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In this evaluation of Biology 361 Principles of Physiology during the Spring 2010, I describe my teaching philosophy, provide pedagogical examples of how I implement that philosophy, and report the statistical analysis of students' learning gains. In addition, I provide literature-based perspectives on the future of the course.

Pedagogical Approach. My teaching philosophy is grounded in a social constructivist framework that aligns with the current practice of the scientific and education communities. I create opportunities for students to uncover physiological principles and allow them to evaluate the strength of their own conclusions from data they collect. Perhaps the two most striking features of my course are a lack of traditional lecture and the requirement of student metacognition throughout the course. Both of these characteristics have been proven essential for genuine learning in the science classroom (Crowe, Dirks, & Wenderoth, 2008; Hake, 1998). Other features of my classrooms include: frequent formative assessment; a heavy reliance on primary literature; an emphasis on critical thinking; and a respect for students as adults.

To learn content, my students must work with new material outside of class, followed by ample classroom time to address their questions and encourage discussion. I regularly guide outside learning via discussion forums in Blackboard. When participation is required, I provide specific instructions as to the type of contributions students can make and a rubric demonstrating how their contributions will be scored (see box). As they contribute, I intervene with suggestions, restrictions, or solutions to their learning debates. When forum participation is required, it is assessed formatively; that is, rather than placing students along a grade spectrum, I offer multiple opportunities for them to succeed. As such, students are more willing to propose new ideas and suggest alternative strategies since they have opportunities to correct themselves later if necessary (see box). Here two students discuss a lab experiment in which behavior of *Betta splendens* was observed with and without treatment with fluoxetine. Student A identifies

Example Discussion Forum Instructions

Below (and in the forum) are the results from the Fish on Prozac lab. You are required to participate in the discussion forum about this lab. This assignment is worth 5 points. To earn...

- **5 points:** Cite or link to a primary article making a connection between the physiology discussed there and the physiology explored during our experiment.--OR-- Explain some aspect of the data and propose a modification to the protocol (or a whole new experiment) that might tease out the physiological phenomena.
- **3 points:** Comment, critique, supplement or modify another thread using upper level Bloom's skills. --OR-- Clarify some aspect of the relevant physiology and explain how your source elucidates the issue.
- **1 point:** Define an important related term. --OR-- Agree, disagree, link to a study site, YouTube, Wikipedia, or other supplemental material without providing context for the contribution.

You may contribute as often as you like (i.e. one 3-pt and two 1-pt submissions), but you may only earn a maximum of 5 points, regardless of quality/quantity of your contributions.

and describes authoritative literature relevant to the experiment we conducted:

> The article in *Science News* states that each year many antidepressants, such a Prozac, end up in the environment from being excreted by patients or from leftover pills being flushed down the toilet. The concentration of anti-depressants may affect the fish inhabiting the polluted waters by impairing the fish's ability to eat, avoid being eaten, or attract a mate. In 2006, chemists studied the affects of antidepressant venlafaxine on fish and saw that the fish didn't respond as quickly to predator-signaling stimuli. This same response took place in the Beta fish exposed to Prozac when they were faced with their mirror image. Antidepressants Make for Sad Fish: Drugs May Affect Feeding, Swimming and Mate-Attracting, Janet Raloff. *Science News*, Vol. 174, No. 13 (Dec. 20, 2008), p. 15

Student B offers several suggestions for future experiments:

> Suggestions to improve this experiment... 1. more subjects in order to reduce uncertainty about the distribution of the data. 2. a revised system of controls that measures the same fish before and after introduction of fluoxetine into the water. Suggestions for future experiments...1. Fish in various treatment groups would be measured before and after exposure to fluoxetine at differing concentrations for each treatment group. This would allow us to show what concentration of fluoxetine is necessary to change behavior in these fish. 2. Fish would be exposed to treatment as in this experiment, but would be exposed to another fish rather than the mirror. The advantage to this is not the same as the advantage of the performed experiment. In the performed experiment, the purpose is to determine if fluoxetine has such an affect on neural response that it affects behavior in the fish. The advantage to the two-fish experiment is to see if this behavior change is carried over to a naturally plausible situation, where there are other factors involved such as the response of the other fish.

In another unique content-learning assignment, students learned about action potentials prior to coming to class. They read a chapter from the Wikipedia article on action potentials, acquired the primary literature Wikipedia cited, determined if the Wikipedia article was correct, and used their textbook and the primary literature to suggest improvements to the Wikipedia article. College of Science and Math librarian visited all three lab sections to help us with literature location and evaluation skills. Subsequent class time was spent answering the specific questions students developed about the nervous system, action potentials, and excitable tissue as they learned important content.

Average number of posts per discussion forum (n = 60 students).

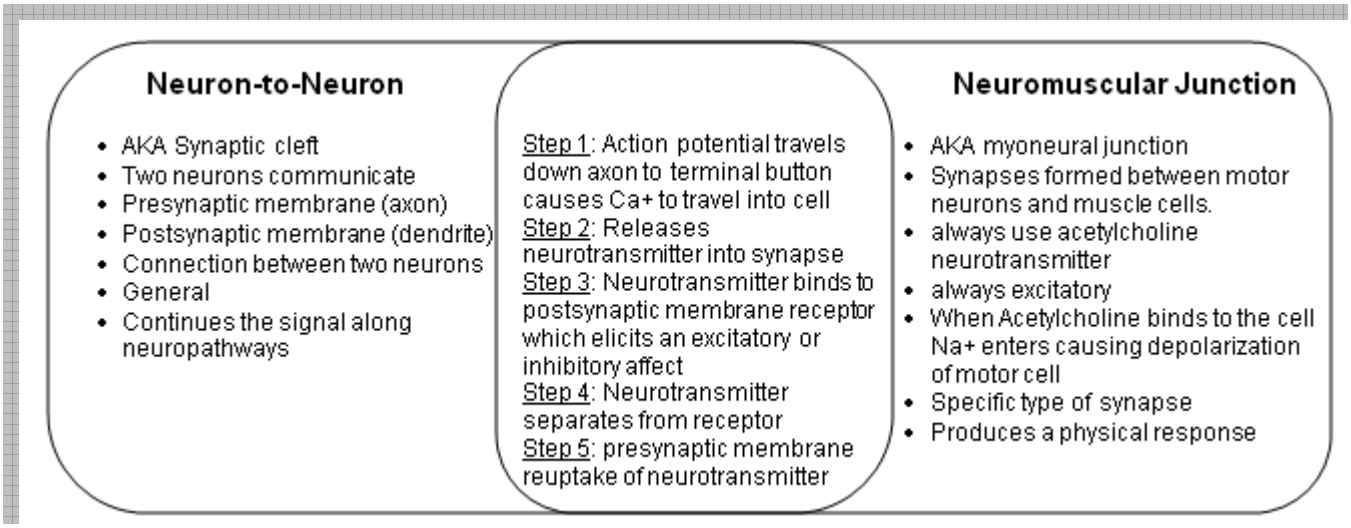
Type of Content	Optional	Required
Exam Questions	103	
Fundamental Principle		118
Lab Investigation		108
Interesting Topic	22	

Here a student reconciles information presented in the Wikipeidia article "Action Potentials" with information from her textbook:

> The article "X-ray structure of a voltage—dependent K^+ channel" does not support any of the facts as they were stated in Wikipedia. Wikipedia is describing an overview of ion channels and the selectivity of the channels, whereas the article describes the structure of the specific ion channel, the voltage—dependent K^+ channel. The source is relevant to the topic of ion channels and is "real" scientific information, but it is irrelevant to the statement in the Wikipedia. This portion of the Wikipedia has cited two sources (17 and 18), but then 17 has more than one source. They are probably closely related. An article that discovered ion channels and proved how selective they are would be a better source. According to the Biological Science textbook, "Cells have many different types of channel proteins in their membrane, each featuring a structure that allows it to admit a particular type of ion or small molecule" (Freeman 2008 p. 111). Figure 6.25b shows a model of how potassium channels only allow potassium ions to pass through (Freeman 2008 p. 112).

Note that I did not "teach" the expertise she displays here, but instead gave her the opportunity to discover and reconcile inconsistencies on her own, thereby making her both the learner and creator of knowledge while I assumed a guidance rather than authoritative role.

Other content-learning activities included Venn diagrams. For example, rather than spending class time describing the similarities and differences between neuromuscular junctions and typical neuron-to-neuron synapses, students learned this content on their own by creating Venn diagrams (below: reproduction of student-generated Venn diagram). Again, learning was entirely student-generated, outside of class time—as such, the open lecture period could accommodate more student-directed questions.



Assess Student Learning. I used two methods to assess students' incoming knowledge as well as provide a baseline for comparison at the end of the quarter: a modified concept inventory and concept maps. Concept inventories are reliable and valid assessment tools that address conceptual understanding using a traditional multiple choice format (Libarkin, 2008). Presently, there is no formal concept inventory in physiology. However, I gathered several questions from the Biology Concept Inventory (Garvin-Doxas & Klymkowsky, 2008) available at: www.bioliteracy.net) and culled a few higher level questions from sample MCAT and GRE practice exams in an attempt to assess student understanding of fundamental concepts in physiology. These 35 multiple choice questions were given during the first and last lab sections. In the second activity, student pairs were given 20 terms (see box) and asked to arrange them in answer to the question: *How do organisms adjust to changing environments?* Concept maps were assessed for the number of connections made among terms, the accuracy of these connections, and the distances between pairs of terms.

Concept Map Terms
Active transport
ATP
Behavior
CO_2
Environment
Enzymes
Excitable cells
Evolution
Feedback
Fluid mosaic model
Gradient
Membrane potential
Metabolism
NaCl
Na+/K+ pump
Osmosis
Receptors
Second messenger
Stress
Water

Seventy-five percent of students in my course exhibited a positive learning gain as measured by the 35 conceptually based questions used as the pre-/post-assessment tool. Assuming that my course had no effect on student learning, half of the students would have a positive gain while half would have a negative gain. Chi-squared analysis reveals instead that this course resulted in significant learning gains ($p < 0.05$). The size of this effect is very large (Cohen's $d = 0.986$). In other words, this class had a very strong positive effect on learning. There was no relationship between incoming knowledge and learning gain ($m = -0.0157$; $r^2 = 0.0722$). Both the mean and median gains were positive (0.200 and 0.179, respectively) indicating that success in my class was not based on high existing knowledge—all students entered the class equally able to succeed. In terms of concept maps, despite being given the exact same 20 terms, at the end of the quarter, students saw more connections among the terms ($p < 0.05$), and the accuracy of the connections they made among them increased significantly ($p < 0.05$). Among pairs of terms, students found the terms "excitable cells" and "membrane potential" significantly more related than they did at the start of class ($p < 0.05$). In conclusion, my pedagogical approach in BIO 361 during Spring 2010 clearly created an environment that allowed students to learn. I am pleased with these large-scale results and will consider them as I revise course materials and design new assignments with the goal of maximizing student learning.

Observations & Suggestions. If Cal Poly wants to train the next generation of scientists, it must be ready to teach skills essential for their success. In addition to faculty competence in effective science instruction pedagogy, several specific suggestions follow.

Teach statistics. One important skill is learning how to maneuver in a body of scientific knowledge that is in constant flux. In the real world, we do not get the privilege of knowing whether or not our results are "right". Students must learn to persevere in light of vague and uncertain data, and if we want them to be successful at this, we must teach them how to do it—this means we must emulate vague and uncertain situations!

Reallocate grading funds. Currently, the department provides fund for grading assistance for instructors in high enrollment, non-majors courses. The funds located to assist me mid-quarter were immensely helpful. Consider that in the advent of technology like Blackboard and iClickers, the need for grading support should be significantly lower since products like these evaluate and record grades instantaneously. If faculty in upper level majors courses had access to grading support they might be inclined to offer formative assessments more often and thereby provide more opportunities for student success. Writing assignments, formative assessments, and other non-traditional evaluations need not require content expertise for proper grading. For example, in Appendices A and B are two assignments (and rubrics) required of my Biology 361 students this quarter and were used by two outstanding Cal Poly student graders, undergraduate student MB and graduate student MD. Bio 361 students were required to do this kind of work approximately 1.5 times per week. The financial assistance provided by the department was instrumental in allowing me to provide the students with the kind of feedback they deserve at this level of their undergraduate careers. Faculty teaching lower division non-majors courses could be encouraged to utilize the already available and often free software and other course support materials thereby liberating these funds to support assessment of cognitive development activities in content-laden upper division courses.

Encourage pre-/post-assessment. At least one way to combat the persistent misconceptions students have about fundamental concepts in biology is to simply find out what it is they don't understand. It's too easy to assume that passing a prerequisite course means they understand the material and are prepared to build on that knowledge. There are a variety of ways in which faculty can assess incoming knowledge—conducting a simple pre-assessment could help shape a course so as to address any lack of incoming knowledge, thereby ensuring mastery of the material at hand.

In sum, I am proud of the accomplishments of my students, particularly in light of the challenges they faced adjusting to a new learning style. Some who went along hesitantly expressed their satisfaction with skills and perspectives they've gained. Other unhappy students whose focus was solely on passing the MCAT were somewhat appeased by primary literature describing the method of learning content in this course as an essential skill for passing evidence-based medicine courses in medical school. I executed this course to the absolute best of my abilities, grounded it solidly in the literature on effective science teaching, and kept the student as a human being always in the forefront of my pedagogical endeavors. The assessments I conducted

demonstrate that my approach offered an effective learning environment for Cal Poly students. I would be happy to further explain any of my techniques during a Brown Bag seminar.

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August 5, 2010

Crowe, A., Dirks, C., & Wenderoth, M. P. (2008). Biology in Bloom: Implementing Bloom's Taxonomy to Enhance Student Learning in Biology. *CBE Life Sci Educ*, *7*(4), 368-381. DiCarlo, S. E. (2009). Too much content, not enough thinking, and too little FUN! *Advan. Physiol. Edu.*, *33*(4), 257-264. Garvin-Doxas, K., & Klymkowsky, M. W. (2008). Understanding randomness and its impact on student learning: lessons learned from building the biology concept inventory (BCI). *CBE Life Sci Educ*, *7*(2), 227-233. Hake. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*, 64-74.Libarkin, J. (2008). Concept inventories in higher education science. Presented at the Undergraduate STEM Education Workshop II, Washington DC. Michael, J., Modell, H., McFarland, J., & Cliff, W. (2009). The "core principles" of physiology: what should students understand? *Advan. Physiol. Edu.*, *33*(1), 10-16.

HORMONES, BRAIN, & BEHAVIOR

Choose from the following two options. Submit your essay in the drop box below before the start of lecture on Tuesday, June 1st.

Option A: Read the two articles below.

Read these two articles and complete essay as directed.

- LeVay, S. (1991). A difference in hypothalamic structure between heterosexual and homosexual men. *Science, 253*(5023), 1034-1037.
- Insel, T. & Hulihan TJ. (1995). A gender-specific mechanism for pair bonding: oxytocin and partner preference formation in monogamous voles. *Behavioral Neuroscience 109*(4), 782-789.

Option B: Choose a hormone of interest.

Read two articles by two different authors published in the journal *Hormones & Behavior*; click here to visit Cal Poly's holdings; use the All Fields search box available at ScienceDirect.

ASSESSMENT

Combine the information from those two articles, your textbook and other supplemental sources of information, and address the following topics in a clear and coherent manner, in fewer than 500 words:

a) What is the brain area of interest? What are some of its primary functions? General statement of normal physiology. (3)
b) What is the hormone(s) of interest? Where is it produced? What are its target tissues? General statement of normal physiology. (4)
c) Why are the subjects in these investigations good experimental models? (2)
d) What new findings does each article report? (4)
e) Are these findings applicable across systems or species? Defend. (2)
f) Does the later author cite the earlier author? If so, how does s/he explain the importance of the earlier findings? If not, either support or refute the authors' decision to exclude it. (2)
g) Identify by page number a place in your textbook the information discovered in your studies could be included, if not there already. If so, locate a second place such studies could be referenced. Include a statement as to why that information could be described there. (2)
h) Proper bibliography. (3)

Visit the Hormones, Brain, & Behavior discussion forum for questions, help, and other information.

ASSESSMENT

Combine the information from those two articles, your textbook and other supplemental sources of information, and address the following topics in a clear and coherent manner, in fewer than 500 words:

Grading notes:

___
22

brain area of interest ☐
its primary function/s ☐
general statement of normal physiology ☐
hormone(s) of interest ☐
site of production ☐
target tissues ☐
general statement normal physiology ☐
good experimental models, Paper 1 ☐
good experimental models, Paper 2 ☐
new finding 1, Paper 1 ☐
new finding 2, Paper 1 ☐
new finding 1, Paper 2 ☐
new finding 2, Paper 2 ☐
applicable across systems or species ☐
defend ☐
latter cite former ☐
explain ☐
page number ☐
statement ☐
cite Paper 1 ☐
cite Paper 2 ☐
cite third reputable source ☐

lacks thoughtful argumentation ☐
grammar, spelling, or technical problems ☐
less than college-level writing ☐

Wikipedia as a Source for Critical Thinking in Science

Summary

Although often eschewed in science education, Wikipedia is an ideal place for students to learn important scientific communication and critical thinking skills. In this assignment, you will learn how to determine the merit of Wikipedia articles, obtain and evaluate the primary literature cited in the relevant article, and generate a written report as to the appropriate inclusion of that literature in the encyclopedia article. In addition, you will become familiar with fundamental concepts in renal physiology, evaluate your textbook's presentation of those same concepts, and provide meaningful suggestions to both authors based on your findings. In its own way, this exercise mirrors the peer review process in scientific communication, and requires your critical evaluation of both the content presented, as well as the rigor with which scientific information is presented.

> *But if [students] can learn about how entries on the site change and how each change is debated in arguments open to anyone's inspection, then Wikipedia can demonstrate to students the process, importance, and excitement of real scholarship.* Crovit[i]

> *It's a matter of priorities. If we consider students to be learners rather than performers, and if we value the learning of thinking skills rather than the carrying out of orders, we won't be afraid to allow students to explore and to not always get the "right" answer.* Maeher[ii]

Protocol

Collaborate with Jeanine M. Scaramozzino, College of Science & Math Librarian

- Review the functions of various types of scientific communications.
- Review the concept of a wiki, how they are generated, and the anatomy of Wikipedia articles; for this assignment, we will refer to the text or section of the appropriate Wikipedia article as the WikiArticle.
- Choose two primary articles referenced in your WikiArticle (options listed in Blackboard) and obtain them from the databases available in the Kennedy Library. Whenever possible, make sure your articles come from two different journals.
- Review proper APA citation style.

Collaborate with your partner

- Read the two articles you've chosen; identify the hypothesis and primary findings of each.
- Go back to the WikiArticle and determine if your two articles were properly interpreted and cited by the WikiArticle authors.

Use your textbook

- Read the section in your textbook that describes the action potential and the synapse. Note these important features: axon, dendrite, soma, neurotransmitter, synapse, receptors, sensory neurons, motor neurons. Note important physiological phenomena including: exocytosis, action potentials, and the movement of sodium and potassium across the membrane.
- Use your text as a reference tool to aid in your understanding of the primary literature.

Refer to your colleagues

- Other students in your lab section may have selected different primary articles on the same chapter or section you're working on; consider consulting your classmates for help interpreting confusing parts of your own primary articles.
- Be sure to ask a classmate for help before seeking help from the librarians or instructors.

Test your understanding: Assume a question similar to the one below will be on the exam. What questions do you need answered in order to prepare a thorough answer? List and number these questions at the end of your paper.

> ***What is the difference between graded potentials and action potentials? Include voltage-gated channels in your answer.***

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[i] Crovitz, D. & Smoot, W.S. (2009).Wikipedia: Friend, not foe. *English Journal, 98*(3), 91–97.

[ii] Maehre, J. (2009). What it means to ban Wikipedia: An exploration of the pedagogical principles at stake. *College Teaching, 57*(4) 229-236

Communicating Findings

- Screenshot of WikiArticle at some point when you're working on it.
- Choose two primary articles from two different journals; book chapters acceptable as well (2). Submit a copy of the first page of each article with your assignment (2).
- Identify the hypothesis (2) and primary findings (2) of each article. *Read the abstract fully and be prepared to explain it to the class. Take notes, draw sketches, or highlight sections of your textbook that enable you to understand the study.*
- State which physiological concept is under investigation (2). *Using the phrase or title of the relevant section of your textbook could help. For example, your text might have a section called "The Vertebrate Nervous System is Regionally Specialized" or "How Cells Maintain Resting Potentials"—descriptive section titles like these are likely good summaries of the concepts under discussion.*
- Copy the relevant sentence(s) from the WikiArticle into your paper (2)
- Explain how the articles you chose do or do not support the facts as they were stated in the WikiArticle (4). *If your article supports the statement, demonstrate how: In your own words, explain the problems the scientists faced and/or the problem they solved with their study. (This means you may have to read more than just the abstract.) Refer to a figure or table in their paper. Show how the information presented in the primary article is a specialization of information available in your text. Include a concept map, Venn diagram, or other demonstration of your making meaning of the science. If the article is not appropriate, explain why. Is the source irrelevant? Is it a book review or press release instead of "real" scientific information? Is the source relevant but misinterpreted by the WikiArticle author? If so, where do you think the misunderstanding occurred? Whenever you negatively critique something, you can convince your reader of your assertions by supplementing your argument with alternative solutions. For example, what could your wiki author have written? What other paper would be a better citation?* When appropriate use your textbook to support your argument (4).
- In the final paragraph, comment on how this activity supports a learner-centered curriculum. List at least 3 anatomical structures you learned about for the first time during this exercise (3); if none, indicate so. Summarize 2 important functions of the nervous system, including in your summary the roles of sodium/potassium pump and voltage-gated channels (4). Then, describe how this assignment helps build critical thinking skills in one area of upper Bloom's Taxonomy (2).
- Option: Choose one of the following: (4)
    a) Critique two aspects of this assignment per Maehre (2009): In what ways does this assignment meet his expectations? How could the assignment be improved?
    b) Critique two aspects of this assignment per Walker (2007): In what ways does this assignment reinforce his concerns? In 1-2 sentences, propose an alternative method for learning about primary literature in neuroscience.
- Properly cite in APA format the materials used in this assignment. Include the 2 primary articles, your textbook, the WikiArticle, Maehre (2009) or Walker (2007) (or both! Go crazy!), and any other materials you used. Refer to APA citation information as per Jeanine and/or OWL. *Reference section properly formatted: 2; minimum of 5 proper references:5; For all in-text citations of your textbook, please include page number (even though this is not traditional APA style…if you're citing your textbook, allow me to read alongside you): 1.*

Screenshot of WikiArticle: ___/1

Article 1

Choice: ___/1
Copy: ___/1
Hypothesis: ___/1
Primary finding: ___/1
Concept under investigation: ___/1
Relevant Wikipedia sentence: ___/1
Support or not: ___/2
Use text to support argument: ___/2

Article 2

Choice: ___/1
Copy: ___/1
Hypothesis: ___/1
Primary finding: ___/1
Concept under investigation: ___/1
Relevant Wikipedia sentence: ___/1
Support or not: ___/2
Use text to support argument: ___/2

Final Analysis

3 anatomical structures: ___/3
2 nervous system functions: ___/2
Sodium/potassium pump: ___/1
Voltage-gated channels: ___/1
Upper Bloom's: ___/2

Critique

2 aspects: ___/2
Support 1: ___/1
Improved/Alternative: ___/1

Bibliography

Article 1: ___/1
Article 2: ___/1
Maehre/Walker: ___/1
Textbooks: ___/1
Other reference: ___/1
Include page numbers: ___/1
Overall section properly formatted: ___/2