"Analyze, Acquire, Apply, and Write" as a New Learning Model in Science

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ABSTRACT

I have developed a new teaching and learning model called AAAW, which stand for Analyze, Acquire, Apply and Write. This model grows from action research and unique experience in teaching a biochemistry course to high school students who are talented in math and science. In this model, students first "Analyze" lab data to generate questions that lead them to "Acquire" background knowledge. Students then go back to the data and "Apply" their new knowledge to better understand the data. Finally, students "Write" about the connections they make from their reading, data analysis, and application of the data. The rationale behind how the AAAW model was developed will be shared in this paper.

Designing and teaching a high school biochemistry course is a unique and challenging experience because biochemistry is typically offered as an advanced elective in college. College students will have taken general and organic chemistry, as well as other advanced science prerequisites prior to taking their biochemistry course. Instead, the biochemistry class that I have been teaching for the past six years is one of the elective courses offered to juniors and seniors at the Illinois Mathematics and Science Academy (IMSA), a residential high school for students who are talented in math or science. Even though the students enrolled in Biochemistry have an aptitude for math and science, they generally have a wide range of chemistry and science backgrounds. The prerequisite for Biochemistry is only a semester-long sophomore chemistry core course, which means that there can be seniors in the elective who have not taken a chemistry course since the first semester of their sophomore year. Conversely, there are students in Biochemistry who have taken many chemistry electives offered including two semesters of advanced chemistry (equivalent to a college general chemistry course), two semesters of organic chemistry, as well as advanced biology courses that touch on related molecular topics.

To accommodate the diverse student background in Biochemistry, I have developed a learning model called AAAW, which stands for Analyze, Acquire, Apply, and Write. In this model, students first "Analyze" lab data to generate questions that lead them to "Acquire" background knowledge. Students then go back to the data and "Apply" their new knowledge to better understand the data. Finally, students "Write" about the connections they make from their reading, data analysis, and application of the data in the context of current research in the field. I have implemented this learning model to an online biochemistry course and teacher resource material, which will be mentioned later. I have also designed the logo as shown in (Figure 1) in which all four letters are embedded in the image.

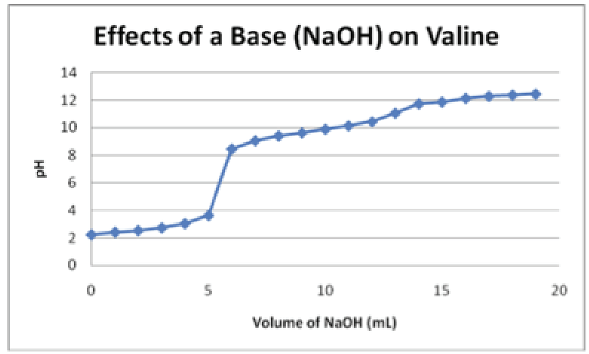
Figure 1. A logo for AAAW learning model, which stands for Analyze, Acquire, Apply, and Write.

The rationale behind how I have developed this model stems from the five initial design elements of the course that I created to help to give students skills and knowledge they need to be successful in the class regardless of their previous chemistry experience. First, I designed practice problems to review previously learned topics and skills, which were especially focused on transfer skills. Often students experience a difficult time transferring their learning to another context. The study I have done shows that a positive effect can be demonstrated in student performance on the unit exam after having them practice transfer skill (Choe, 2014). The practice included spending instructional time in analyzing practice problems in a systematic way and making connections between and within concepts. For example, when students learn about the overarching concepts of equilibrium, they are guided to make connections between different topics that are related to it including osmosis, buffer, and amino acid titration. This is accomplished by providing the students with sets of carefully designed guiding questions that are designed to help them make connections between the topics.

Second, I added more structure to the class by dividing the course into five units that cohesively flow from small to large molecular structures, starting with Water and Equilibrium, Amino Acids to Protein, Protein Structure and Function, Enzyme Kinetics and Inhibition, and finally ending the course with Metabolism (Table 1). The logic behind the sequence is to have students start the course with concepts that are related to the last unit of their introductory sophomore chemistry course, which is equilibrium and acid-base chemistry. This design makes taking the biochemistry course more equitable to the students whose only experience is the introductory chemistry course as opposed to those who have taken multiple chemistry and biology elective courses prior to entering biochemistry. Also, this sequence helps the course to be more coherent as it builds from smaller to larger molecular structures, going from amino acids to proteins, and then to protein function, such as enzymes.

Third, for each unit, students are required to come prepared to class with some background knowledge from the textbook. I provide students with reading questions for guidance and then go over the material in class. Table 2 shows some sample questions from the first unit, which is the one on Water and Equilibrium. I find this method to be more effective than lecturing because students are more engaged in the discussion. From time to time, students are asked to present specific sections of the reading to classmates.

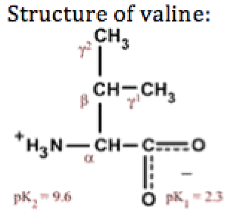
Fourth, students collect and analyze data to look for trends, resulting in learning through inquiry. Examples of student data from titration of amino acid lab and a sample of guiding questions are provided are shown in Figure 2. These questions help to



Sample of Guiding Questions:

1. First, write down all the observations you make.
2. Based on the structure of valine and the pka table provided to you below, can you make connections between all three? What questions do you generate as you are making these connections?

Structure of valine:



pKa table of valine:

	a-CO_2H	a-NH_3+	Side	Side Chain ID
Valine	2.3	9.6	N/A	—$CH(CH_3)_2$

Figure 2. A sample of student data on titration of amino acid lab and guiding questions that are provided to the students

focus the activity so that the students can draw conclusions and build their understanding of concepts. This practice immerses students in the authentic practice of science, which aligns well with the Science Practice Standards from Next Generations Science Standards (NGSS, 2013).

Lastly, I created supplementary multimedia videos that reinforce class concepts so students can review and study on their own time. As this generation of students regularly uses their mobile devices to access information, I created videos specifically for my students to enhance their classroom learning and reinforce the concepts. All students, especially those with learning differences, expressed that they were able to review the materials at their own pace by playing and pausing as needed as they were reviewing the materials outside of their classroom environment. My students as well as others were frequently using these biochemistry multimedia videos. For instance, one of the unedited vid-

Unit 1: Water and Equilibrium Structure and Properties of Matter: HS-PS1-3 Stability and Change: HS-PS1-6 Analyze and Interpreting Data: HS-PS2-1 Constructing Explanation: HS-LS1-3	1. Apply molecular structure of water to thermal and solvent property of water 2a. Relate equilibrium to osmosis 2b. Apply the concept of the water molecule and osmosis to solve problems. 3. Relate equilibrium to buffer.
Unit 2: Amino Acids to Protein Structure and Properties of Matter: HS-PS1-3 Organization for Matter: HS-LS-6 Structure and Function: HS-LS-1, HS-LS1-2 Using Computational Thinking: HS-LS2-1 Developing and Using Models: HS-LS1-4, HS-LS1-5, HS-LS1-7 Analyze and Interpreting Data: HS-PS2-1 Obtaining, Evaluating, and Communicating Information: HS-PS4-5	1. Build background knowledge on structure of amino acid and examine how amino acid structures influence their properties 2. Understand amino acids as building blocks of proteins and how they play role in different levels of protein structure
Unit 3: Protein Structure and Function Organization for Matter: HS-LS-6 Structure and Function: HS-LS-1, HS-LS1-2 Analyze and Interpreting Data: HS-PS2-1 Planning and Carrying out Investigations: HS-LS1-3 Obtaining, Evaluating, and Communicating Information: HS-PS4-5	1. Relate structures of proteins to their functions 2. Use protein technology tools to isolate, purify, and analyze structure of protein
Unit 4: Enzyme Kinetics and Inhibition Chemical Reaction: HS-PS1-4, HS-PS1-5 Analyze and Interpreting Data: HS-PS2-1 Planning and Carrying out Investigations: HS-LS1-3 Obtaining, Evaluating, and Communicating Information: HS-PS4-5	1. Use data and Michaelis-Menten and Lineweaver-Burk plot models to analyze enzyme kinetics 2. Classify enzyme inhibition into competitive, uncompetitive, and mixed inhibitors 3. Apply enzyme kinetics and inhibitions to medicinal drugs
Unit 5: Metabolism Definition of Energy: HS-PS2-1, HS-PS2-2 & HS-PS2-5 Organization for matter and Energy Flow in Organisms: HS-LS-6 & HS-LS1-7 Energy in Chemical Process: HS-PS3-3 & HS-PS3-4 Chemical Reactions: HS-PS1-2 & HS-PS1-7 Developing and Using Models: HS-LS1-4, HS-LS1-5, HS-LS1-7 Constructing Explanation: HS-LS1-3	1. Make connections between metabolic cycles

Table 1. Structure of the biochemistry course provided by the five units

Topic	Sample Reading Questions
Thermal Properties of Water	a. Describe the intermolecular structure of ice, liquid and vapor. Also, discuss how many percentages of molecule form hydrogen bonding. b. Human may eliminate as much as 1200 g of water daily in expired air, sweat, and urine. The associated heat loss may amount to approximately 20% of the total heat generated by metabolic processes. How is this possible?
Solvent Properties of Water	Water is ideal biological solvent. It easily dissolves a wide variety of the constituents of living organisms. a. Describe hydrophilic molecules: b. Describe hydrophobic molecule (Water Hating):

Table 2. Sample Reading Questions from Water and Equilibrium Unit

eos I quickly created on Amino Acid Titration for my students, http://www.youtube.com/watch?v=T-wa0LiKCRc , gained thousands of viewers in a year.

What other challenges do we face as educators as technology advances? I have noticed a couple of shifts among the way my students learn. Students are spending more time acquiring their knowledge from electronic and mobile devices rather than from textbooks. Also, they score better on quantitative type questions on their assessments compared to qualitative type questions (Figure 3). This result shows that there is a need for my students to improve their explanation skills. For instance, my sophomore students from Introductory Chemistry Course-Scientific Inquiries in Chemistry (SI Chemistry) offered during Spring 2013 demonstrated a test average of 92% when the assessment was primarily focused on their quantitative skills compared to 76% as the focus shifted to assessing their qualitative skills ($p < 0.05$). The assessment that measured students' quantitative skills was based on the Stoichiometry unit and the assessment that measured their qualitative skills was based on the Equilibrium and Acid-Base Chemistry unit. In the Biochemistry elective, the gap between student performance on the quantitative and the qualitative scores on the unit exams decreased by 5%. Although there may be a limitation in comparing student performance from two different courses, students enrolled in the Biochemistry elective still did significantly better on the unit test on Enzyme Kinetics, which was quantitative in comparison to the unit test on Protein Structure and Function, which mainly required qualitative reasoning. The average on the Enzyme Kinetics unit test was 92% as opposed to 81% on the Protein Structure and Function test. While the difference is still significant, the decrease in the gap between the qualitative and quantitative exam scores may be due to self-selection in that students who have done well on chemistry or biology tend to take the biochemistry course. This difference in their performance is shown in Figure 3.

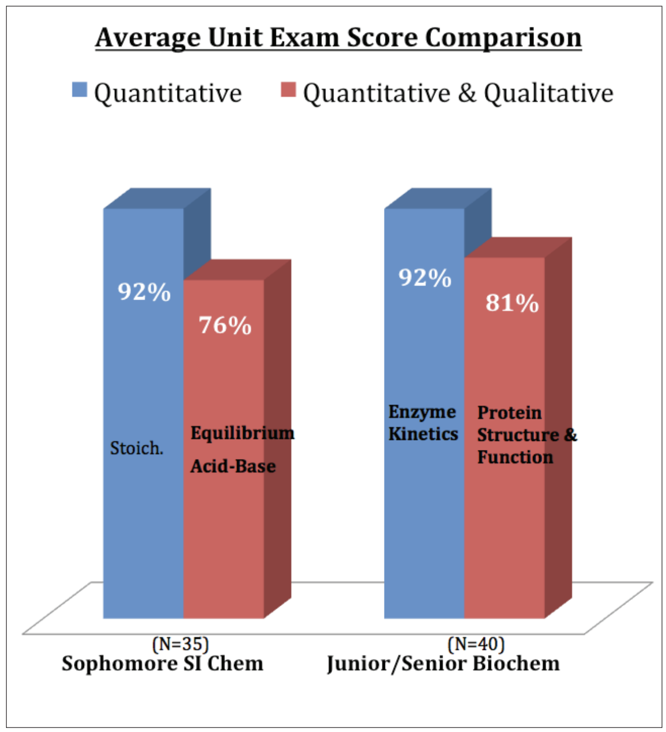


Figure 3. Student performance on quantitative versus qualitative based test in two courses, Scientific Inquiries in Chemistry and Biochemistry offered during spring semester of 2013, significant at the p<0.05 level.

Due to the strong need that I see in my own students to improve their ability to learn and explain qualitatively, I started including more writing pieces that required students to explain their understanding. This also led to designing an online biochemistry course where students are guided to make connections and explain through writing. This type of a writing-focused course may not be a typical setting for a science class and it may be more challenging to engage students without being face-to-face. However, computer-mediated communication can encourage more distributed participation and equitable discussion (Swan, 2002). This could mean that the online biochemistry course can be a place for students to write to learn and improve their skills in explaining their understandings qualitatively. If designed well, even the introverted students who may not typically participate in verbal discussions and/or the students that may dominate the discussion could more equitably contribute their thought process and gain from feedback on the topics covered.

In my experience described previously, students in the biochemistry elective need to improve their qualitative learning. This need, in conjunction with the five design elements of the biochemistry course, led to development of a one-semester online Biochemistry course to implement AAAW model. This course addresses fundamental concepts in chemistry, such as Equilibrium, Acid-Base, and Kinetics that addresses chemistry in the context of biology. The content includes: 1) applying equilibrium process to study biochemical reactions as well as cell structure, 2) studying the structure and function of amino acids and proteins, and 3) analyzing the kinetic parameters of enzymes including different mechanisms of how drugs are used to inhibit enzymes. The course is similar to my traditional course (Table 1) except Metabolism is not included in the online version. That is because the extra time that is originally designed for learning about connections in metabolism in biochemical pathways is spent in writing about making connections, and applying, and transferring the learning to literature articles. The online course is designed for non-IMSA students who do not have access to a biochemistry course in their schools. Also, this online offering can be used by teachers who are interested in adapting the AAAW model or in need of a resource to develop units in amino acids or protein, and/or to design a high school biochemistry course.

Lesson	Learning Outcomes	Learning Model, Content, Process	Assessments
2-1 Analyze	Analyze the titration pattern of amino acid that is similar to buffer.	*Student will be analyzing the data from the titration of amino acid lab	*Assess student ability to make observation and generate questions on titration of the amino acid lab.
2-2 Acquire	Build background knowledge on structure of amino acid	*Students will acquire knowledge on basic structure of amino acids. *Students will acquire background knowledge on how amino acid can be in protonated and deprotonated form based on the buffer condition it is placed in.	*Assess student ability to acquire background knowledge and answer questions about the structure of amino acids.
2-3 Apply	Utilize the background learned from 2-2 in analyzing the data given in 2-1 Apply the titration of amino acid to buffer and solve buffer type problems	*Apply the background acquired to further analyzing the data *Students will be solving problem	*Quiz: Assess student ability to solve amino acid and buffer problems
2-4 Write	Write a review article making connections from 2-1 thru 2-3 to the article	*Apply concept of buffer and amino acid titration to a research article, a case study of a patient experiencing imbalance and acidosis in the blood buffer system.	* Writing Assignment: Assess students ability to make connections between concepts and write their own review article

Table 3. A sample of how AAAW is used in one of the units on Equilibrium in Amino Acids

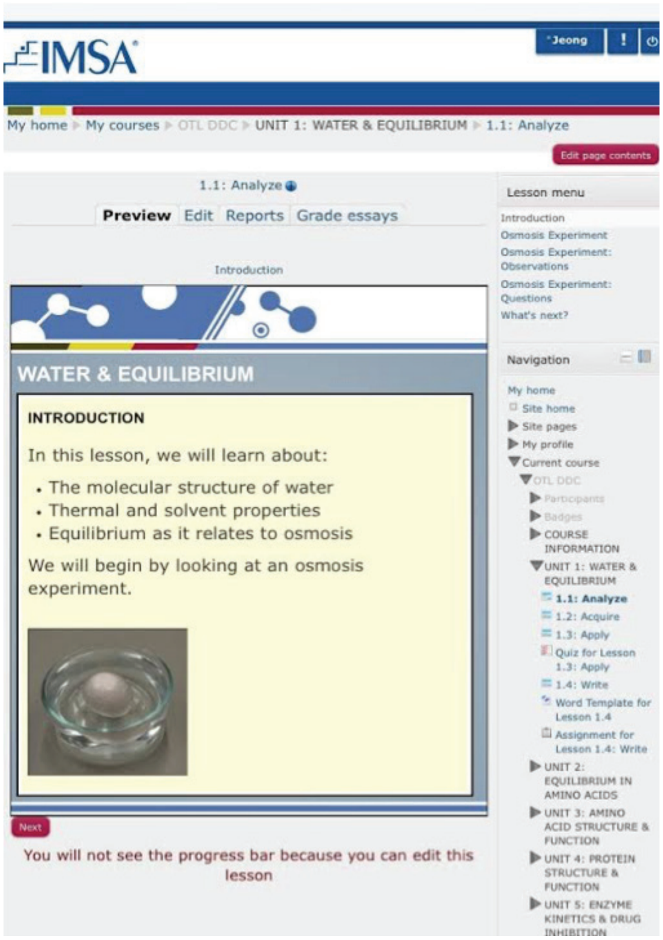


Figure 4. A snapshot example of an introduction page to the Water and Equilibrium unit that outlines the goals for the section

The online biochemistry course is built on the Analyze, Acquire, Apply and Write (AAAW) model that I developed. A sample of AAAW model for one of the units on Equilibrium in Amino Acids is shown in Table. 3. The online course, similar to the original course (Table 1), consists of the following five units in order: Water and Equilibrium, Equilibrium in Amino Acids, Amino Acid Structure and Function, Protein Structure and Function, Enzyme Kinetics and Drug Inhibition. The main difference is that the online version is writing-focused and follows the AAAW model.

As I created and used the AAAW model for my online biochemistry course, I wanted to outline the goals clearly for both teachers and/or students in each unit to avoid any confusion (Figure 4). I also tried to address the following question in my course design: How can the online biochemistry course be effectively used either by students or teachers of students who have been exposed to digital media their entire lives? This question was addressed by adding interactive pieces such as having students write

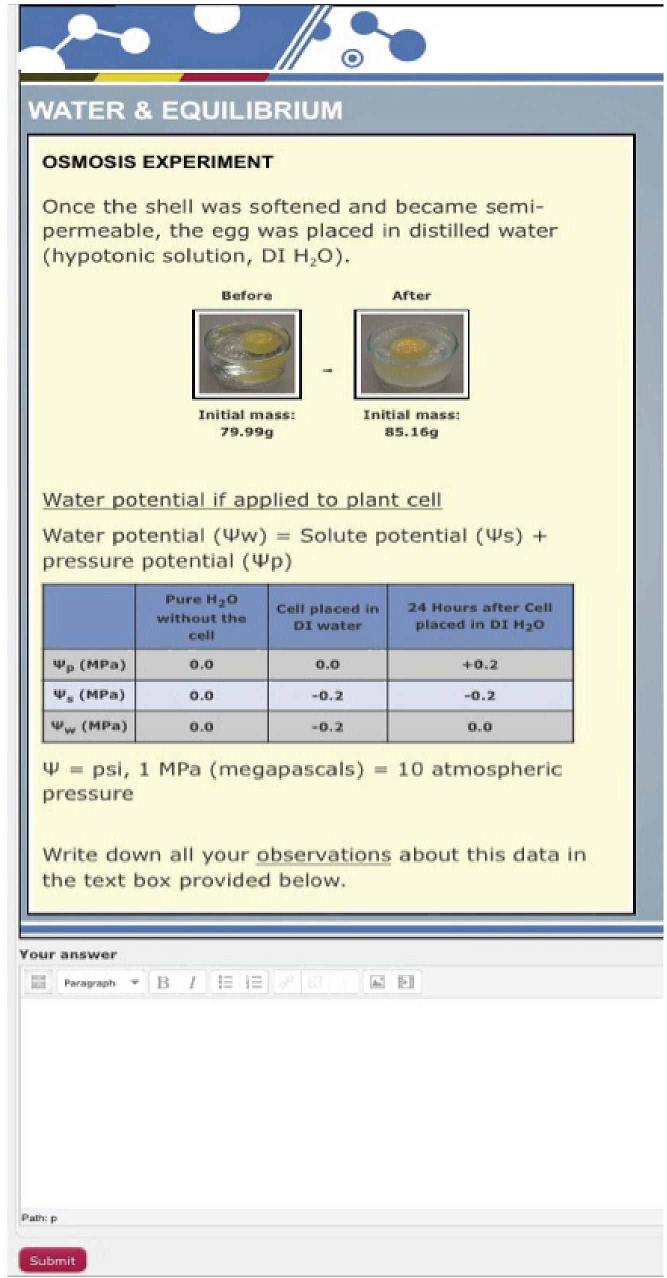


Figure 5. A snapshot example of "Analyze" section from Water and Equilibrium unit, which shows an interactive piece of where students have to make an observation of data to move on to the next step.

data-driven analyses (Figure 5). Students are also asked to share their analysis before they move onto the next step, which serves as a personalized learning space for each student as they write about their own analysis of the data, explanations of their understanding and connections they make as well as others. This model also may help teachers who are used to traditional ways of teaching to adapt to changes in how students learn and process information. It has become more important that students express their understanding as they have tendency to passively gain understanding through online materials rather than integrating knowledge and expressing qualitatively. I offer the AAAW model as one of the data-driven ways to promote student writing in science classes. This is accomplished as students initially start with data analysis, then acquire concepts that allow them to go back to the data and further apply their understanding. I hope deeper understanding of concepts occurs as students write about connections they make during the AAAW processes.

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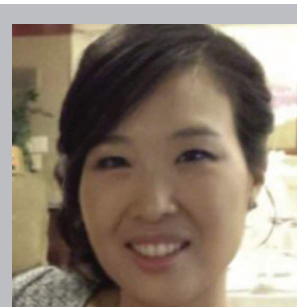
REFERENCES

Choe, J. (2014). Developing Transfer Skills in a Biochemistry Class, ISTA Spectrum, 39: 3,19-24.

Next Generations Science Standards (2013). Retrieved July, 2014 from http://www.nextgenscience.org/sites/ngss/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

Swan, K. (2002) Building Learning Communities in Online Courses: The Importance of Interaction, Education, Communication & Information, 2:1, 23-49.



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