the behavior of sensors in homeostatic systems. It appears that for nearly ½ of the students the function of such a system is determined by an ON/OFF switch. In fact, these systems operate constantly to determine the value of the regulated variable.

Two different courses in the biology curriculum at the University of Washington participated in our survey. Students in a junior level (BIO 350) and senior level (BIO 460) physiology course took the survey (see Figure 4). Student performance in 460 was better than student performance in 350 ($p < 0.05$). Further, students in 460 did NOT exhibit a difference in performance with model and application questions ($p=0.224$), while students in 350 did ($p<0.05$).

COMPARISON OF PERFORMANCE BY STUDENTS IN TWO DIFFERENT COURSES	**BIO 350 (% correct)**		**Bio 460 (% correct)**
Class performance on CAP	65.3%		79.3%
Difference between classes		***p = 0.034***	
Class performance on general model questions	74.9%		83.7%
Class performance on application questions	61.3%		79.6%
Difference in performance by question type		***p = 0.224***	

Figure 4: Student performance in a junior level course (Bio 350) and the subsequent sensior level course (Bio 460)

Summary and Conclusions:

1. We have developed a concept inventory assessing student understanding of homeostasis.
2. We have tested the inventory with 244 students at seven of colleges and universities across the United States.
   a. There are no obvious language problems affecting student performance on the questions in the inventory.
   b. Interviews with a small number of students confirms this.
3. Students perform better on general model questions (no actual physiological system mentioned in the stem of the question see Question 4 on left) than on application questions (which did refer to a specific physiological system – Question 9 on left).
   a. General model questions appear to test students memory of descriptions of homeostasis provided by instructors and/or textbooks ("awareness" of the concepts).
   b. Application questions require the integration or application of several "facts" about homeostasis.
4. Data from two courses in the Biology program at the University of Washington suggests that learning about homeostasis does occur as students advance into higher level courses.
5. Responses to several questions suggest that student mental models of homeostasis are flawed. Student models have sensory receptors only firing when the regulated variable is too high or too low. Similarly, the mechanism that controls the regulated variable is active only when the value of the regulated variable is outside the normal range for that variable. Such a faulty model can be likened to an ON/OFF switch.
6. Our results point to the direction to go for a more complete inventory of student understanding of the concept of homeostasis. We will be administering the inventory to more and more varied students. We will also be conducting additional interviews to better understand student mental models of homeostasis.

References:

1.Michael, Modell, McFarland, and Cliff. (2009). The "core principles" of physiology: What should students understand? Adv. Physiol. Educ. 33: 10-16.

2.Michael and McFarland. (2011). The core principles ("big ideas") of physiology: Results of faculty surveys. Adv. Physiol. Educ. 35: 336-341.

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