TEACHING AND LEARNING PORTFOLIO

by

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Introduction

There are many concepts and practices that are important to me in my approach to teaching. So many, in fact, that I found it difficult to try to summarize my thoughts about teaching and learning, and my experiences as a teacher and mentor in this one document. Despite this difficulty, I have chosen three concepts (collaboration, inquiry and critical analysis) and have highlighted these in my teaching philosophy. My teaching philosophy acts as a map and outline for the rest of my portfolio. My portfolio is organized into three sections of reflections and artifacts, each section focusing on one of the three concepts. Through these reflections and artifacts, I attempt to illustrate how I implement my teaching philosophy in practical situations across diverse settings: from the college classroom, to the greater scientific community, and lastly to mentoring in the laboratory.

Summary of my Delta experience

I believe excellence and scholarship in education is a critical to being a successful professor. However, my graduate program focuses mainly on research, leaving it to me to find avenues for learning how to be a successful educator and mentor. I have striven to take advantage of opportunities on campus to supplement my growth in the area of science education. The Delta program (www.delta.wisc.edu) has been instrumental in organizing many of these outside experiences into a program of progressing understanding and responsibilities, leading to the defense and certificate. My experience with Delta and the Delta community has helped me to build a cohesive understanding of my teaching experiences. The community has been an invaluable resource, providing expertise and council about science education that I could not find elsewhere. In the Delta classes, I obtained broad coverage of concepts in science education, highlighting many areas I may not have found on my own. In particular, the emphasis on diversity in each class developed my awareness and sensitivity to issues beyond my own personal experience and has become an integral part of my approach to science education. Specifically, my approach to evaluating the quality of learning materials has been transformed and now includes careful consideration of the students as individuals, each with his/her own qualities that may impact the efficacy of these materials.

The addition of the internship, acting as a practical realization of past course discussions, helped me cement concepts and learn caveats involved in classroom implementation. For example, I have learned first-hand about the time investment involved in active learning opportunities. In addition, the internship experience and my participation in Expeditions in Learning provided me with opportunities to reach out to the University of Wisconsin, Madison campus and become involved in the larger community of science educators and learners. Understanding how different types of science classes are structured and how different instructors approach teaching has been instrumental in helping me create an idea of what my own preferences are, and has allowed me to introduce new ideas and materials to Biology 151, hopefully making a difference in how this class will be taught.

Overall, by preparing me to be a successful educator and mentor, my experience in Delta has been at the core of my personal journey of preparing to be a successful professor.

Teaching Philosophy

Teaching Students to Become Scientists

When learning science, students need to learn content, but they also must learn how to think and act as scientists. It is vital to create a classroom where learning scientific content is interwoven with learning the discipline of science. Many students bring the misconception that science is a world of black and white with them into the college science classroom. Instructors have an enormous influence on their students and with this influence comes a responsibility to take great care in teaching each individual student not only course content, but also a deeper understanding and appreciation of how science works. This is important for all students, not just science majors. Collaboration, inquiry, and critical analysis are essential tools for creating an environment that mimics the greater scientific field and facilitating the formation of a learning environment where students take an active role in engaging with each other and with the content, while also becoming discerning consumers of that content.

Collaboration

Progress in science relies on discussion, multiple approaches, and teamwork. I instill the students with an appreciation of the importance of working and discussing science with one another. Working cooperatively encourages student ownership of the scientific ideas they are studying, which is important for engaging students in science and enhancing understanding [1]. Collaborative work in the classroom also facilitates peer-learning, creating a community of learners where students can teach and learn from one another in a reciprocal fashion [2]. Therefore, I think it is important for instructors to use group activities. It was for this reason that I designed and implemented case studies used as collaborative activities in a biology course at the University of Wisconsin, Madison. After working together, students become aware of new perspectives and listen to each other with respect. In this way, students interact with the content in an open environment and learn the collaborative aspect of science.

However, in addition to this student-student collaboration, collaboration must also exist between the instructor and the students. I view my role as a mentor as a form of collaboration. While mentoring students in my current research laboratory, I thought of my mentees as scientific collaborators. Guiding students, but also really listening to them and being open to their diverse backgrounds and experiences, encourages a true and equal exchange of ideas. Collaboration via mentoring can also be used in the classroom. By being open to an exchange of ideas about the course, the students and I become collaborators, together creating the end product. I used periodic anonymous feedback questionnaires in my teaching assistantship to foster this interchange of ideas. I believe this interchange of ideas is essential for the second tool, asking questions through the process of inquiry.

Inquiry

Inquiry, asking questions and testing answers, engages students in the process of science [3] and naturally fits within the collaborative setting. Inquiry allows students to try new approaches and examine the process of scientific investigation and experimental design. It is the responsibility of the classroom instructor or research mentor to integrate exploration of experimental possibilities into the laboratory. Students then have the responsibility to take an active role in exploring these

possibilities. This flexibility allows the students to learn in a differential fashion – using their own learning styles and approaches to understanding. In my teaching assistantship, I provided diverse materials in the laboratory to facilitate student inquiry and to allow students to use their own ideas of how to approach scientific questions.

However, the laboratory is not the only setting for inquiry. Small group discussions and whole-class discussions conducted in lecture lead to conversations about how to test scientific questions experimentally. During my guest lecture experiences, I found that given the chance, students took the opportunity to ask questions in both small and large group discussions. By way of this foundation in inquiry, formed both in the laboratory and in the lecture, students become amateur scientists – asking questions and then thinking about how to test possible answers. It is essential to teach how to ask and discuss questions, if we want students to be able to think critically about scientific pursuits.

Critical Analysis

Students cannot be expected to critically analyze scientific material if they think of science as black and white. However, in a collaboration- and inquiry-based environment, students are able enter into the real world of science, where debate dominates the field. To develop students' ability to be critical of scientific data, it is important to discuss the experimental basis for established scientific mechanisms [4]. Experimental processes should be discussed in terms of their strengths and weaknesses. Students learn that there is no such thing as an experiment that "proves" a hypothesis and that science is built on good fits and good reasoning. This understanding grows within the laboratory, where students quickly learn that experiments have their weaknesses and are subject to the environment and to human error. In lecture, critical analysis skills can be enhanced if students interact with scientific literature as early as the first semester in college. Discussion and analysis of empirical data can be interwoven with the presentation of new course material. While mentoring a high school student in the laboratory, we spent time discussing how to access scientific literature and asking questions about papers related to our project. Because of this, I believe my students more fully appreciated the contribution of his project to the larger field. Learning how to access publications and how raw data is interpreted into conclusions is essential for learning how to think critically about science. These skills will enable students to develop into mature citizens who will be able to make intelligent and informed decisions based on scientific evidence.

These three core aspects of science — ***collaboration***, ***inquiry*** and ***critical analysis*** — lead to a learning environment that comprises a culture of mutual respect and cooperation, fosters self-motivation to learn, and enables genuine analysis of course material. In this way, students studying science content grow and become able to think and act like true scientists.

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Collaboration and Reciprocal Learning

Reflection and Artifact #1

Reflection

To instill the value and the feeling of collaboration within the classroom, I think it is important to increase the amount of collaborative and reciprocal learning that takes place among the students and also between the students and instructor. It is important for students to understand that they can learn a great deal from their classmates, and that I can learn from them just as they can learn from me.

I designed and used an in-class activity involving a case study about cellular respiration as part of my internship program with Delta. As described in the artifact, I worked with a faculty member to integrate a newly developed animation and set of case studies into a large introductory biology course (Bio151). The case studies were designed to incorporate collaboration among the students and between the students and the instructors. All of the case studies were conducted in groups and responses were collected and read by the instructors. This way, the students were not only working together, but their level of understanding was shared with the instructors, thereby acting as a communication link between the instructor and the students.

The analysis of test scores before and after the in-class case study implementation shows small improvements in content knowledge and some student support for the use of the case study in lecture. However, the response was not as positive as I had hoped. I think that there were some substantial flaws in the implementation of the case study, rather than a problem in the case study or in the idea of using the case study in lecture. In short, I think the process was too rushed and not enough time was given to the students to work together on the case study. In addition, the case study was too independent in that it was not mentioned in the lecture slides. Student responses in the post-implementation survey were diverse, but reflected a desire for more time and for more discussion of the case study and how it related to lecture material.

One of the lessons I learned from this experience is that collaboration in the classroom can be a valuable part of the students' experiences, but it takes time. Collaborative activities will likely lead to a cut in lecture time, and all instructors involved in the class need to be willing to make these cuts. I also learned that the collaborative activity is less powerful on its own and is more worthwhile if it is integrated into the class as a whole, becoming a part of lab, lecture, and study time. In particular, if enough time is given to the activities, the students are able to connect with their fellow students and only then will they really start to learn from each other. Lastly, I learned that it takes practice to implement new activities in a class. My internship project was the first time these materials were implemented, and thus can be considered pilot of the materials. This pilot will serve to improve future classes, and the next implementation should be more successful. In the end, I believe this implementation did achieve its main goal – to bring the students together and allow them to learn from each other, and to give the students a way to communicate to the instructors and for us to learn from them. Most importantly, this experience has convinced me to strive to achieve this goal in all of my classes.

Artifact #1

Delta Internship Reflections and Summative Report

REFLECTIONS

Teaching-as-Research

In my internship, I explored the process of introducing and evaluating new instructional materials. Our goals were to increase student performance, as well as to increase interest in the content and increase diversity in the content delivery. We assessed our success toward these goals using a pre- and post-test system, comprising content and attitude questions. I believe these assessments were appropriate, but the timing could be improved. Although it was good to get some immediate reactions to the new materials, it would have been helpful to get student responses to the materials after they had more time to use them. The assessment materials did provide substantial feedback and data on student attitudes to and evaluations of the new materials. It might be helpful to add a question about how student interest in the content has changed.

This internship has confirmed my belief that student feedback is invaluable when assessing teaching. I will continue to use formal and informal periodic feedback in my classes. I have learned a lot about the challenges of working with other instructors and within a class structure. Highly networked classes, involving many instructors of different levels, make change very difficult. Not only are there a lot of people to work with, but also it can be hard to change the section one is responsible for without asking other people to change their sections. In the future I will involve auxiliary participants earlier in the process and budget more time for working with other people.

Learning Community

I really enjoyed creating the materials for my internship through Delta's Instructional Materials Development course. I feel that my faculty and graduate partners were equal contributors and that we really formed a community while trying to work on this problem. It was exciting to be involved in this process from idea generation to implementation. I hope that my faculty partner continues to improve on the materials and employ them in his future classes. It would be very rewarding to hear about the evolution of these materials. I also enjoyed the community we formed within the Delta Internship Seminar series. It was very interesting to see the different types of projects being implemented and the different areas that presented challenges. I appreciated having a format outside of my internship group to discuss my internship project and experiences.

After my internship experience, I became more aware that learning communities are important for collaborative projects. Having a one-time quick classroom experience is probably much less effective than using the materials in an experience where the students work together often and truly begin to learn from each other. It would be interesting to test this hypothesis the next time these materials are implemented.

Learning-Through-Diversity

Part of our goal in developing the materials was to create more options for non-traditional students. We hoped that the animation would help both global and visual learners, while the case study would help kinesthetic learners. We also made the materials available on-line for students to access and use independently in their own way. In addition to trying to support the diversity of learning styles, we used small-group

discussion, in an attempt to give everyone a chance to contribute. There were many students who reported that they appreciated the different approach to learning provided by the materials, providing evidence that there may be students with different learning styles or abilities who were able to capitalize on the benefits of these new materials. However, I think more students would have benefited from the materials, if the materials were part of a series of group activities. As discussed in the learning communities section, I think spending time developing connections between the students might enhance the amount gained from the materials, as well as the involvement of students who may not initially be as comfortable or able to interact with other students.

SUMMATIVE REPORT

Introduction

In this internship, I applied and analyzed new instructional materials developed in Delta's Instructional Materials Development course. These materials, a set of case studies and an animation, involved the topic of cellular respiration (glycolysis, the Kreb's cycle and the electron transport chain). We focused on improving the lecture on this topic because Dr. Nihal Ahmad, the partner for this internship, found that students had many difficulties in this area when he taught in the Fall 2006 semester. The developed materials were incorporated into the introductory level course, Bio151, comprising 3 lecturing professors, approximately 200 first- and second-year students, 3 graduate teaching assistants, and laboratory personnel. I evaluated the efficacy of materials used in two lectures taught by Dr. Ahmad. Results from Fall 2006 were used as control group data. I created a pre- and post-test to examine gains in learning, student attitudes and, using control group questions, efficacy of the materials themselves.

During the Delta course, we consulted the literature to find evidence of misconceptions that interfere with understanding of cellular respiration. Some of these misconceptions included: 1. Thinking cells get energy from air; 2. Believing plants do not respire; 3. Thinking respiration occurs only in the lungs; 4. Difficulty transitioning between cellular and organismal levels of understanding [1-7]. Overall, the references identified the problems, but did not test remedies. However, most groups suggested that acknowledging the misconceptions and addressing them in class would be an effective way to minimize their impact and increase students' understanding. In order to identify misconceptions within ~~out~~ our general audience, we used diagnostic assessments to better define the difficulties students were having in Bio151 and also used in-depth pedagogical discussions and research to find a way to confront the identified problems[8-18]. The end result of these efforts was the development of the case studies and an animation.

Before the unit on cellular respiration, the students were given a multiple choice pre-test examining their understanding of the content. At the beginning of lecture 1 of the unit, Dr. Ahmad played the animation without annotation. After this, lecture 1 continued, using stills from the animation in a traditional Power point presentation. After the content presentation, we had originally planned to allow 15-20 minutes for small- and large-group discussion of the case study. However, in practice, students spent about 5 minutes discussing a case study with two or three of their neighbors (Appendix

I), and the group worksheet and large-group discussion were cut. Lecture 2 started with more presentation of material, using Power point lecture, containing stills from the animation. The case study was mentioned at one point in the presentation. At the end of lecture 2, the animation was shown in its entirety, but this time with labels. The original plan was to use the last 15 minutes of class to revisit the discussion on the case study and to conduct the post-test at the beginning of lecture 3. However, this plan was rearranged and the last 15 minutes of the class were dedicated to the post-test. This post-test included questions from the pre-test, questions from the Fall 2006 semester unit test, and attitudinal questions about the materials (Appendix I).

Both the case studies and the animation were designed to include students with different learning styles. Together, they provide opportunities for visual, global, sequential, and kinesthetic learners. TA assistance during the implementation of the small-group discussions attempted to ensure the involvement of students who may not identify with others in the class and may be excluded otherwise. In addition, the animation and case study were available on-line for students who prefer independent learning, who require more viewings of the materials, or who have special needs. The use of small-group discussions was used to encourage learning communities within the class and as the class as a whole. Students were encouraged to work with others outside of class to think about the other 2 case studies that were not used in lecture.

Results

Answers to the content questions showed a small increase in percent correct for most of the questions. For a list of the content questions and answers, please refer to Appendices I and II. The 2 questions that saw a small decrease in percent correct each had 2 sets of possible answers: organismal-level and cellular-level. Answers “Because oxygen will replace carbon dioxide in the cells”, “To increase lung capacity and relax muscles”, “The yeast are enzymes that break down the flour”, and “The yeast expands when combined with the other materials” were considered organismal-level answers, and answers “To increase the amount of oxygen in the blood,” “To increase the amount of oxygen for glycolysis,” “The yeast creates the texture by making the dough sticky,” and “The yeast makes the bread rise by producing CO_2” were considered cellular-level answers. For these 2 questions, there was an overall increase in cellular-level answers, suggesting that students did move from an organismal understanding to a cellular understanding, but were distracted by incorrect cellular-level answers (Figure 1).

Answers to the attitude questions show most students felt that there was some advantage to using the new materials in the course (Figure 2A). For a list of the attitude questions, please refer to Appendices I and II. However, the feedback for the individual materials was lukewarm (Figure 2B). Most likely, this is due to problems with the implementation or the materials themselves (see next section). The open-answer attitude questions provided information about what the students liked and disliked about the materials (Figure 2C). Suggestions for improvement based on this feedback can be found later in this report. In short, the animation was cited as providing a good visual overview of the processes, although it would be improved with more labels and a slower pace, while the case study provided rationale by showing a practical application of the material to a real-world situation, but would be improved with more discussion in class and more discussion of the answers.

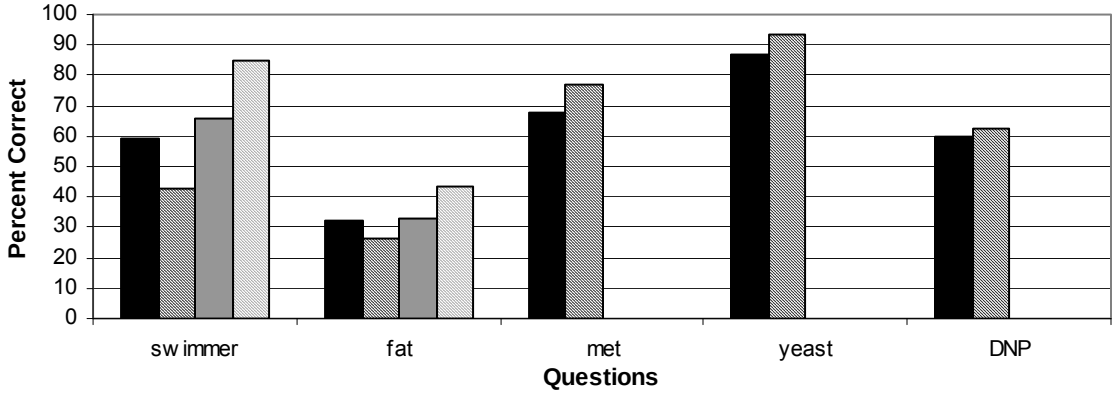
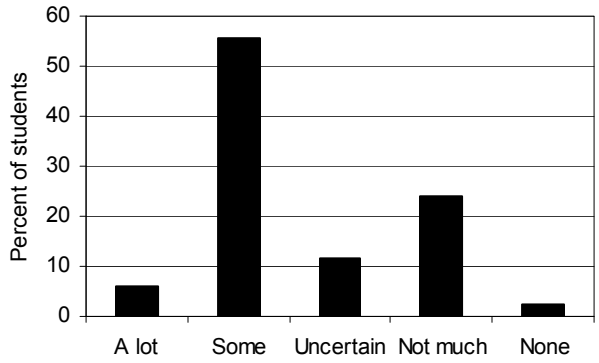


Figure 1: Content Questions. Percent correct answers from content questions on the pre-test given Fall 2007 before the unit (swimmer and fat questions) or from the unit exam given Fall 2006 (met, yeast and DNP questions) are shown as solid bars (,) . Refer to Appendix I and II for complete questions and answers. Answers from the post-test given Fall 2007 as a quiz at the end of the cellular respiration section are shown as striped bars (,). For the swimmer and fat questions, percent of answers qualifying as cellular-level answers for the pre- and post-test are shown in grey (,).

A.



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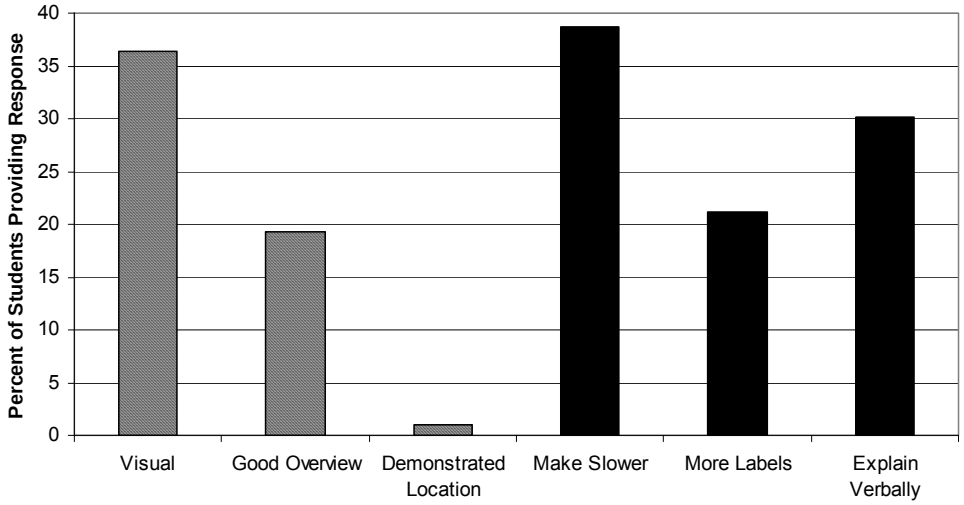

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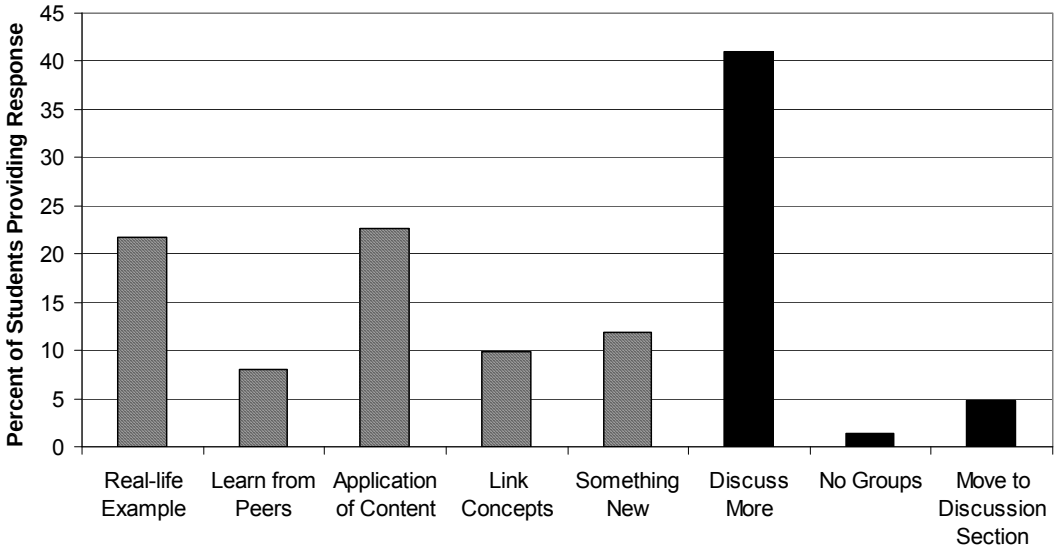

Figure 2: Answers to attitude questions asked on the post-test given at the end of the implementation provided by 212 students. A. Student attitudes on how helpful the materials were overall. **B. and C.** Student responses to the animation and case study, respectively. Suggestions for improvement are shown as black bars and positive elements of the material are shown as striped bars. Each category is marked as percent of students providing specific response (maximum of one mention per student per category).

Problems with implementation

Upon evaluation of the class schedule and during the actual implementation, the plan for how to use the materials was changed. Some of the changes compromised the efficacy of the materials. Most of these problems were highlighted by the student feedback on the post-test attitude questions (Figure 2B and C). For example, in the interest of saving time, we had increased the speed of the in-class animation, but many students responded that the speed of the animation was too fast. An unintended change in implementation of the case study was that small group discussion was cut short and that large-group discussion was not conducted. Also, in the interest of time, the follow-up discussion at the end of the second lecture was taken out of the implementation plan. This resulted in a greatly abbreviated discussion of the case study and little to no explanation of the answers to the questions on the case study. Many students felt that the case study would be greatly improved with more discussion in small and large groups, with follow-up with answers.

Suggestions for future implementation

The impact of the animation was limited by the increased speed and unclear labels. In the future, I would recommend using a slower version of the animation, with added labels of chemicals and of cellular compartments, in the lecture and on-line. In addition, the instructor should discuss the animation while it is playing, to add a verbal aspect and to help orient the students in the process.

Responses to the case study indicate that the materials did not need modification, but the major area for improvement was the in-class implementation. Much more in-class time needs to be given to the students for discussion. Returning to the original plan of in-class discussion at the end of the first and second lectures would help. Also, the post-test quiz should be moved to after this discussion or to the beginning of the next unit. To accommodate these changes, large changes in the lecture are needed. There would be much less time for lecturing, and a greater requirement of student preparation. Alternatively, another lecture period could be assigned to this section.

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APPENDIX:

- **I. Pre-Test**
- **II. Post-Test**
- **III. Case Study Materials**

I. PRE-TEST

Name:_____

Part One: Content Questions

1. Often swimmers will take a few deep breaths before starting a race. Why do they do that?

    a. Because oxygen will replace carbon dioxide in the cells
    b. To increase lung capacity and relax muscles
    c. To increase the amount of oxygen in the blood
    d. To increase the amount of oxygen for glycolysis

2. Why do bakers use yeast when making bread (other ingredients: flour, sugar, water)?

    a. The yeast are enzymes that break down the flour
    b. The yeast expands when combined with the other materials
    c. The yeast creates the texture by making the dough sticky
    d. The yeast makes the bread rise by producing CO_2

Part Two: Attitude Questions					
1.	What is your current level of understanding of cellular respiration?				
	A. Very High	B. Somewhat High	C. Neither high nor low	D. Somewhat Low	E. Very Low
2.	Generally, I find animations helpful tools for learning science.				
	A. Strongly agree	B. Agree	C. Uncertain	D. Disagree	E. Strongly Disagree
3.	Generally, I find I prefer to work alone.				
	A. Strongly agree	B. Agree	C. Uncertain	D. Disagree	E. Strongly Disagree
4.	Generally, I feel class discussion helpful and interesting.				
	A. Strongly agree	B. Agree	C. Uncertain	D. Disagree	E. Strongly Disagree
5.	Generally, I can find connections between science learned in class and “real-world” experiences.				
	A. Strongly agree	B. Agree	C. Uncertain	D. Disagree	E. Strongly Disagree

II. POST-TEST

Name:_____

Part One: Content Questions

1. In the 1940s, some physicians prescribed low doses of a drug called dinitrophenol (DNP) to help patients lose weight. This method was abandoned after a few patients died. DNP uncouples the chemiosmotic machinery by making the lipid bilayer of the inner membrane leaky to H^+. What impact does this have on ATP production?

    a. Reduces substrate level phosphorylation
    b. Increases substrate level phosphorylation
    c. Reduces oxidative level phosphorylation
    d. Increases oxidative level phosphorylation
    e. This would have no impact on ATP production

2. You have a friend who lost 20 pounds of fat on a diet. Where did the fat go (how was it lost)?

    a. It was released as CO_2 and H_2O
    b. Chemical energy was converted to heat and then released
    c. It was converted to ATP, which weighs much less than fat
    d. It was broken down to amino acids and eliminated from the body
    e. It was converted to urine and eliminated from the body

3. The metabolism of glucose to carbon dioxide within the cell

    a. Occurs completely inside of mitochondria giving evidence that mitochondria were once free-living bacteria capable of all metabolism
    b. Requires three turns of the Krebs cycle since each turn of the Krebs cycle results in the release of two carbon dioxide molecules
    c. Normally involves three different organelles, one for glycolysis, one for the Krebs cycle, and one for oxidative phosphorylation
    d. Results in a modest amount of ATP from substrate-level phosphorylation and a lot of reducing power that can be converted to ATP by electron transport and oxidative phosphorylation
    e. All of the above

4. Often swimmers will take a few deep breaths before starting a race. Why do they do that?

    a. Because oxygen will replace carbon dioxide in the cells
    b. To increase lung capacity and relax muscles
    c. To increase the amount of oxygen in the blood
    d. To increase the amount of oxygen for glycolysis

5. Why do bakers use yeast when making bread (other ingredients: flour, sugar, water)?

    a. The yeast are enzymes that break down the flour
    b. The yeast expands when combined with the other materials
    c. The yeast creates the texture by making the dough sticky
    d. The yeast makes the bread rise by producing CO_2

Part Two: Attitude Questions					
1.	Before Bio151, my level of understanding cellular respiration was:				
	A. Very High	B. Somewhat High	C. Neither high nor low	D. Somewhat Low	E. Very Low
2.	My current level of understanding cellular respiration is:				
	A. Very High	B. Somewhat High	C. Neither high nor low	D. Somewhat Low	E. Very Low
3.	For me, the animation was an effective way to learn about cellular respiration.				
	A. Strongly agree	B. Agree	C. Uncertain	D. Disagree	E. Strongly Disagree
4.	The “Poison” case study helped me understand cellular respiration.				
	A. Strongly agree	B. Agree	C. Uncertain	D. Disagree	E. Strongly Disagree
5.	The class discussion on the case study was productive.				
	A. Strongly agree	B. Agree	C. Uncertain	D. Disagree	E. Strongly Disagree
6.	Overall, how much do you think the animation and “Poison” case study contributed to your understanding of cellular respiration?				
	A. A lot	B. Some	C. Uncertain	D. Not Much	E. None
7.	Please tell us what you liked about the animation and the “Poison” case study.				
8.	Please tell us what needs improvement in the animation and the “Poison” case study.				

III. CASE-STUDY MATERIALS

Case Study Directions/Answer Sheet

Directions:

1. Take 5 minutes to read the Poison case study and to think about the questions individually.
2. Take 5 minutes to discuss and write down the answers to the questions with your neighbors in groups of 3-5 people.
3. Be prepared to discuss your answers with the rest of the class.

Answers:
Names of group members:

1) What chemical process did the Fleacide impair?

2) How could a product that is normally harmless to humans and pets have killed the girl?

3) What specific cellular process (such as glycolysis, Kreb's cycle, or ETC) do you think was affected by the Fleacide? Why?

4) Some health food stores sell supplements containing NAD+. If you administered the supplement to the girl, could you save her? Why or why not?

5) Would artificial respiration or oxygenation save the girl? Why or why not?

Poison [1] Case Study:

Cynthia is a very busy Medical Examiner at the Dane County Hospital and specializes in solving medical mysteries.

One night, her assistant Charlie called her office and said, "We've got a dead body of a kid up here that you'll want to look at right away."

Cynthia said, "I'll be there ASAP."

In the morgue, Cynthia examined the report from the hospital: At 5PM, the father came home from work and found his daughter vomiting and sleepy. Fifteen minutes later, he noticed that his daughter's breathing became slow and irregular. He tried to wake her up without any luck and the child became comatose. He called 911 and the girl was admitted to the hospital, with no heartbeat or breathing. A police report showed that the girl was going to give her dog a bath using a flea dip called Fleacide, which contains rotenone and is an insecticide appropriate for external use on animals.

Cynthia conducted an autopsy that revealed the following:

1. The girl died within three hours of first vomiting
2. There were symptoms suggesting hypoxia (lack of oxygen), but evidence that oxygen was never low.
3. Tissue sections from major organs show massive cell death
4. Staining with cellular dyes indicates that the mitochondria within the affected tissues were damaged
5. <u>ATP & Subcellular Analysis</u>
   ATP levels were reduced in the mitochondria
   ATP levels in the cytoplasm were normal
   Acetyl-Coenzyme A levels were normal
   Glucose levels were normal
   Pyruvate levels were normal
   NAD+ levels were low
   NADH levels were high

Questions: In groups, write answers on the Case Study Directions/Answer sheet.

1) What chemical process did the Fleacide impair?
2) How could a product that is normally harmless to humans and pets have killed the girl?
3) What specific cellular process (such as glycolysis, Kreb's cycle, or ETC) do you think was affected by the Fleacide? Why?
4) Some health food stores sell supplements containing NAD+. If you administered the supplement to the girl, could you save her? Why or why not?
5) Would artificial respiration or oxygenation save the girl? Why or why not?

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[1] Baines et al. 2004. Mystery of the Toxic Flea Dip: An Interactive Approach to Teaching Aerobic Cellular Respiration. *Cell Biology Education* Volume 3: pages 62-68.

Inquiry

Reflection and Artifact#2

Reflection

Science cannot exist without inquiry. However, it can be a challenge to promote and develop this skill in students. In biochemistry courses, molecular graphics programs are becoming essential tools to ask questions about biomolecule structure and function. These programs can be extremely powerful tools to enhance the ability of students to visualize chemical structures and explore how small changes can lead to disease and other functional variations. As inquiry-based instructional materials, they are very attractive, but students who are visually impaired or have difficulties with spatial visualization are excluded from much of the benefits of these programs. I became involved in a project to create a new program that could reach these students.

One of my colleagues, Tim Cordes, is blind and had a very difficult time accessing the information about the proteins and protein-DNA complexes he was studying for his graduate work. He developed a novel molecular visualization program, Tonal Interface for MacroMolecules (TIMMol), which uses textual and tonal output of molecular information. Working together, we examined ways that TIMMol could be enhanced to improve its accessibility to other blind users and also to users with alternate learning styles, while also allowing these users to work with people with traditional abilities. We added a simple graphical interface that was tied to the tonal and textual output, thus creating a program that could be used by all. In addition, the simultaneous output of graphics and tones added a new dimension to the information received by the user.

In order to assess the impact of TIMMol, we performed a pilot study. An interesting result of this study was that users with the lowest self-identification as a visual-based learner gained the most from TIMMol, suggesting that the textual and tonal output particularly helps users who might have problems with traditional software packages. Thus, TIMMol allows these users to ask questions they might not have been able to with other programs. TIMMol is available to anyone at: http://www.bact.wisc.edu:16080/TIMMol/ and a published manuscript (see artifact) discusses TIMMol in detail.

Personally, I learned a great deal from this collaboration. Through many conversations and brain-storming sessions with Tim, I was able to reflect on how inquiry can be integrated in a class with a diverse population. Differing learning styles and abilities make involving students in learning as an interactive and dynamic process very complex. In a traditional format, all students are asked to adapt to the instructor's teaching style. However, in student-centered classes, the instructors must learn how to adapt to the students' learning needs. Through my experience working on TIMMol, I was able to learn about the literature and resources available to instructors for material development. I also learned how to look at instructional materials from a new perspective and found that materials that have worked well for me may be of very limited use for some of my students. I believe it is essential that materials be accessible for all students to participate in the inquiry process. My involvement in the TIMMol project has started my life-long process of evaluating and modifying my thinking about the needs of the students and how these needs influence the design of instructional materials and the level of learning in a student-centered inquiry-driven classroom.

Artifact #2

TIMMol Manuscript

Cordes, T.J.*, Carlson, C.B.*, and Forest, K.T. (2008) Tonal Interface to MacroMolecules (TIMMol): A Textual and Tonal Tool for Molecular Visualization. *Biochemistry and Molecular Biology Education* *Co-first authors (in press)

Tonal Interface to MacroMolecules (TIMMol): A Textual and Tonal Tool for Molecular Visualization

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Running Title: Tonal Interface to Macromolecules (TIMMol)

ABSTRACT

We developed the three-dimensional visualization software, Tonal Interface to MacroMolecules or TIMMol, for studying atomic coordinates of protein structures. Key features include audio tones indicating *x, y, z* location, identification of the cursor location in one-dimensional and three-dimensional space, textual output that can be easily linked to speech or Braille output, and the ability to scroll along the main chain backbone of a protein structure. This program was initially designed for visually-impaired users, and it already has shown its effectiveness in helping a blind researcher study X-ray crystal structure data. Subsequently, TIMMol has been enhanced with a graphical display to act as a bridge to ease communication between sighted and visually-impaired users as well as to serve users with spatial visualization difficulties.

We performed a pilot study to assess the efficacy of the program in conveying three-dimensional information about proteins with and without graphical output to a general scientific audience. Attitudes regarding using TIMMol were assessed using Rasmol, a common visualization package, for comparison. With the use of text and tones exclusively, a majority of users were able to identify specific secondary structure elements, three-dimensional relationships among atoms, and atoms coordinating a ligand. In addition, a majority of users saw benefits in using TIMMol and would recommend it to those having difficulty with standard tools.

INTRODUCTION

Spatial visualization and interpretation of three-dimensional information prove to be difficult for many students [1]. However, these skills are an integral component of understanding in many fields, including geology [2], chemistry [3], engineering [4], and increasingly in biochemistry [5]. Graphics-based molecular visualization programs such as DeepView, Rasmol, and Protein Explorer improve student understanding of spatial concepts [6-9]. However, such graphics-based programs require students to integrate visual information in order to understand the three-dimensional character of objects on the screen. Many students do not have this ability and are excluded from the benefits of these programs [10]. In particular, it has been shown that women often have more problems than men in deconstructing visual images and creating a spatial understanding of three-dimensional objects [4, 11]. Similarly, these programs are limited in their accessibility for students with visual disabilities or with alternate learning styles [10]. For example, the program Rasmol allows for command line input, which a blind individual can use to export a subset of atomic coordinates to a file for further reading in a text editor. However, this process is non-interactive and provides little context for the atoms selected. In addition, when using these programs, students who are not naturally visual learners are not able to use their other strengths, such as aural or musical abilities.

According to Gardner's theory of multiple intelligences, spatial perception is only one of eight areas in which human intelligence can be understood [12]. Graphical depictions of three-dimensional objects ignore the kinesthetic, linguistic, mathematical, or musical strengths of students. Alternate strategies to assist students with different learning styles have been shown to be effective. For example, Roberts et al. (2005)

have shown that physical models of proteins enhance learning in an introductory biochemistry course [13], demonstrating the benefit of appealing to the kinesthetic intelligence. In addition, audio tones, appealing to the musical intelligence, aid in the localization of points in 3-dimensional space by visually-impaired and sighted users [14]. Visually impaired students must rely on other intelligences and means of perceiving three-dimensional data in order to grasp spatial concepts, and require instructional materials that build on these other ways of learning [15].

Given the need for a molecular visualization program that presents structural data in alternate ways, including textual and tonal output, the goal of this project was to develop a simple, easily portable, and extendable software system to aid in the exploration of three-dimensional protein structures by individuals whose needs are not adequately addressed with standard software. In designing TIMMol, we were aided by an illustrative review by Wu et al. (2004) that outlined fundamental features of chemical visualization software [3]. These features include providing multiple representations and descriptions, making linked referential connections visible, promoting transformation between two-dimensional and three-dimensional representations, and reducing the cognitive load by making information explicit and integrating information for students [3]. These features were carefully incorporated into the basic design and key features of TIMMol, as described in detail throughout this text.

TIMMol allows users to orient themselves in linear space by providing information about amino acid location in the primary sequence of the molecule. Individuals can scroll in three dimensions through a protein structure, while receiving textual output in a manner analogous to how visually impaired individuals scroll through a document in two dimensions. The textual output is formatted to be easily directed to Braille or synthetic speech output, according to the preference of the user. TIMMol also presents atomic coordinates and distances, which should appeal to more mathematical learners. Likewise, by presenting this information as text, this program provides an opportunity for linguistically oriented students. Based on the success of Mereu et al. (1996) with using tonal cues to locate points in three dimensions [14], tonal output was incorporated to provide feedback on spatial location to aid auditory learners. Lastly, TIMMol also offers a simple graphical interface for molecular visualization to help students grow accustomed to the standard graphical format and to act as a bridge between learners with differing styles and abilities.

PROGRAM DESCRIPTION

Programming Language

Practical Extraction and Reporting Language (PERL) was chosen to implement this application. Perl interpreters are available for numerous platforms including Windows, Mac, and Unix. Text processing tools found in Perl simplify extraction and manipulation of coordinate information. In addition, the PerlMol project and Windows midi packages allowed for extension of the program to handle aspects of chemistry and musical tones, respectively [16, 17]. Implementation of the graphical interface was based on a tutorial in The Perl Journal [18, 19]. With these tools, we constructed software that depicts data with linked text, graphical, and audio representations [3].

A TIMMol executable that runs on Windows Vista, NT, 2000 and XP is available for download at: http://www.bact.wisc.edu/timmol/. We anticipate the Macintosh OSX executable will be available at the same web address before Summer 2008. In addition the PERL source code is available.

The Sphere Concept

In order to make structural data accessible in a textual format, a three-dimensional cursor was developed for molecular exploration. This cursor is represented by a sphere and the atoms present within this sphere are reported in a text window (Fig. 1). The location of the sphere is controlled by keyboard commands. Thus, examining a protein with the sphere-cursor involves interactive scrolling with the keyboard and examining the textual output. Individuals who use speech or Braille output will be familiar with this technique of exploring by keyboard manipulation of a cursor. TIMMol extends the familiar two-dimensional cursor, which moves left, right, up and down, to one that can now move in an additional dimension, in and out.

Just as when a user visually inspects a protein and chooses to expand or narrow the focus, the sphere cursor can be resized. The level of detail that is reported can also be varied to include the textual equivalent of a Cα trace, backbone rendering, or a complete list of atoms. The sphere can be moved directly to an atom of interest using a "go to residue" command, or stepped along the Cα backbone, using the + and - keys. In addition, the sphere can be moved in three-dimensions, using keyboard commands for movement in positive and negative *x*, *y*, and *z* directions. In this way, the cursor provides detailed information about local environments in a three-dimensional manner.

Tonal Output

Whereas the sphere cursor provides information about the contents of a local region, tonal output was added to convey global structural information. To achieve this task, the tonal cues provide an indication of where the cursor is in relation to the rest of the protein. For a given cursor position, a musical note is played representing the atom, if present, at the center of the sphere. Left and right tonal balance conveys changes in the *x*-axis position, variation in pitch conveys changes in the *y*-axis position, and variation in volume indicates the *z*-axis position. Stepping along the protein main chain while listening to the tonal output allows users to recognize secondary structure elements. For example, in a protein sequence containing a loop element, a user moving along the backbone may hear the tone balance shifting to the right (+*x*) and the pitch increasing (+*y*), until the peak of the loop. After this point, the tone will continue to shift to the right (+*x*), but the pitch will decrease (-*y*) until the end of the loop. Any movement of the loop in the *z*-axis will be relayed to the user by a change in volume. These tonal cues help reveal the positions of secondary structure elements, such as α-helices and β-sheets, and structural motifs, such as β-turns, within the protein sequence. They also could help a user determine how regions distant in primary sequence might be close in three-dimensional space since atoms in these regions would have similar sounding tones. Thus, transformations between 1-dimensional (primary) and 3-dimensional space are facilitated, as recommended by Wu et al. (2004) [3].

Textual Output

TIMMol commands are initiated by single keystrokes in the graphical window. After this, the TIMMol text window serves as the main command interface. Using the "help" function, users can list all available commands to find out more about each TIMMol function. An example of one of the available commands is 'r' for 'resize.' Pressing 'r' in the graphics window allows the user to re-adjust the sphere radius in the text window by typing in a new radius of the selection sphere.

The text window also serves as the site for textual output of information about the macromolecule of interest. This output is separated into two main sections (Fig. 1B). The first section is a sequence list of the entire macromolecule, including any heteroatoms, such as water or ligands. If the sphere is centered on an atom, this atom will be highlighted within the sequence output by a pair of asterisks. The second section includes information about the location of the sphere and details about sphere contents. The radius of the sphere and its *x*, *y*, *z* coordinates are listed followed by a detailed list of sphere contents, including *x*, *y*, *z* coordinates of all atoms within the sphere. An asterisk highlights the central atom. In this way, users are provided with a mechanism to transfer between information about the primary and tertiary structure involving any given atom [3].

Graphical Output

To supplement the textual and tonal output for more visual learners and to provide a communication bridge between individuals with differing learning styles or visual abilities, a simple graphical display that depicts the cursor as a webbed sphere was added to the program (Fig. 1A). Outside the sphere, a protein is rendered as a Cα trace while inside the sphere a protein backbone is highlighted and the sphere contents are shown in a ball and stick representation. This serves to focus visual attention on the contents of the sphere and reduce the presentation of extraneous information, thus decreasing the cognitive load [3]. As the cursor moves and is resized, the visual contents within the sphere are updated. The graphical display also provides the ability to zoom and rotate, similar to other visualization packages, which helps novices familiarize themselves with the graphical display. Depth-cued shading and interactive manipulation of the image aids in understanding the transformation between a 2-dimensional representation and the 3-dimensional structural data it describes [3].

Integration

We have carefully integrated the textual, graphical and tonal properties of TIMMol. By simultaneously providing users with these different forms of output, TIMMol provides a mechanism for the assimilation of molecular information [3]. With one click on the keyboard, users receive tonal information about movement along the polypeptide chain according to the shift in *x*, *y*, *z* position, textual information indicating the identity, primary sequence placement, and three-dimensional location of the new amino acid, and graphical information about the amino acid in the context of the entire protein, including side chain position and identification of interactions with ligands or other amino acids. Users can choose one or all of these forms of informational output to facilitate

the understanding of the molecular structures. By providing these diverse types of information simultaneously, TIMMol enhances the integration of the information and decreases the demands on the user [3]. This combination of output modalities provides a mechanism for individuals with differing learning styles or visual skills to examine the same structure at the same time. Each individual is able to explore the structure, in his or her own way, and ultimately be able to communicate about the structure effectively.

Initial Usefulness for a Visually Impaired Researcher

TIMMol was originally developed by TJC to meet his own needs as a blind structural biologist in the laboratory of KTF. For him, the interactive nature of TIMMol greatly reduced the need to use existing molecular visualization packages. In order to use these packages, he performed cycles of atom selection, exportation of the atom lists to text files, and manipulation of the files with a text editor and synthetic speech output. After developing TIMMol, however, he was able to access molecular information in a direct and concise manner utilizing speech software to read TIMMol's text output. While in the Forest laboratory, TJC solved the structure of virulence factor regulator protein (Vfr) from the bacterium *Pseudomonas Aeruginosa* (PDB code: 2OZ6, manuscript in preparation). He investigated this structure using an early version of TIMMol, featuring a text display and audio tones. By moving between atoms and expanding the radius of the sphere, TJC was able to explore structural features of Vfr, such as examination of side chain atoms involved in cyclic-adenosine mono-phosphate binding to Vfr. The tonal output aided in understanding three-dimensional relationships among these atoms. Having recognized TIMMol's potential for the visually impaired, a collaboration was undertaken with CBC to add a graphic interface and modify TIMMol to increase its usefulness for other users who may not receive the full benefit from traditional molecular visualization packages.

PILOT STUDY

Study Design

We conducted a pilot study to generate suggestions for improvement of TIMMol, to assess satisfaction with using TIMMol, and to gauge the efficacy and utility of TIMMol for simple structural tasks. A human subjects research protocol exemption was obtained from the Educational Institutional Review Board at the University of Wisconsin for this trial. Volunteers were solicited from two structural biology laboratories. Nine sighted participants, comprising graduate students, postdoctoral researchers, and research staff members, volunteered to participate in the pilot study. They were shown a short tutorial on how to use TIMMol and Rasmol. The participants were then asked to practice using both software programs, with representative samples of β-sheet, α-helix, and loop secondary structures, in addition to several standard PDB files. After approximately 45 minutes of exploration, participants were asked to complete a two-part questionnaire. For part one of the questionnaire, the graphical interface of TIMMol was disabled and participants were asked to use the tonal and textual output to perform tasks interpreting aspects of the structure of the copper binding domain of Alzheimer's amyloid precursor protein (PDB code: 2FK1) [20]. Tasks for part one of the questionnaire included: 1. Identification of secondary structure elements (α-helix, β-

sheet and loop structures); 2. Identification of atoms involved in binding a ligand; 3. Ability to identify *x, y, z* location with respect to other parts of the protein (Table 1). Part two of the questionnaire was an attitude survey, where participants answered questions based on their experience with TIMMol and Rasmol in the practice session (Table 1).

RESULTS

Pilot Study Results

The participants of the pilot study comprised a cohort of sighted individuals without previous experience using textual or tonal output to understand 3-dimensional information. A majority of the participants (5/9) were able to identify β-sheets and loops in the test protein using only textual and tonal information. However, slightly fewer participants (4/9) were able to recognize an α-helix by sound, indicating that α-helices may be a more challenging secondary structure element to identify with this limited amount of practice. It is worth noting that TIMMol presents secondary structure information encoded in a PDB file in the text display when it is available, but this feature was disabled for the evaluation.

In addition to exploring secondary structure, participants demonstrated an ability to understand tertiary relationships within the test protein. When asked to identify amino acids above (+*y*) and behind (-*z*) a designated amino acid, most participants were able to list appropriate amino acids, with only 2/18 incorrect responses. When testing the ability of TIMMol to convey three-dimensional information regarding ligand binding, all participants except one were able to correctly identify coordinating atoms for an ion ligand in the test protein. These tasks validated the usefulness of TIMMol as a non-graphical tool. However, it is likely that user performance would improve further when all forms of data output are available.

Part two of the questionnaire reported attitudes and questions about TIMMol and its efficacy, compared to Rasmol. In this section, participants were asked if they "strongly agree," "agree," are "uncertain" about, "disagree," or "strongly disagree" with a series of statements. A majority of participants agreed or strongly agreed that TIMMol and Rasmol were both effective tools to investigate secondary structure (5/9) and tertiary structure (7/9). In addition, most users agreed or strongly agreed that the textual and tonal output increased their level of understanding (7/9). When asked about the benefits of TIMMol, 6/9 participants could see added benefits of TIMMol, 6/9 participants would choose to use TIMMol when trying to convey a structural concept to someone experiencing difficulties with traditional software, and all participants would recommend TIMMol to such a person (Table 1).

The feedback portion of the questionnaire identified several weaknesses in TIMMol, which have been subsequently remedied. Participants recommended identification of the selected atom on both the graphical and textual views, and this was incorporated. In addition, since the audio output is based on a fixed axes system derived from the original orientation of the molecule and not the current viewing angle, a keyboard command was added to restore the viewing perspective to the original orientation. When used, the direction of movement visualized on the graphical display will agree with the change in balance, pitch, or volume of the tonal output. In order to aid in the identification of overall structure, several participants requested the ability to

scan through an entire protein chain with one keystroke. Consequently, a function was implemented that allows the user to scan the selection sphere along an entire protein chain, playing a note at each Cα position. Participants also requested help in distinguishing movements from left to right (-*x* and +*x*), so a short percussive sound was added in either the left or right ear proceeding the main tone, in order to clarify the direction of movement.

An interesting trend emerged where participants who reported stronger visual tendencies or more experience with molecular visualization software performed more poorly with TIMMol. For example, the three individuals who disagreed strongly with the statement, "I have problems with visual based learning," produced only one correct answer among them for the three questions requiring identification of secondary structure by sound. In contrast, the six individuals who only "disagreed" with the statement had four, five and six correct answers on the same questions. Likewise, those who professed "very high" familiarity with molecular visualization software did more poorly than all others on these same tasks (Table 1).

This trend suggests that individuals who have less experience or comfort with molecular visualization software or who have more difficulties with visual based learning are the most likely to benefit from TIMMol. This finding agrees with other studies that have reported the impact of prior content knowledge and visuospatial ability on success in learning from graphical displays [10]. In addition, people who are already functioning well with traditional software may have difficulty obtaining additional benefits from TIMMol. This analysis suggests that educators who are comfortable with current packages may require practice in learning to use TIMMol in order to assist their students with alternate learning styles or visual difficulties. Perhaps this is best summarized by a pilot study participant who wrote, "It got easier to use the more I used it, and I think with more practice it would become very easy and informative." Whereas individuals with experience using traditional packages had some increased difficulty with TIMMol, it is likely that visually impaired students and researchers, who are accustomed to keyboard scrolling and using auditory cues, will be more able to readily utilize the features found in TIMMol.

SUMMARY

We report the development and testing of a novel molecular visualization program that combines graphical, textual, and tonal cues. This program, TIMMol, makes strides to increase the accessibility to biochemical information for blind and visually impaired users, as well as for other users who have difficulty with traditional software packages. We conducted a pilot study on TIMMol and illustrated that it is an effective tool to explore structural aspects of proteins, and it provides added benefits for these tasks when used alone or along with traditional programs.

Although TIMMol has specifically been designed for understanding protein structure, the application of the general tools of a three-dimensional cursor coupled to textual output, tonal cues, and a simple graphical presentation, developed in TIMMol could be adapted for understanding a variety of spatial systems. This could include understanding human anatomy from computed tomography (CT) or magnetic

resonance imaging (MRI) data, cellular structure and events through confocal microscopy data, or even architectural plans or geological formations.

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Task-based Questions	**Number correct (organized by familiarity with molecular programs)**			
	Very High	Some-what High	Neither High nor Low	Some-what Low
I believe residues 175-177 form a:(**loop**)	0/2	1/2	3/4	1/1
I believe residues 146-161 form a:(**α-helix**)	0/2	2/2	1/4	1/1
I believe residues 178-188 form a:(**β-strand**)	0/2	2/2	2/4	1/1

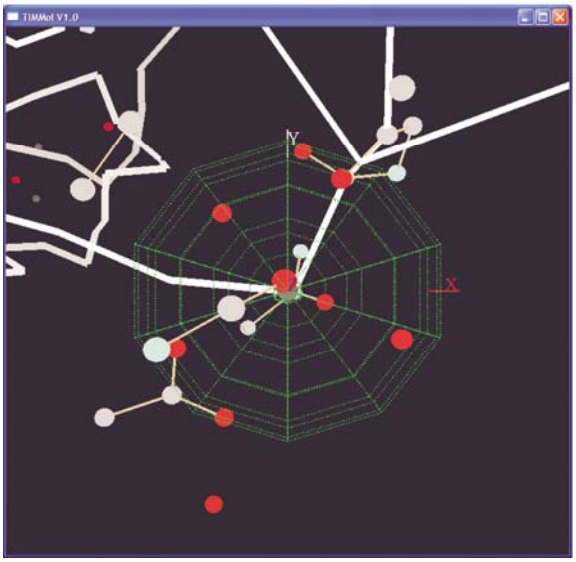
	Number correct (organized by problems with visual-based programs)	
	Strongly Disagree	Disagree
I believe residues 175-177 form a:(**loop**)	1/3	4/6
I believe residues 146-161 form a:(**α-helix**)	0/3	4/6
I believe residues 178-188 form a:(**β-strand**)	0/3	5/6

Attitude Questions	**Answers (nine participants)**		
	Strongly Agree	Somewhat Agree	Uncertain
The sounds and textual output used in TIMMol increased my understanding of the proteins	1	6	2
Overall, I can see additional benefits in using TIMMol instead of or along with Rasmol	2	4	3
I would recommend TIMMol to students or colleagues having difficulty with traditional 3D images and software	3	6	0

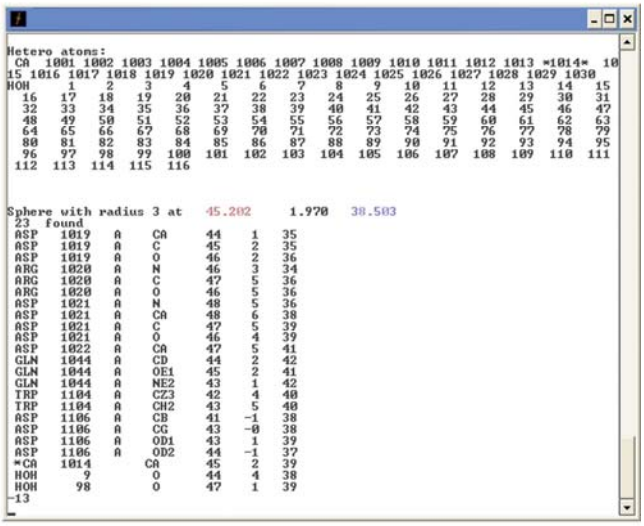
	Rasmol	**TIMMol**	**Tactile Models**
If I were trying to convey a structural concept to a colleague with visual or spatial difficulties, I would use	1	6	3

Table 1. Pilot Study Results: Sample questions from pilot study questionnaire are listed on the left. The answers to the task questions are written in bold and are in parentheses. Participant answers to the task questions are organized by participants' answer to the question, "Before participating today, my level of comfort with molecular graphics programs was:" and also on participants' answer to the question, "I often have problems with visual-based learning." Answers for task-based questions are reported as number of correct answers out of total number of individuals in each category, while answers for attitude questions are reported as total number of answers (nine participants).

A.



B.



```
Hetero atoms:
 CA  1001 1002 1003 1004 1005 1006 1007 1008 1009 1010 1011 1012 1013 *1014*  10
15 1016 1017 1018 1019 1020 1021 1022 1023 1024 1025 1026 1027 1028 1029 1030
HOH     1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
  16   17   18   19   20   21   22   23   24   25   26   27   28   29   30   31
  32   33   34   35   36   37   38   39   40   41   42   43   44   45   46   47
  48   49   50   51   52   53   54   55   56   57   58   59   60   61   62   63
  64   65   66   67   68   69   70   71   72   73   74   75   76   77   78   79
  80   81   82   83   84   85   86   87   88   89   90   91   92   93   94   95
  96   97   98   99  100  101  102  103  104  105  106  107  108  109  110  111
 112  113  114  115  116


Sphere with radius 3 at   45.202     1.970   38.503
 23  found
 ASP   1019    A     CA      44    1   35
 ASP   1019    A     C       45    2   35
 ASP   1019    A     O       46    2   36
 ARG   1020    A     N       46    3   34
 ARG   1020    A     C       47    5   36
 ARG   1020    A     O       46    5   36
 ASP   1021    A     N       48    5   36
 ASP   1021    A     CA      48    6   38
 ASP   1021    A     C       47    5   39
 ASP   1021    A     O       46    4   39
 ASP   1022    A     CA      47    5   41
 GLN   1044    A     CD      44    2   42
 GLN   1044    A     OE1     45    2   41
 GLN   1044    A     NE2     43    1   42
 TRP   1104    A     CZ3     42    4   40
 TRP   1104    A     CH2     43    5   40
 ASP   1106    A     CB      41   -1   38
 ASP   1106    A     CG      43   -0   38
 ASP   1106    A     OD1     43    1   39
 ASP   1106    A     OD2     44   -1   37
 *CA   1014          CA      45    2   39
 HOH      9          O       44    4   38
 HOH     98          O       47    1   39
-13
```

Figure 1. Graphical and textual output. **A.** Graphical output shows the green web of the three-dimensional cursor sphere centered on a calcium ion (CA1014) in thrombospondin-2 [21] (PDB code: 1YO8). The central calcium ion is shown as a grey sphere. Atoms within 3Å of the calcium ion are shown in ball and stick representations and are colored in the CPK convention (carbon: white, oxygen: red, nitrogen: blue, sulfur: yellow). Atoms outside 3Å are shown as a Cα-trace. White *y*-axis, red *z*-axis, blue *x*-axis are labeled on the sphere. **B.** Textual output shows a partial sequence view and sphere contents view. Central calcium ion is shown in the heteroatoms sequence and is indicated by asterisks. The sphere contents show the radius of the sphere, the *x*, *y*, *z* coordinates of the central calcium ion, the atoms within the sphere radius, and the central calcium ion indicated with an asterisk. All coordinating oxygen atoms (Asp590OD2, Leu591O, Glu593OE1, Asn612OD1, Thr613O, Gly616O) are included in the textual output.

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Critical Analysis

Reflection and Artifact #3

Reflection

Knowing how to critically evaluate and analyze scientific data is one of the most difficult skills to teach, and yet it is one of most important skills to have to be successful in science. In lecture, one strategy is to expose students to scientific literature early in their career. Understanding the experimental basis for textbook content is invaluable. In the laboratory, it can be difficult to foster critical thinking skills because of the tendency to do experiments to get the data, rather than to reflect on why or how we are doing the experiments. However, these skills can be developed through repeated reflection on and communication about the research project, methods, and progress. I tried this approach with Allen Young, a high school student who I mentored the summer of 2007. At the end of the summer, Allen wrote a report reflecting on his research experience and this is the artifact that I chose to illustrate my approach to fostering critical analysis.

Allen worked on making mutant DNA constructs for future protein production and studies. At the start of the summer, I asked Allen to write a proposal for his research project. This gave him the chance to think through the rationale for the project. At the end of the summer, Allen wrote a summary of his project and gave a Power Point presentation of his work to the laboratory staff. I learned a lot about the development of critical skills through the improvement of each draft of Allen's report. The first draft of his report was basically a list of procedures. I believe this was a reflection of what he knew best: the laboratory tasks he performed every day, without much analysis. The second draft of his paper incorporated these tasks into the context of the goals for his summer research. At this point, I believe he had started synthesize the day-to-day work (how) and the results (what) of completing these tasks. The final draft of Allen's paper added in more detail about rationale (why). Through this process of writing a report about his research, Allen progressed to a point where he was able to analyze why he had done the tasks and how his work would fit into a larger research project. He was also able to make a final step to suggest future plans for the project.

I believe this approach worked really well with Allen. I think writing the report made him stop and think about the reasons behind the work. I learned a lot from the process too. I learned that Allen and I have very different learning styles – where I need a lot of one-on-one explanations and demonstrations, Allen would likely prefer a good laboratory manual. It took me a long time to realize he was not gaining a deeper understanding of his experiments because I was not explaining them in the best way possible for him. I also learned that we both have the tendency to want to get the experiments done for the sake of getting more data quicker and that I really had to slow both of us down so that Allen had time to think critically about his work. It was when I was working with Allen on his reports that I really appreciated these two issues in our experience together. In the future, I plan to ask for more regular written reports from my student researchers and I will be more attentive to the learning styles of the student, rather than relying on my individual preferred learning method. I believe that these analytical reports could be an invaluable tool for identifying gaps in communication and learning, as well as for developing the critical thinking skills of the student.

Artifact #3

Research Report by Allen Young

There are five members of the thrombospondin (TSP) family, found throughout the body. The version we are concerned with is with TSP-5 also known as COMP. This protein is usually found in the connective tissue such as cartilage, tendons and ligaments and is associated with certain health defects such as dwarfism. However in our research, we will use a portion of TSP-2 because of its similarities with TSP-5 and that it is easier to work with and more readily available in the lab.

Our goal is to better understand how a mutation in the structure of the protein can affect the health of an individual. We will create a mutation within the protein and see how it affects the overall structure and how that correlate with the effects it may cause on a human being. Currently, we have five mutations: G868E, T1013M, D901G, D738V, and delD897.

G868E was chosen because a previously made mutation was made in the lectin-like domain of the protein in an area facing the wire (repeat 9C) and was shown to have a major impact on the structure. The purpose of the G868E mutation is to change the wire (repeat 9C) area of the protein facing the lectin-like module to examine if it has a similar effect on the structure.

The T1013M mutation was chosen in order to see the effects that can come about when the amino acid tyrosine is changed to either arginine (studied previously) or methionine.

D901G was chosen because of its location. It coordinates two calcium atoms, both by side chain oxygens. This has been studied in cell-trafficking studies by a different research group. There are three different TSP-5 mutations that cause disease at position 901.

D738V was chose because it coordinates two calcium ions: one through the main chain oxygen and one through a water molecule. We have not studied a residue that binds to two calcium ions before. It is also located in position 10, which is the same location of N700S: a polymorphism linked to heart disease when found in TSP-1.

DelD897 was picked because it coordinates two calcium atoms, and is a deletion: the most severe form of mutation. It is also the most commonly found mutation in PSACH patients. It is a "worst-case" and a "most-common" scenario.

Before any molecular biology work, we ordered the primers and amplified them using PCR so that we may have enough DNA for further procedures. We came across problems when one of our mutations, G868E, didn’t show on an analytical gel after PCR. This became a problem because it meant that there was no DNA. After several tries, it finally worked and we had DNA to do experiments with.

Due to the fact that we cannot buy an entire mutation because it would be extremely long and impossible to handle, we used the primers to create DNA fragments A and B. Once our DNA fragments were completed, we needed to ligate them to create the entire mutation. Before we ligated however, we digested the ends of the fragments with enzymes that sawed off the rough edges and gave the two parts compatible ends which would facilitate ligation. The finished product was C.

After creating C, we performed another digestion on C to cut off the ends to facilitate its ligation to the protein vector. Aside from digesting the mutations, we also cleaved the vectors. We used vectors 314B and coco and sawed them with the same

compatible enzymes. After the digestion for 314B, we needed to perform a CIP-treatment where we took away the phosphate so that it will not glue itself back together due to the fact that it only has one enzyme cut whereas coco had two which makes it harder to self-ligate.

After the ligation, we started the transformation. In transformation, we placed the DNA with bacteria on a solid substance of LB and Amp (bacterial food) and used the bacteria to create more DNA. The LB was the food for the bacteria, but the ampicillin is an antibiotic. Amp kills bacteria, but inside the coco/314B vectors we are using, there is DNA for ampicillin-resistance, which is not found in environmental bacteria. This is a way to decrease the amount of contamination by other bacteria, while still allowing our transformed cells (only the ones that have the vector in them) to grow. The reason we used solid food is because it would be easier to pick the colonies of bacteria and the solid nature would allow us to distinguish between different colonies so we can be sure that we are not collecting colonies of different DNAs. We encountered troubles in this stage when several of our mutations did not yield colonies. After several tries, we discovered that it might be a vector problem.

When the colonies formed, we picked them and placed them in a liquid solution of LB and Amp so that the bacteria may grow even more. After the rapid growth of bacteria, we performed a miniprep in which we extracted the DNA. We used a special kit that sliced open the cells and allowed the DNA to escape the cell. Once we had the DNA, we performed a diagnostic digest to test if the insert was put in correctly. We digested them with BamHI which told if the insert was in and SpeI and XmaI which confirmed if the insert was in the right position. After running an analytical gel to see the results, we picked the minipreps with the correct inserts and cleaned it for sequencing.

During sequencing, we sent the DNA to the Biotech Lab and they gave us data on all of the bases of the DNA. We compared the bases and made sure that we found the location of the mutation as well as potential trouble spots that may causes shifts or changes in the DNA. We were able to have our mutations T1013M and G868E to work and we prepared them for transfection.

In transfection, we used viruses to absorb the DNA. Once the virus contains the DNA, we will allow it to infect other sf9 insect cells and insert their DNA into the cells. In turn, the cells will be forced to use the DNA and create more versions of the virus. After 5-7 days, we will stain the plaque with dye and pick the plaque, which is another work for virus colonies, and use it to reproduce even more virus.

Unfortunately, summer was too short and I ran out of time to finish the process. If I were to continue this experiment, our next step would be creating the protein. Once the highly efficient virus reproduces enough duplicates, we will put it together with cells and have an enormous output of the protein. Using further procedures, we shall collect the protein and study them.

During my research, I have learned much about molecular biology and laboratory techniques. I learned about the process of ligation, digesting, transformation and transfection. Laboratory skills I developed included gel-making, purification and autoclaving. I also learned about the strict contamination rules. Gloves were always mandatory for DNA work and the sterile conditions expanded even more during transfection. Overall, I had an excellent experience in the lab and greatly expanded my

views on science. I learned about the field of molecular biology and performed experiments using this whole new realm of science that I never knew. The lab experience and knowledge I gained was unmatched compared to any class in high school and I extremely enjoyed this opportunity.

Curriculum Vitae

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EDUCATION

2004-present	University of Wisconsin – Madison	PhD Dissertator, Biomolecular Chemistry
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TEACHING EXPERIENCE

Fall 2007-April 2008	Mentor for Undergraduate Researcher	University of Wisconsin – Madison
Fall 2007	Mentoring Seminar Participant	University of Wisconsin – Madison
7/2007-8/2007	Mentor for High School Student	University of Wisconsin – Madison
Fall 2006-present	Active Participation in Delta, a Center for the Integration of Research, Teaching and Learning (CIRTL) program	University of Wisconsin – Madison
Fall 2006	Guest Lecturer for Plant Pathology 123: Plants, Parasites and People	University of Wisconsin – Madison
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8/2001-7/2002	English Instructor	Shanghai University of Finance and Economics, China

RESEARCH EXPERIENCE

6/2004-present	Graduate Student Research Assistant *Structural Determinants of Diseases Associated with Thrombospondins*	Biomolecular Chemistry, Lab of Deane F. Mosher, University of Wisconsin – Madison
9/2002-6/2004	Associate Research Specialist *Structural Determinants of Diseases Associated with Thrombospondins*	Lab of Deane F. Mosher, University of Wisconsin – Madison
10/2001 - 6/2001	Analytical Chemist *Redispersibility Analysis of Pharmaceutics*	Élan Pharmaceutical Technologies, King of Prussia, PA
3/2000 - 8/2000	Research Assistant *Coordinator of a Generalized Anxiety Disorder Study*	The Institute for Advanced Clinical Research, Elkins Park, PA
Spring 1999	Undergraduate Researcher *Analysis of Atrazine Levels in Local Ground Water*	Earlham College, Richmond, IN
Summer 1997	Summer Research Assistant *Amanita spp. Herbarium Maintenance*	Assistant to Rodham E. Tulloss, Roosevelt, NJ

AWARDS

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