| PART I: BACKGROUND | |
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| **Title** | Using 3D Molecular Models in Biology and Chemistry Courses |
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| **Discipline(s) or Field(s)** | Biology, Chemistry, Biochemistry, Cell Biology |
| **Submission Date** | June 12, 2015 |
| **Course Name** | General Biology, Cell Biology, Organic Chemistry and Biochemistry Survey |
| **Course Description** | Briefly describe the course, its place in the curriculum, and where the lesson fits into the course. If relevant, include pertinent facts such as course level, class size, student population, length of lesson, and learning environment.<br><br>We focused on learning goals associated with biomolecular structure, with an emphasis on water and proteins. In the biology curriculum, the structure of biomolecules is first introduced in General Biology (BIO 105) and is elaborated on in Cell Biology (BIO 315); both General Biology and Cell Biology are part of the biology core so each serve hundreds of students each semester and is taught by many instructors. In the chemistry curriculum, the structure of biomolecules isn't introduced until students take Biochemistry, which occurs as a 400-level course for majors, but is introduced at the 200-level as an organic chemistry and biochemistry survey course (CHM 250) for nonmajors. |
| **Abstract** | Provide an overview of your learning goals, lesson plan, and major findings.<br><br>Given the difficulty that many students have understanding the concepts of polarity and hydrogen bonding as they apply to water and biomolecules such as DNA and proteins, 3D models were integrated in units on water, protein and DNA in a variety of 100-, 200-, and 300-level biology and chemistry courses in order to gather preliminary data on the effectiveness of these models for student learning. We found that 100- and 200-level students rated these models as very effective learning tools, but the 300-level students did not. Further studies will focus on assessing the impact of these models on student learning in the introductory levels. |
| **PART II: THE LESSON** | |
| **Learning Goals** | List your student learning goals. Include broad developmental and disciplinary goals as well as lesson-specific goals. Write goals in terms of the knowledge and qualities students should exhibit as a result of the lesson. In addition, comment on how the lesson is designed to promote achievement of your goals.<br><br>We focused on learning goals associated with two major topics that in several biology and chemistry courses: water structure and protein structure.  We would like students to understand how basic chemistry concepts such as polarity underlie the structure and function of biomolecules. |

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| **Lesson Plan** | Describe the steps of the lesson, providing enough detail for other teachers to use it in their classes. Include any pre or post-lesson work, the specific wording of prompts, time required for each task, and explanations of any distributed materials.<br><br>We developed introductory and advanced lesson plans for both water structure and protein structure. The advanced lessons, which were designed to be used in 200-level and 300-level courses, builds on the introductory lessons, which were designed for 100-level courses. Each lesson is designed for easy integration into a PowerPoint presentation so that an instructor could swap out traditional slides for slides containing the 3D modeling activity without changing the original learning objectives. Activity modularity is important for courses with large enrollments and multiple instructors.<br><br>The lesson plans are included in Appendix A. |
| **PART III: THE STUDY** | |
| **Approach** | Describe your plan for conducting observations and the types of evidence you collected.<br><br>We have carried out preliminary observations of students interacting with 3D molecular models in General Biology, Cell Biology, and Survey of Organic Chemistry and Biochemistry in order to determine which activities are suitable for each of these courses so that a more thorough study of model effectiveness could be conducted in the 2015-2016 academic year.<br><br>Multiple instructors from multiple courses used a shared collection of 3D models in their classrooms during the 2014-2015 academic year. Courses and instructors included General Biology (J. Klein, B. Klein) for majors, General Biology for nonmajors (M. Litster) Cell Biology (J. Klein, D. Howard), and Survey of Organic Chemistry and Biochemistry (B. Bhattacharyya). Some instructors collected survey data regarding student's perceptions of the usefulness of models and other instructors made observations of their students interacting with models. |
| **Findings/Discussion** | Present major patterns and tendencies, key observations, or representative examples in the evidence you collected. Discuss what your study suggests about student learning, including any misconceptions, difficulties, confusion, insights, surprising ideas, etc. Recommend revisions to the lesson.<br><br>Instructors in multiple sections of General Biology (Howard and Klein), each section enrolling 60-100 students, an instructor in Organic and Biochemistry Survey (Bhattacharyya) with a section of ~30 students, and an instructor in Cell Biology (Klein) with a section of ~60 students used the water and protein models in class and measured student perceptions of learning using their own in-class and end-of-semester surveys.<br><br>In General Biology (Bio 105), there is a major focus on understanding polarity in simple molecules such as water and then, later in the semester, this understanding is applied to proteins. A majority of Bio 105 students (73% in Howard's section) felt |

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| | that the water models used in class helped them to understand polarity, hydrogen bonding, and the properties of water—96% agreed that they were, at the very least, a fun break from lecture. Only a small fraction of students (17%) felt the models took up too much class time and an even smaller fraction (5%) felt the models were unnecessary because they already knew the material.<br>In Cell Biology (Bio 315), models were used in the protein unit to review amino acid polarity and protein folding, similarly to how they were used in General Biology. General Biology and Cell Biology are the only two instances that biomolecules and protein folding are explicitly addressed in the biology curriculum. At the end of the semester, students were asked to rate the usefulness of each kind of class activity on a scale from 2 to 5, with 5 being an activity they got a lot out of and 2 being an activity they got nothing out of. In all sections, much of the class time was spent on traditional PowerPoint slides and some of every class was devoted to in-class problems involving data interpretation related to primary literature or process-oriented guided inquiry (POGIL) activities. Only one class period involved 3D models. Nearly all students (96%) reported getting “a lot” or “enough” out of lecture and most students reported getting “a lot” or “enough” out of in-class problems (79%) and POGIL worksheets (82%). In contrast, only 32% of Cell Biology students felt that they got “a lot” or “enough” out of modeling activities. When General Biology students (with the same instructor) were asked the same questions at the end of the semester, 56% reported that they got “a lot” or “enough” out of modeling activities. Since the Cell Biology students were mainly seniors, half of whom were co-enrolled in Biochemistry, they were likely to have already gained a detailed understanding of protein folding, rendering the modeling activity less useful to them than a General Biology student engaged in this learning for the first time.<br>All students in Organic and Biochemistry Survey (CHM 250) felt that using models in class helped them to better understand properties of amino acids and protein folding (39% strongly agreed and 57% agreed with the statement). Nearly 100% of students were able to answer a foundational question about protein folding correctly only one class period after using the models. However, 48% of students answered a foundational question about amino acid polarity incorrectly. Without a control, it isn’t clear why this was the case.<br>Students in CHM 250 were taught DNA structure using a variety of approaches that included a traditional PowerPoint lecture containing images of DNA structure, the 3D model of a DNA helix in class, and a movie on DNA structure containing some animations. Nearly all students felt that the 3D model in class was the most effective tool for helping them to learn DNA structure.<br><br>**Conclusion**<br>Overall, it is clear that introductory level students in biology and chemistry enjoy using models and feel they are useful to them for learning difficult concepts such as polarity, hydrogen bonding, water properties, and protein folding. Student response to models in the 300-level course was not as positive, indicating that these particular models are probably not as suitable for advanced students, although they may serve to remediate learning for students who failed to master these concepts in their 100-level or 200-level courses.<br>In the 2014-2015 academic year we did not yet know enough about these models and how students would react to them in a variety of classes to assess their impact |

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| | on learning. This pilot study has provided some parameters within which we can plan a real study. In Fall 2015, models will be offered to all instructors in Bio 105. A pre- and post-test focusing on content will be administered to students in sections using and not using models so that we can quantify the impact of using models on student learning in an introductory course. |
| **APPENDIX** | |