

Articles

Developing Transfer Skills in a Biochemistry Class

Jeong V. Choe

Illinois Mathematics and Science Academy

Introduction

Students seem to struggle with transferring prior knowledge if the new problem they are given is in a different form from the way they learned the material. The process of transfer can be identified by four components: 1) recognizing the similarity between the old and new contexts; 2) identifying the potential of a certain skill or concept that has worked in the past, to give solutions to new problematic situations; 3) mental testing of the application of the potential solution; and 4) an attempt to apply the skill or concept to a new context (Georghiades 2000). These four components are important in preparing students to transfer knowledge learned during school to other situations as they enter the work force and are asked to solve real-world problems. However, the Committee on Science (2007) reports that the learning that occurs in high school classrooms does not prepare students well to solve real-world problems.

The inability of students to develop transfer skills in the classroom raises a question of how we, as educators, can better prepare our students with transfer skills? During the fall of 2011, after years of asking students to transfer knowledge, I implemented two new strategies

The learning that occurs in high school classrooms does not prepare students well to solve real-world problems.

for practicing transfer. I chose two that aligned with the instructional design of my biochemistry class. The first is to have students make analogies between biochemistry topics and concepts that they have encountered in other classes; the second is to ask students to compare the contextual similarities and differences between various problems I designed for class (Fogarty, R., Perkins, D. N. & Barell, J., 1992). The course that I implemented these two methods in was Biochemistry which is an elective course at the Illinois Mathematics and Science Academy (IMSA). Students enrolled in Biochemistry are in eleventh and twelfth grade. IMSA is a public, residential school for tenth through twelfth graders who are academically talented in math and science. Biochemistry is a one semester elective only for juniors and seniors, and the course has a requirement that students must have successfully completed their sophomore level biology and chemistry courses.

c) The equilibrium constant, K_{eq} , for the dissociation of HAc is 1.8×10^{-5} . What is the pH of this solution when the concentrations of both HA and A⁻ are equal to 0.5 M? What happens to the pH when both of these two concentrations are changed to 0.7 M? Based on the patterns you observe, can you find the relationship between pH and pKa when the concentration of the weak acid and the conjugate base are the same?

d) Rearrange the dissociation equation of HAc from the above problem, parts a through c, to derive the Henderson-Hasselbach equation. In other words, start from the K_{eq} expression to get to

$$pH = pKa + \log \frac{[Ac^-]}{[HAc]}$$

e) Let's now transfer your understanding of equilibrium and buffer to a different context. The active component of aspirin is acetylsalicylic acid, $HC_9H_7O_4$, which has a K_a of 3.0×10^{-4} . Calculate

the pH of a solution made by dissolving 0.600 g (600 mg) of acetylsalicylic acid in water and diluting it to a final volume of 50.0 mL. The molar mass of acetylsalicylic acid = 180.16 g/mole. If you accidentally spill a drop of 3.0 M NaOH, and you were able to identify that the spilled amount of NaOH has a volume of 0.05 mL, how would you use the Henderson-Hasselbach equation to calculate the new pH?

3. Connection between topics of osmosis and equilibrium.

What kind of salty food do you like? Draw a process of what a cell in your body might experience in order to maintain its volume and osmotic equilibrium with the surrounding environment as you intake this salty food. What would be the signs for the solute potential (Ψ_s), pressure potential (Ψ_p), and water potential (Ψ_w) when it reaches equilibrium? (In other words, fill in the blank with +, -, or 0). Use the word hypertonic and hypotonic in your explanation in addition to the drawing.

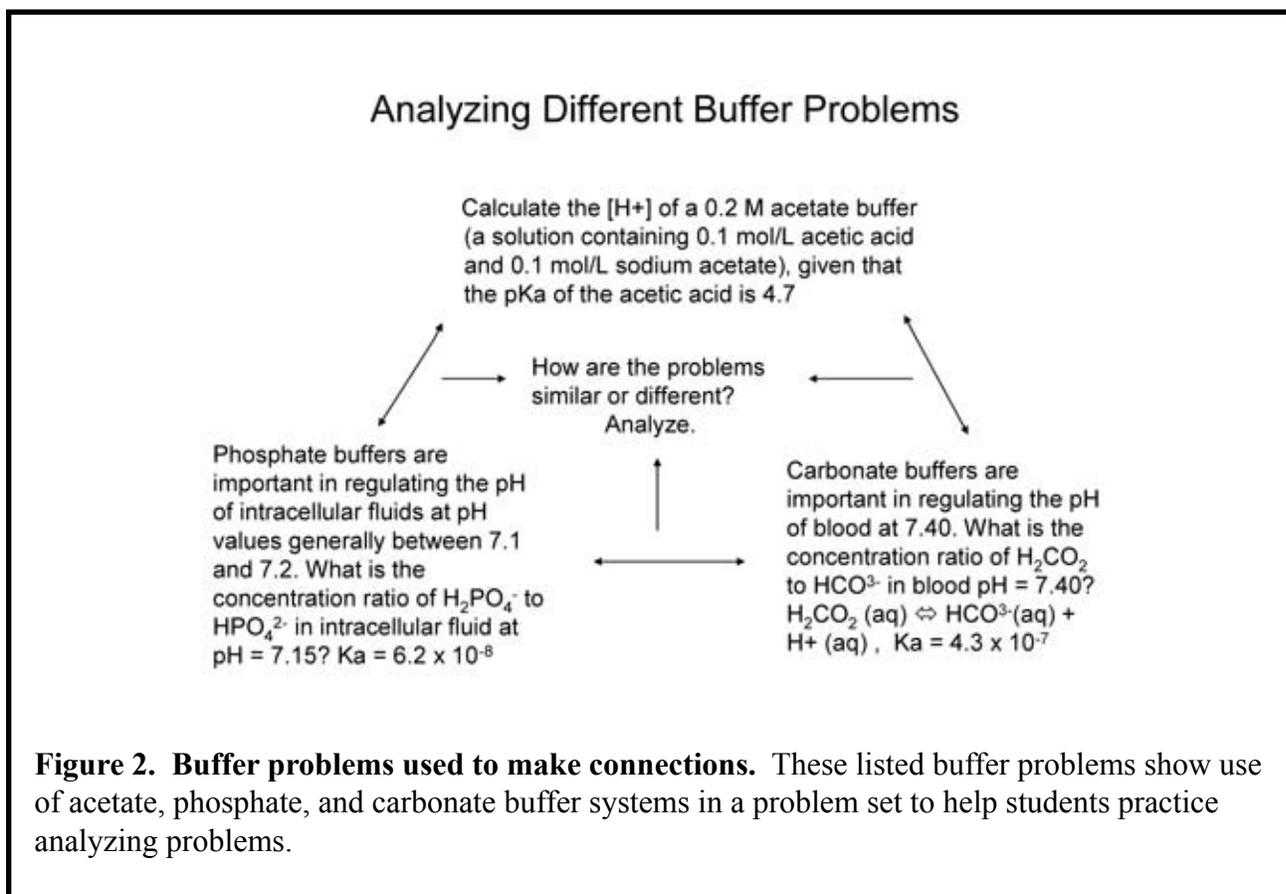


Figure 2. Buffer problems used to make connections. These listed buffer problems show use of acetate, phosphate, and carbonate buffer systems in a problem set to help students practice analyzing problems.

a) Drawing and explanation:

b) Signs for Ψ_s , Ψ_p , and Ψ_w at equilibrium:

Ψ_s _____, Ψ_p _____, Ψ_w _____

Part II: Guiding students to find similarities and differences between problems

Students were guided towards making connections between the practice problems. They were asked to analyze how some problems were similar or different from each other; they were then asked if they noticed any patterns in the problems. Figure 2 demonstrates different types of buffer problems that the students analyzed for similarities and differences. They are typical buffer problems using acetate, phosphate, and carbonate buffer systems. Students had class discussions to describe the similarities and differences between the problems. As students generally find the buffer problems to be difficult, they struggled to determine where to begin. To help ease into the problems I guided students with the following questions; listed underneath each question are typical responses from the students.

Question: Identify or underline what the question is asking.

Typical student response:

- acetate buffer problem: Calculate H^+ concentration.
- phosphate buffer problem: Find concentration ratio of $H_2PO_4^-$ to HPO_4^{2-} .
- carbonate buffer problem: Find concentration ratio of H_2CO_3 to HCO_3^- .

Question: Do you see any similarities or differences in the three problems?

Typical student response:

- Both the phosphate buffer and the carbonate buffer problems ask for the concentration ratio between the weak acid and the conjugate base given K_a and pH values, whereas the acetate buffer problem gives you the ratio and pK_a and we have to find the pH to find the H^+ concentration.

Question: How can we link all three problems?

Typical student response:

- They are linked through the Henderson-Hasselbach equation which is derived from the equilibrium constant expression of the weak acid as done in the lab.

Once students answered these three questions, they started to realize that these three problems were the same, except they were asked to find different variables based on the buffer system in the problem. Students were guided not only by these questions, but they were also given a table to fill out to organize their analysis of the questions. An example of this is shown in Table 1.

By discussing the problems in this way, not only do the students seem to solve all three problems more easily than before, but they also learn to break down the problems to analyze the pattern. Some of them find it useful to break down the problem in this way especially when a wordy or complex problem is given to them. Consistent practice such as this helps students to transfer their knowledge to different settings.

Results and Discussion

Students enrolled in the spring semester were asked the same buffer questions as the students who enrolled in the fall semester on their unit exam. The difference was that during the spring semester, students were not guided to practice

	Variables that describe buffer $pH = pK_a + \log \frac{(\text{base})}{(\text{acid})}$		
Problem	pH	pKa	Ratio of acid and conjugate base
a. Acetate	Question asked	Given	Given
b. Phosphate	Given	Given	Question asked
c. Carbonate	Given	Given	Question asked

Table 1. Table used to help students organize their analysis process. Students were given the table to organize their process as they analyzed the three buffer problems.

Semester	Full Credit (2pt)	Partial Credit (1pt)	No Credit (0pt)
Spring Semester (N=17)	3	14	0
Fall Semester (N=37)	30	7	0

Table 2. Semester comparison of the number of students receiving different credit for the buffer problem.

The table compares the number of students who received full, partial, and no credit in the spring semester without students practicing transfer skills compared to the fall semester after practicing transfer skills.

transfer skills. However, during the fall semester, transfer skills were heavily emphasized by having students make connections between concepts and analyze different problems before they solved them.

The effect of student performance after having them practice transfer skills was analyzed through the following question on the unit exam.

Question: “Chemi” is widely used in biochemical research for the preparation of buffers. It offers low toxicity and it has a pKa of 8.08 making it convenient for the control of pH in clinical applications. This buffer is made by mixing 0.050 moles of chemi with 0.025 moles of NaOH in a volume of 2.00 L. What is the pH of this buffer?

More students in the fall semester received credit on the buffer problem than did students in the spring semester (Table 2). When students practiced recognizing patterns in the fall semester, 81.1 percent of the students received full credit.

Only 17.6 percent received full credit on the same problem during the spring semester (Figure 3). Practicing transfer skills increased the number of biochemistry students who received the full credit on the buffer question by 63.5 percent, and decreased the number of students who received partial credit by the same percentage. None of the students received zero credit in either semester.

It has been widely demonstrated that it is valuable to teach students transfer skills so they can transfer their learning to other contexts and become better problem solvers. This study demonstrates a short term effect of having students practice transfer skills. If we continue to guide students to practice this skill in a more consistent way, students should be better prepared to transfer what they have learned during school to other contexts in the longer term.

The short term outcomes of this study were geared towards having students practice transfer skills in a more content specific way,

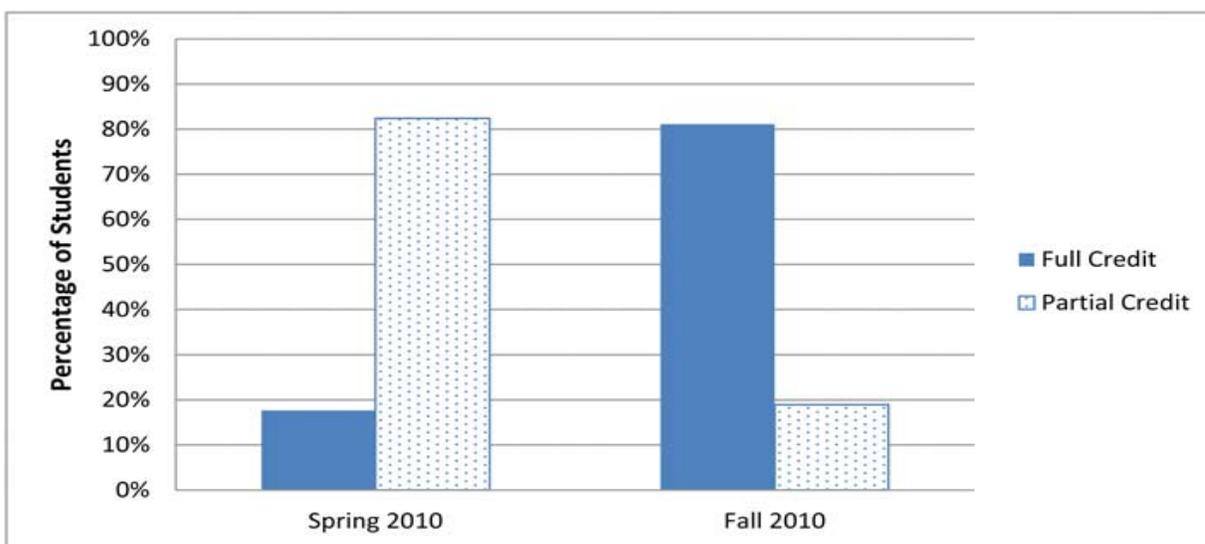


Figure 3. Semester comparison of student performance on the buffer problem. The graph shows percentages of students who received full and partial credit in the spring semester without practicing transfer skills compared to the fall semester after practicing transfer skills in the unit exam.

related to the Next Generation Science Standard (NGSS) HS-PS1-6: “Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium (NGSS, 2013).” The overall purpose of the NGSS is to emphasize the key knowledge and skills that all students need in order to engage fully as workers, consumers, and citizens in twenty-first century society (NGSS, 2013). This includes process skills as well as content skills. If we provide students with an environment where they can continue to consistently practice transfer skills, in the long run, they should be better prepared to apply their knowledge to real-world situations. These would include the ability to “design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering” (NGSS: HS-ETS1-2, 2013) or to “come up with a computer simulated model to propose solutions to a complex real-world problem by analyzing numerous criteria and making connections between interactions that are associated with the problem (NGSS: HS-ETS1-4, 2013).” It is important as an educator to consider both short term and long term outcomes and identify effective ways for students to practice

the transfer skills which also align well with their instructional design.

References

- Committee on Science (2007). *Rising above the gather storm: Energizing and employing America for a brighter economic future*. Washington DC: National Academies Press.
- Fogarty, R., Perkins, D. N. & Barell, J. (1992). *How to teach for transfer*. Palatine, IL: Skylight Publishing.
- Georghiades, P. (2000) Beyond conceptual change learning in science education: focusing on transfer, durability, and metacognition, *Educational Research*, 42:2, 119-139.
- Next Generations Science Standards (2013). Retrieved January 27, 2014 from <http://www.nextgenscience.org/next-generation-science-standards>

Author Information

Jeong Choe is a National Board certified chemistry teacher at the Illinois Mathematics and Science Academy, a position that she has held since receiving her Ph.D. in 2008 from the University of Illinois at Chicago. She can be contacted at jchoe@imsa.edu.

Do You Know an Exemplary Science Student?

ISTA members in good standing who would like to honor one high school science student each year, may request an **ISTA medallion and certificate** by contacting pamela.spaniol@yahoo.com. The first medallion is free of charge; additional medallions may be obtained for \$15 each.

This award program is supported by contributions from the Illinois Petroleum Resources Board.