Building an Online Biochemistry Course With Assessment and Feedback Embedded Into All Online Instructional Activities.

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Abstract: This interactive poster session will demonstrate how we are embedding assessment activities within online STEM (science, technology, engineering and mathematics) course materials in such a way as to provide immediate feedback to students as well as to provide meaningful data for instructor feedback. The activities include animations of biochemical processes, virtual lab environments that are driven by true molecular simulations, and molecular visualization tools. The collection of these materials, along with supporting text and example problems, are the backbone of a publicly available online Biochemistry course.

Promoting Active Learning

Our interactive showcase will demonstrate the current state of our online Biochemistry course which is in the process of being made openly available to all students and educators via the Open Learning Initiative (OLI). This course can be used in conjunction with any biochemistry textbook. We have developed a number of animations, simulations (virtual labs) and structured molecular visualization exercises to augment the content students are currently provided by their textbooks. However, even when students are provided with "interactive" materials, created by the instructors or by the textbook publishers, many do not engage sufficiently with the materials. We believe it is because most of these materials do not really support active learning where students are encouraged to be an active participant in the exploration of learning objectives. To facilitate this engagement, we are embedding assessment questions into all of the online activities within the course. Students are asked questions as they explore animations and simulations. They are provided hints and feedback to their responses - a virtual conversation with the instructor, and a time to reflect. The feedback is also provided in the form of causal reactions by the simulations as well as text responses. Those questions that are tagged as measuring mastery of a particular concept are recorded to provide feedback to the instructor.

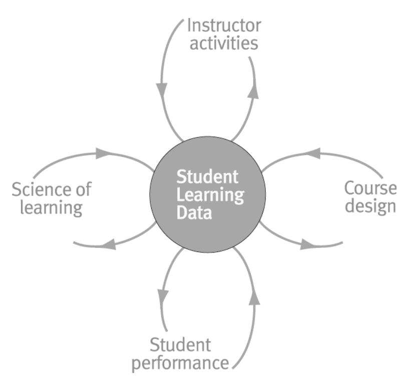

Figure 1: The 4 powerful feedback loops centered around student learning data.

We have chosen to deploy these materials in three formats: i) materials that can be linked to from our server, ii) downloaded and deployed from with standard course management system (e.g. Blackboard), and iii) in OLI. OLI represents an example of leveraging information technology to create a scientific approach to designing, delivering, assessing, and improving instruction. OLI courses use simulations, visualization software and other activities that have proven to be very effective in supporting novices in independent practice and observation. One of the most powerful features of the OLI web-based learning environments is that they enable us to embed assessment into every instructional activity and use the data gathered from these assessments to drive 4 powerful feedback loops: i) to the learner, ii) to the instructor, iii) to the course design team, and iv) to the science of learning (See *Figure 1*). The instructor-student loops are described in more detail in *Figure 2*.

Studies have shown that students' learning improves and their understanding deepens when they are given timely and targeted feedback on their work (Hattie & Timberly, 2007; NRC, 2004.) Reports from the National Science Research Council and others (e.g., NRC, 1996) have recognized the importance of feedback provided through formative assessments as vital to effective learning environments. They describe assessment and instruction as being "two sides of the same coin," emphasizing that when students engage in assessment activities, they should learn from them. This learning can come in the form of scaffolding and feedback constructed within the assessment activity by the instructor as well as additional scaffolding and feedback provided by the online learning environments in which the students study. Major findings from a recent study include that students who learn with OLI statistics course, learned a full semester's worth of material in half as much time and performed as well or better than students learning from traditional instruction over a full semester (Lovett, Meyer, Thille, 2008).

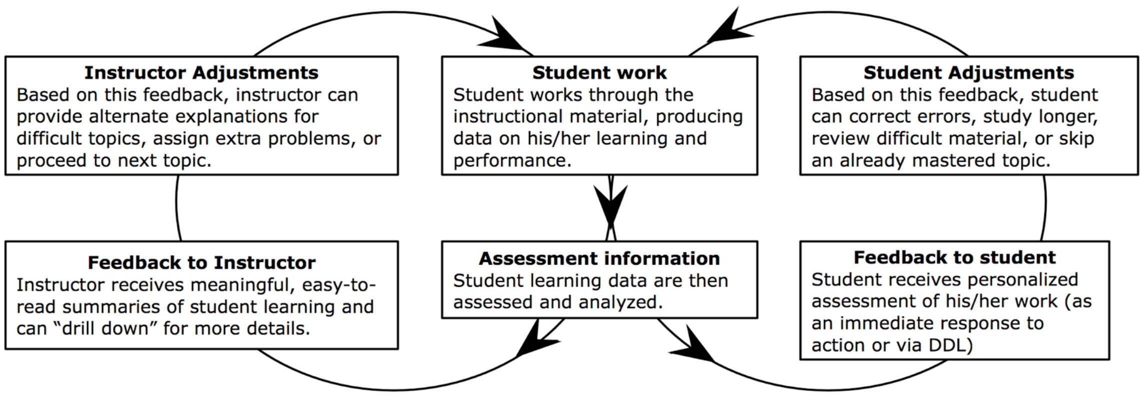

Figure 2: Illustration of the feedback cycle in instruction. Note that the right-hand cycle involves feedback to the student, and the left-hand cycle involves feedback to the instructor (Figure courtesy Dr. M. Lovett,

Using Embedded Assessment Activities Within Instructional Activities

Well designed technology-enhanced learning environments enable us to embed ongoing formative assessment and feedback into the instructional activities. In this way, the student not only gets the chance to practice what they are learning but also receives performance feedback that they can immediately use to tune their learning.

Two examples of our existing learning activities are shown in *Figure 3* and *Figure 4*. The example in *Figure 3* shows an activity using a virtual lab/simulation as the learning object. The simulators use real-time calculations and algorithms to determine the behavior of the molecules. Each type of molecule, or cast member, in the animation is given a set of properties and behaves according to these properties. Consequently, there is no pre-defined script and it is possible to modify the properties and numbers of the cast members at any time during the "animation." At the beginning of each animation the molecules are placed at random positions on the stage and given a random velocity. The simulator then calculates new positions of the molecules based on Newtonian mechanics. The behavior of the molecules when colliding with boundaries and other molecules is determined by the properties given to each species at the beginning as well as by student accessible controllers if provided. *Figure 4* is an illustration of mixing multiple representations of an activity, including computational aspects. The student are given instruction by the assessment text which then querries the student for an explanation of the behavior he encounters. When the student selects the incorrect explanation, the instructor feedback as well as the resulting lines drawn on the graph demonstrate the flaw in the students's solution.

In both of the above activities the text region on the left guides the students through their exploration of the simulation on the right by asking them questions to focus their attention on important features of the simulation or data chart. When the students respond, or ask for hints, they are provided with the explicit feedback relevant to the current state of the activity. Students' answers to the questions on the left are recorded and can also result in varied behavior of the simulation on the right, which is another form of feedback.

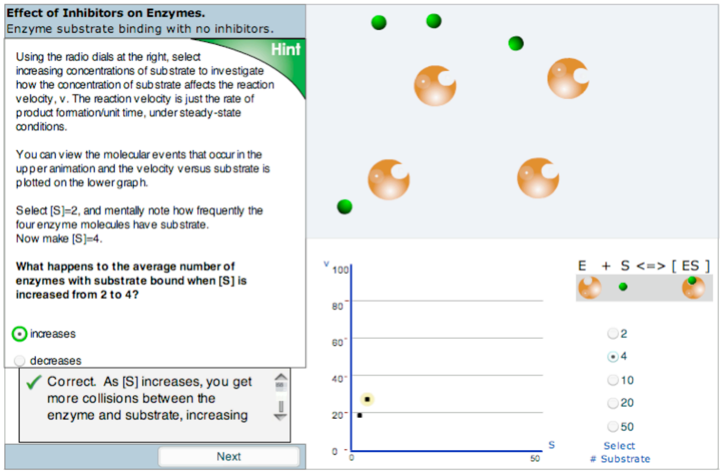

Figure 3: Assessment and Instruction in Enzyme Kinetics. The upper right panel shows the output from the simulator. The larger spheres are enzymes, with an open active site on the right and an allosteric inhibitor site on the left (small white dot). The green dots are the substrate, no inhibitor is present on stage at this point of the exercise. The lower right part of the panel shows the student input area (radio buttons) and the measured data. In this simulation a discrete number of substrates can be chosen by the student. This could be replaced by a slider bar, allowing any concentration to be entered. The graph in the lower section of the frame shows the resultant initial velocity. The left half of the image shows an embedded mini-tutor that directs students through the exercise, providing hints, assessment, and feedback along the way. We are currently developing the capability of

Because students pay more attention to questions they believe will end up in the gradebook, integrating scorable questions within the context of the material they are learning causes them to think more actively about content they are reading so they can generate a response. The very content of the questions, answers, hints and feedback provide additional opportunities for learning. Students have told us they intentionally select the incorrect response to see the feedback analysis on why that selection is incorrect.

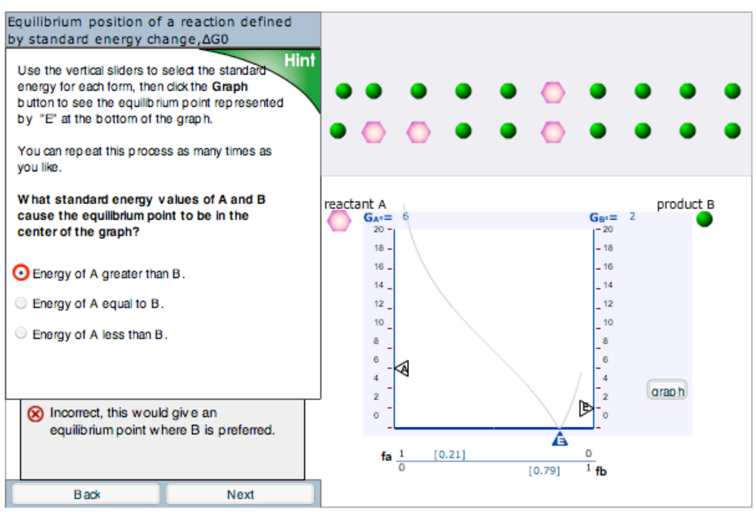

Figure 5 provides an alternative, earlier format for providing a simulation activity. In this case the students are guided through the simulation, and then they complete the assessment questions at the end of the activity. Although this approach is somewhat easier to construct in course management systems, it is not as useful to the learning process because the assessments are physically and temporally disconnected from the learning activities.

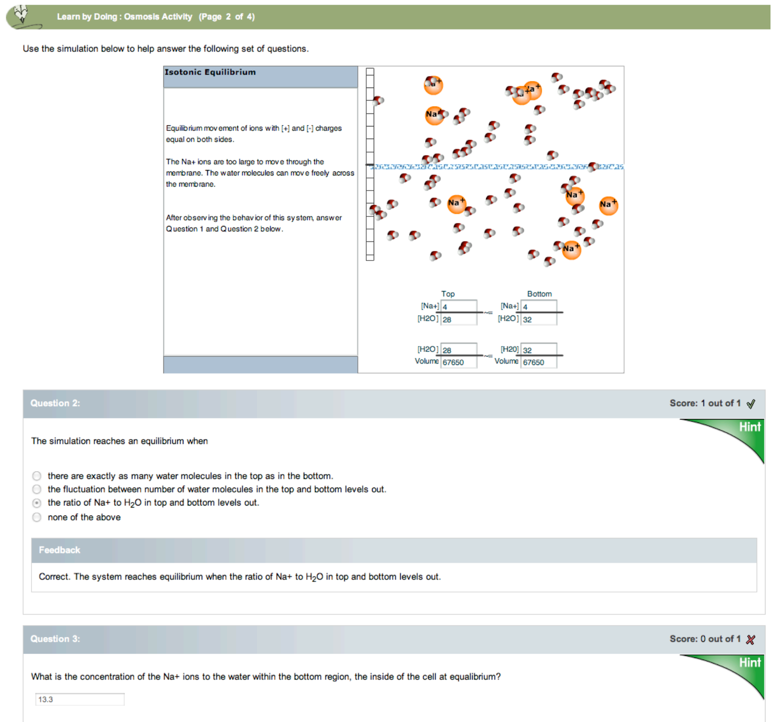

Figure 5: Example of activity providing the students with a learning object which can be manipulated and explored by the student providing data for analysis and visualization for interpretation. Immediately below are assessment questions requiring the student to articulate what they believe they are learning about the activity. Results of these questions are accumulated and added to feedback reports.

Extending Embedded Assessments to Molecular Visualization.

Research and education in biochemistry and molecular biology has benefited from fast desktop computers and free and commercial software for the visualization of molecular structures. The software supports instructors to demonstrate, and students to practice, operations that would be nearly impossible to carry out by hand. The importance in authentic visualization in STEM education has been echoed by the National Research Council (2000):

> "The same kinds of computer-based visualization and analysis tools that scientists use to detect patterns and understand data are now being adapted for student use. The ability of the human mind to quickly process and remember visual information suggests that concrete graphics and other visual representations of information can help people learn (Gordin and Pea, 1995), as well as help scientists in their work (Miller, 1986)".

Computer visualizations are widely used by instructors for classroom demonstration of material science and biochemical phenomena. These visualization software and simulations are very effective teaching tools when used by an expert human guide. Although it is currently possible for instructors to point their students to web pages where they can view the same complex molecular structures seen in lecture, deep learning requires that students do more than manipulate these structures and "marvel at their beauty." Although separate worksheets (i.e. homework) and simple scripting of the visualization web page can aid in navigation through complex structures, these supports are insufficient for supporting novices in independent practice and observation. Students must be guided through activities that help them focus on specific features and relationships and develop hypotheses for resulting behaviors. Related computational activities can then demonstrate the validity of these hypotheses.

One of the most prevalent of these visualization tools is Jmol: an open-source Java viewer for chemical structures in 3D with features for chemicals, crystals, materials and bio-molecules. There are databases of tens of thousands of structures that can be viewed and manipulated with this tool. Jmol is a widely-used and sophisticated molecular viewer that allows users to turn on and turn off various features, including surfaces and measurements of the models. Instructors often use Jmol visualizations during lecture to illustrate various properties of the current molecular structure. One of the many advantages of Jmol is that the models can be embedded on a web page. Thus, the student does not need any special software aside from a current version of Java on the client machine, thus avoiding the frustrating necessity of having students download the visualization packages or having the package installed on public clusters. As a viewer of these structures, Jmol provides students access to scholarly research within these sciences, and as such provides authentic activities for the students.

Our current focus is to provide a bridge between current Jmol capabilities and the rich assessment/feedback infrastructure in the OLI environment. This process will require connecting the Jmol javascript library to the OLI assessment engine via the standard OLI flash mini-tutor tool used extensively for our molecular simulations that were discussed above. This will allow the assessment and feedback activities to control the activities in the Jmol window and collect student responses, mouse clicks, exploration of the structure by the student, as well as student evoked status changes. Jmol pages we develop will have the following general features

- Provision of scaffolding during the learning process such that the student's experience is both comprehensive as well as efficient.
- Providing directed feedback to the students while they are interacting with structure. Studies have shown that the earlier feedback results in greater learning and retention of material.
- Feedback is given to the instructor such that critical misunderstandings in student knowledge can be identified and addressed in a timely manner. The instructor feedback can also be used to improve the design of the activity.

A mock-up of a Jmol exercise for serine proteases is shown in *Figure 6*. This mock-up demonstrates the pedagogical advantage of having active student involvement with the molecular visualization software, coupled with immediate feedback on their work.

Engaging Students: If You Build It – Will They Use It?

Instructors strongly feel that the feedback and animations they are providing to their students are extremely helpful in explaining the content. Many instructors cannot understand why students fail to use them on a consistent basis. Based on our experiences thus far, most students will not utilize the material unless the activity can directly enhance their course standing; the potential to reap benefits in distant exams is not a sufficient incentive. Within the course we are designing, we are exploring ideas for assigning micro points to encourage students to engage in these activities. We would also like to tag certain questions as representing mastery of a particular concept. In this was we can look across activities to provide both the instructor as student with a summary for concept mastery.

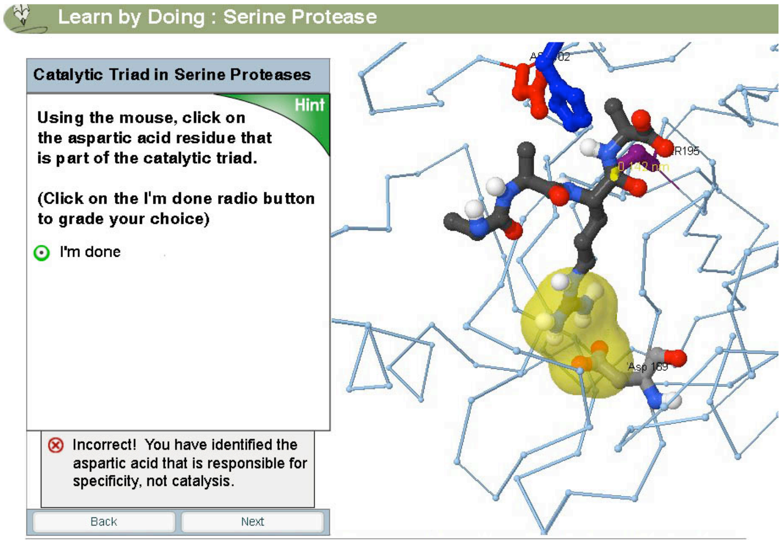

Figure 6: Mock-up of one of the student activity pages for investigating serine proteases. After reading explanatory text that frames the entire exercise the student navigates through a series of pages using the "Back" and "Next" buttons. Each page may contain additional text in addition to a question that prompts the student to interact with the Jmol visualization on the right. The student can receive hints by clicking on the "Hint" tab on the upper right. When the student has completed the exercise, clicking on the "I'm done" radio button will initiate the evaluation of the recent Jmol activity to determine if the question was answered correctly. Navigation through the exercise can be controlled such that loading the subsequent page can require the successful completion of the previous page.

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