A Study on the Use of Protein Crystallization with Standard Physical Science and Honors Physical Science Students

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Abstract:

Entering high school freshmen at Ponte Vedra High School in the St. Johns County school district are enrolled in one of four science courses depending primarily on where they are in the math course progression and on teacher recommendations. The strongest students begin with Biology 1 Honors. Those freshmen who did not take Algebra I in middle school generally take Physical Science Honors. The weakest freshmen take standard Physical Science. The course descriptions for Physical Science and Physical Science Honors are quite similar, and they include expectations that students evaluate the impact of biotechnology on individuals, understand the concept of pH, and explore applications of the theory of electromagnetism. I propose to evaluate and compare the understanding of protein crystallography and its applications for biomedical research in Physical Science and Physical Science Honors students. Specifically I propose to use the Lysozyme Crystallization protocol developed by Robert McKenna, PhD, and evaluate students using multiple choice and short answer questions. In addition I will assess student attitude towards biotechnology after completion of the lesson.

Rationale:

Because the Florida State Department of Education course descriptions for Physical Science (20003310) and Physical Science Honors (20003320) are extremely similar, while the student populations are distinct, and because I will be teaching both courses for the first time during the 2010-2011 school year, I am interested in comparing learning outcomes in these two populations of students following a lecture and hands-on laboratory experience in protein crystallography. I hypothesize that the Physical Science Honors students will perform better on objective assessments of knowledge acquired during these activities because they were identified as “honors” students by their middle school teachers. However, I predict that the students taking the standard Physical Science course will have a more positive attitude toward biotechnology because they are typically not exposed to laboratory activities using innovative technology and the novelty may provide a more excitement.

Dunham, T. , & White, K. (2002) argued that biotechnology teaching should incorporate a blend of direct instruction, cognitive problem solving, and constructivism. Consistent with their findings, I intend to introduce the science of protein crystallography using a direct teaching approach. Next I will instruct students on the laboratory procedures, and encourage them to use their cognitive abilities to implement the protocol and modify it when appropriate. Finally, I will use video and anecdotal clinical studies from Dr. Robert McKenna’s presentation to assist students as they construct their own appreciation for this technology’s applications to medicine.

Dawson, V., & Soames, C. (2006) used a pre-test post-test scenario and observed that, after a 10-week course in biotechnology, students in Australia demonstrated increased understanding of the technology, but little change in their attitude towards applications of biotechnology, with the exception of their increased acceptance of medical applications of biotechnology. The researchers were not able to discern a trend in individual student’s responses to questions about the morality of biotechnology before and after completing the biotechnology curriculum. I will also evaluate both understanding of and attitudes towards biotechnology in my research.

Dawson, V. (2007) surveyed 12-17 year old students with regards to their understanding and approval of various biotechnology applications, and determined that older students generally responded more favorably towards biotechnology than younger students. This research involved interviews and surveys. I am interested to determine whether there is a significant attitude difference in my two student populations following their biotechnology lesson. I understand that there are many variables between these populations and the results will need to be interpreted with caution.

The purpose of this study is to compare the effects of a lecture and a hands-on laboratory experience in protein crystallization on two groups of students’ understanding of this biotechnology application. Student understanding will be measured objectively using multiple choice and short answer questions. A Likert scale will be used to assess attitudes towards medical applications of biotechnology.

Action research intervention:

Protein Crystallization Lesson Plan.

Lesson Title: Protein Gems

Grade Span: 9th and 10th grade high school students

Content Emphasis: Physical Science and Biotechnology

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School: Ponte Vedra High School

District: St. Johns County

Learning Goals: This lesson will teach students a variety of kinesthetic and cognitive skills. They will learn to

- accurately pipette small volumes of solution using micropipettes,
- collect data in a student-generated data table,
- graph data,
- interpret phase transitions using kinetic molecular theory,
- identify variables that influence the formation of protein crystals,
- form rational hypothesis about the effects of pH on the structure of and formation of crystals from lysozyme,
- form rational hypothesis about the effects of salt concentration on the structure of and formation of crystals from lysozyme,
- explore applications of the theory of electromagnetism to x-ray crystallography, and
- describe how protein crystallization can be used in rational drug design.

Estimated time: This lesson will require approximately 7 days of class time (45 minutes/day).

- Day 1 – introduction to protein crystallography
- Day 2 – introduction to micropipetting
- Day 3 – set up protein crystallography lab
- Day 4 – applications of protein crystallography to rational drug design
- Day 5 – data collection and graphing

- Day 6 – data interpretation and conclusions
- Day 7 – qualitative and quantitative assessment of student learning

Materials and Resources:

This activity will require

- “Clickers” and appropriate pre-test quiz to diagnose misunderstandings of pH, phase transitions, and kinetic molecular theory.
- Dr. Robert McKenna’s PowerPoint presentation to CPET Bench-to-bedside teachers on June 24, 2010
- Copies of the “Crystallization Hand on, Lysozyme crystallization” lab instruction.
- Micropipettes and tips (P-1000,P-200 and P-20)
- 64 well dishes
- Two colors of dye for practicing micropipetting
- 24-well Limbro plate
- forceps
- Plastic micro-bridges for use in Limbro plates – 12 per student group
- 22 mm Round cover slips for covering wells
- Vacuum grease and tooth picks for sealing cover slips on trays
- Lysozyme at 50 mg / ml – on ice
- ddH_2O
- 4M NaCl
- 0.5M Sodium Acetate, pH 4.2
- 1M Tris-HCl, pH 7.0
- Dissecting microscopes
- Objective quiz to measure student learning
- Likert quiz to measure student attitude towards medical biotechnology

Teacher Prepartion:

In preparation for this lesson, teacher should

- Review Dr. McKenna’s PowerPoint presentation
- Make copies of Lysozyme crystallization lab instructions
- Make copies of micropipette practice lab instructions

- Develop and makes copies of quiz and Likert survey

Lesson Procedure and Evaluation

Introduction:

I will introduce this lesson by reviewing concepts of pH, kinetic molecular theory, and phase transitions, and I will assess student understanding with eInstruction ("clicker quizzes"). I will attempt to clarify any misconceptions.

I will ask students to brainstorm in small groups and propose ways this physical science information could be used to improve human lives, how they think medical research scientists identify new drugs to treat disease, if they have heard of drugs that lose their effectiveness, and what they think the term "rational drug design" means. I will tell them that they will now engage in an activity used by research scientists who are rationally designing pharmaceutical drugs.

Exploration: After teaching students to micropipette accurately, I will allow them to set up a 24 well Limbro plate containing varying concentrations of NaCl at two different buffered pH levels (4 and 7). Students will then add lysozyme protein to sitting and hanging drops. After 4-7 days, students will evaluate the results of the experiment and determine which combination of NaCl and pH allowed the formation of large protein crystals.

Application: Students will be able to apply their knowledge in data collection and graphing to a wide variety of laboratory activities both in this course and in future science courses. They will be able to apply the technique of micropipetting to future labs in this course on PCR of genomic DNA and electrophoresis of PCR-generated DNA fragments. Students will be taught applications of protein crystallization technology to rational drug design using Dr. Robert McKenna's PowerPoint lecture given to teachers at the 2010-2011 Bench to Bedside summer workshop.

Assessment: Students will be assessed with objective multiple choice and short answer questions on the following SSS benchmarks:

MA.912.S.1.2 (Determine appropriate and consistent standards of measurement for the data to be collected in a survey or experiment.)

MA.912.S.3.2 (Collect, organize, and analyze data sets, determine the best format for the data and present visual summaries from the following: bar graphs, line graphs, stem and leaf plots, circle graphs, histograms, box and whisker plots, scatter plots, and cumulative frequency graphs).

SC.912.L.16.10 (Evaluate the impact of biotechnology on the individual, society, and the environment, including medical and ethical issues).

SC.912.N.1.1 (Define a problem based on a specific body of knowledge….. Basically use the scientific method).

SC912.P.8.11 (Relate acidity and basicity to hydronium and hydroxyl ion concentration and pH).

SC,912.P.10.18 (Explore the theory of electromagnetism by comparing and contrasting the different parts of the electromagnetic spectrum in terms of wavelength, frequency, and energy, and relate them to phenomena and applications).

SC,912.P12.11 (Describe phase transitions in terms of kinetic molecular theory).

Teacher Self-Reflection:

Connections to Bench to Bedside summer institute:

The protein crystallization technique used in this study will be nearly identical to that developed by Dr. Robert McKenna for the Bench-to-Bedside summer institute for teachers through CPET at University of Florida. We will utilize the technology made available by the CPET staff to conduct the experiments and study the applications presented in Dr. McKenna's PowerPoint lecture on June 24, 2010.

Data Collection and Analysis:

Students will be divided into two groups: those enrolled in Physical Science (Group 1) and those enrolled in Physical Science Honors (Group 2). Each group's understanding of crystallization will be evaluated prior to the laboratory experience. Each group will be asked to complete an objective assessment of their understanding of crystallization after completion of the laboratory activities, and the number of correct responses from each group will be compared. Pretest and post-test data will be summarized by mean, standard deviation, and analysis of variation statistics. Data collected about the two groups of student's attitudes towards biotechnology will also be compared and summarized.

Literature cited:

Dawson, V. (2007). An Exploration of High School (12–17 Year Old) Students' Understandings of and Attitudes Towards Biotechnology Processes. *Research in Science Education 37,* 59–73.

Dawson, V., & Soames, C. (2006). The effect of biotechnology education on Australian high school students' understandings and attitudes about biotechnology processes. *Research in Science & Technological Education, 24:* (2), 183-198.

Dunham, T., Wells, J., & White, K. (2002). Biotechnology Education: A Multiple Instructional Strategies Approach. *Journal of Technology Education, 14* (1) 65-81.

Budget and budget justification:

The $200 equipment will be applied towards the purchase of consumables including lysozyme, and 24-well Limbro plates. Any remaining funds will be used to purchase student test tube racks and ice buckets.

Assessment of student attitude towards biotechnology.

Please respond to the following items by drawing a circle around the number corresponding to the response that most closely reflects your opinion: strongly disagree (1), disagree (2), undecided (3), agree (4), or strongly agree (5).

		Strongly disagree	Disagree	Undecided	Agree	Strongly agree
1.	I feel good about my problem solving skills.	1	2	3	4	5
2.	My problem solving skills increased as a result of this laboratory activity	1	2	3	4	5
3.	My understanding of biotechnology has increased as a result of this activity.	1	2	3	4	5
4.	My interest in biotechnology has increased as a result of this activity.	1	2	3	4	5
5.	I enjoyed the experimental aspects of this activity.	1	2	3	4	5
6.	I want to learn more about jobs in the biotechnology industry.	1	2	3	4	5
7.	I am interested in pursuing a career in biotechnology.	1	2	3	4	5
8.	I understanding of the processes associated with “rational drug design”.	1	2	3	4	5
9.	I have an increased understanding of the ways that mathematics can be used in biology.	1	2	3	4	5
10.	Research on medical applications of biotechnology should be funded by tax dollars.	1	2	3	4	5