

Learning Biology With A Web-Enhanced Curriculum

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Session abstract:

We are currently conducting a formative evaluation study on a new basal biology curriculum for ninth and tenth grade students that integrates the World Wide Web with a short topic-oriented textbook. The curriculum is based on the National Science Education Standards and emphasizes an active, constructivist learning program that integrates interactive, Web-based instructional media. The new curriculum utilizes the interactivity of the World Wide Web, the storytelling abilities of a short textbook, and an inquiry-based program of "wet" labs and fieldwork. National Science Foundation funding supports the formative and summative evaluation of this curriculum. The evaluation program focuses on the effectiveness of integrating Web-based instruction into the biology curriculum, both in terms of helping students learn and helping teachers teach. In this session, we will present the results from the first year of our evaluation study. The presentation will show how the Web-based materials address the important goals of biological science teaching and learning and how the World Wide Web is used to promote inquiry-based learning in high school biology settings.

Objectives of the Study

We have completed the first year of a formative evaluation study to guide the design and development of a basal biology program for ninth and tenth grade students that integrates the World Wide Web with a short topic-oriented textbook. The curriculum is based on the *National Science Education Standards* and emphasizes an active, constructivist learning program that integrates interactive, Web-based instructional media. The new curriculum utilizes the interactivity of the World Wide Web, the storytelling abilities of a short textbook, and an inquiry-based program of "wet" labs and fieldwork. National Science Foundation funding supports the formative and summative evaluation of this curriculum that is being developed by Pearson Education. The evaluation program focuses on the effectiveness of integrating Web-based instruction into the biology curriculum, both in terms of helping students learn and helping teachers teach.

The major formative evaluation questions addressed in this research are,

- Do the materials address the important goals of biological science teaching and learning?
- Are the topics of the unit and the modes of instruction developmentally appropriate?

Significance

Since the post-Sputnik spike in our nation's commitment to science, math, and technology education, a chorus of committees and commissions has called for reform of science learning in our schools (Bybee, 1996). Most of these reform initiatives advocate a change in emphasis from students memorizing facts and terminology to students investigating nature through active participation. Research on learning supports what many teachers have always believed from experience: students understand and apply concepts better when they construct their own understanding than when they are passive vessels in the educational process (Vygotsky, 1978). In 1996, the *National Science Education Standards (Standards)* developed by the National Research Council, amplified the call for active learning as the cornerstone of nationwide reform to make science accessible to all students and lead to a more scientifically literate citizenry. Even a broad consensus, however, will not produce the needed change until science teachers are equipped with the strategies, tools, and support they require to provide an investigative environment for all of their students. The *Standards* articulate the "what to" and "why to" for reforming science education, but purposefully leave the "how to" for developers of instructional materials.

Learning Science with the World Wide Web

Learning science in today's classroom does not have to be restricted to text-based curricular resources. Web sites present learners with a wide range of science activities in various formats ranging from text-only information to providing authentic real-time data sets and interactive simulations. Owston (1997) contended that the World Wide Web is likely to bring new learning resources and opportunities into the classroom, provide teachers and students access to more resources, and promote improved learning. Many Web-based curricular resources have been developed for use in K-12 science classrooms. Some of these resources have been described in the literature (Bodzin & Park, 1999; Cohen, 1997; Feldman, Konold, & Coulter, 2000; Songer, 1998).

Theoretical Underpinnings

Few would disagree that the formative evaluation process of a Website design, its implementation, and its use can help increase the quality of those designs and the likelihood of student learning. The techniques associated with formative evaluation of computer and Web-based courseware have been the subjects of a much research over the past few years (see for example Jacobs, 1998; Maudlin, 1996; Northrup, 1995; Phelps & Reynolds, 1999). However, a lack of rigorous evaluation in practice may have led to a relatively low level of integration of Web-based learning in science curriculum. While much attention has been given to interface and instructional design issues, development teams sometimes have paid less attention to evaluating instructional support issues for successful implementation of science curricula with both teachers and students in classroom settings.

Initial Program Design

The products that have been developed to directly facilitate student learning inquiry-based activities and simulations presented over the World Wide Web, and

investigative "wet" laboratories, field studies, and include a short, concept oriented textbook. To provide the active involvement required for effective learning, the developers have created inquiry-based activities and simulations to be delivered over the Web. A series of Web-based activity types have been developed to deliver instruction on the Web. These include:

(a) WebQuests - These are short, activities that engage students in the chapter subjects before they have even learned the key concepts.

(b) Concept Activities - For each concept in a chapter, there is an accompanying activity on the Website. The activities animate biological processes and promote active learning through self-assessment activities such as problem solving, drag-and-drop sorting, building a structure, playing a game, competing in a challenge or calculating a solution.

(c) Chapter Quizzes - Learners are able to take an online quiz of 10-15 multiple choice questions at the end of each chapter. Feedback on each answer will direct students to appropriate places in the Website for review.

(d) Explore! In contrast to the concept activities, which mainly reinforce the textbook concepts, the Explore! are longer-range activities that are designed to enable students to apply and extend the concepts through active participation.

(e) Laboratories - The Website would include some virtual laboratory procedures. These procedures would be designed complement, not replace, real lab and field experiences. Thus, many of the virtual experiments at the Website will provide students with some background and practice that would make their actual labs more meaningful.

Design and Procedure

Throughout the development of *Exploring Life*, we have employed a user-centered design strategy that focuses simultaneously on interface issues, students and teachers' subjective experiences in using Web-based interactivities, and student learning outcomes. A concurrent integrative formative evaluation process was used to evaluate the *Exploring Life* program. The aim of the formative evaluation was to assess the materials in terms of their ease of use, pedagogy, program performance, and clarity and depth of content. Our mixed method approach combines experimental methods and qualitative approaches. An illuminative approach was used to observe and measure the teaching and learning process. Our aim was to discover which factors and issues are important for biology teachers in successfully implementing *Exploring Life* with their students and to convey this information to the developers of *Exploring Life* for their use in helping the program achieve its intended objectives. We proceeded through iterative cycles of design and evaluation.

A battery of methods and instruments was used in the Year 1 evaluation. These included:

1. *AAAS Criteria for evaluating instructional support*. This evaluation instrument examines how well the instructional materials are likely to help students learn the important ideas and skills in the widely accepted Benchmarks for Science Literacy and in the National Science Education Standards (AAAS, 2000). Biology teacher participants completed this after each evaluation workshop.
2. *Usability analysis*. We focused on determining whether or not the interfaces were consistent and easy to use (user evaluation) and determining whether or not the

program performed as specified (functional evaluation). Data were collected in evaluation workshops and site-based field observations. In addition, an instructional design expert reviewed the materials and provided analyses and recommendations at three main stages of development.

3. *Attitude measures.* Biology teacher participants completed a post-implementation survey consisting of Likert-type and open-ended questions. These participants also submitted a journal that used open-ended questions.
4. *Content knowledge assessments.* High school biology students completed content assessments for each Exploring Life chapter piloted as a pre and posttest measure. Each question corresponded to a distinct learning objective. For consistent marking, these assessments were multiple choice.
5. *Interviews with students and teachers.* Semi-structured interviews with a sample of students were conducted to initiate discussion about their perception of learning with *Exploring Life*.
6. *Student response journals.* A sample of students were asked to write a student reaction paper about their experience using the *Exploring Life* materials.
7. *Computer experience questionnaire.* This instrument asks about past and current computer and Internet training, usage, skills, and confidence about computers and Web-based learning.

Implementation

Forty-two high school biology teachers, one preservice biology teacher, and one science supervisor, selected from a stratified sample of thirteen distinct geographical regions that included Alaska and Hawaii, participated in the evaluation of the *Exploring Life* materials during this first year. The participants reviewed the *Exploring Life* Web-based and text materials in various stages of development at one of three evaluation workshops. Workshops were held in August 2000, October 2000, and March 2001.

A prototype chapter for cellular respiration was developed prior to the August 2000 workshop. Feedback from the first evaluation workshop, the interface analysis reports, and initial pilot testing with classroom students resulted in the development of rapid prototypes of two new interfaces for the Website. Rapid prototyping allows for rapid construction of different design approaches for the purpose of evaluating strengths and weaknesses of the instructional system interface before full-scale production. Participants in the October 2000 workshop evaluated both rapid prototypes. Participant feedback about the prototypes and the interface analysis reports led to adopting a new interface design for the Website.

The cellular respiration and photosynthesis chapters were developed using the new interface design prior to the March 2001 evaluation workshop. An ecology chapter was developed in May 2001.

During the school year, eighteen participants pilot tested *Exploring Life* materials with 783 students. The evaluation team conducted five classroom field observations during the school year. The findings of the classroom field observations and each evaluation workshop were discussed with the development team. Recommendations

resulted in the modification of Website features and the development of new interactivities. Resulting modifications to the Website were evaluated in each succeeding workshop and by our interface design expert. Students completed pre- and posttests for biology content knowledge and concepts before and after using the chapter materials. After students completed a chapter, each teacher submitted a post-implementation survey and a journal with open-ended responses. Follow-up phone interviews were conducted with selected teacher participants. Throughout the first year of the project, close, almost daily contact has occurred among the evaluation team, the development team, and the teacher pilot testers through an e-mail listserv.

Redesign of Product Materials to Improve Learning

Significant product improvements have been made in the design of the instructional materials since the original prototype chapter was developed. Table 1 summarizes the changes made to the prototype chapter of *Exploring Life* as a result of the evaluation feedback. The resulting modifications are currently being used in the development of additional media for succeeding chapter development.

Our concurrent integrative formative evaluation process has been extremely useful in producing Web-based instructional materials for high school students to learn biology in an active learning environment. In our iterative evaluation process, the teachers' and students' feedback became an integral part of the program developers' decisions to make relevant changes to the instructional program. Since the evaluation occurred in different stages of the development work, it was relatively easy for the developers to modify interactivities and alter instructional design features according to the recommendations of the evaluation team. The resulting modifications were then tested during the next phase of the evaluation.

The next stage of the project is to test revised chapters with a larger sample of biology classrooms. We plan to use additional data collection methods including performance assessments and the use of experimental control groups. This will build on the evaluation described here and enable us to learn valuable lessons about the implementation of a Web-integrated program in diverse educational settings.

Table 1: Exploring Life Product Improvements as a Result of the Formative Evaluation.

Instance Prior to Feedback	Evaluation Feedback	Resulting Product Change
<p>The prototype chapter did not have adequate "teacher resources" available to assist teachers in using Exploring Life with their students.</p>	<ol style="list-style-type: none"> The evaluation team made recommendations for the "teacher resources" section based on the results from the AAAS criteria for evaluating the quality of instructional support instrument, workshop surveys and focus group responses. Pre- and posttest content assessments revealed students' misconceptions. 	<ol style="list-style-type: none"> Current Website contains a revised "teacher resources" section that includes alternative assessment ideas, suggestions for teaching in different computer settings, troubleshooting suggestions, tips for teaching each concept, hypertext links to additional content information, and examples of student data. A "teaching for conceptual change" section of the teacher resources is currently under development.
<p>User interface issues:</p> <ol style="list-style-type: none"> The concept backbone structure. Showing the relationship between labs/explores and their parent concepts. Color scheme Confusion over how to page forward within an activity and the function of the breadcrumb (navigation trail) feature. Difficulty finding and reading instructions for the activities. 	<ol style="list-style-type: none"> Teachers had trouble understanding how each Website component related to the entire site. User interface recommendations made. Teachers expressed confusion over the different types of activities and how they all fit together. User interface recommendations made. Teachers expressed concern that the screen looked too "bland." Color scheme recommendations made. After completing an activity, students and teachers had trouble figuring out how to page forward. Many did not understand the page stepper and most did not use the breadcrumb (navigation trail) feature. User interface recommendations made. Learners would scan the text for specific instructions, not bothering to read carefully. User interface recommendations made. 	<p>See new user interface on the Website:</p> <ol style="list-style-type: none"> New concept backbone as it appears on the chapter table of contents and on each activity page. New concept backbone. New color scheme. Page stepper was revised for greater clarity and put in its own frame so it became enduring no matter where the user was located in the activity. The breadcrumb (navigation trail) was increased in size and colored blue to make it more obvious to the user. Developers added a blue instruction box to each activity to house specific interactive instructions. The type size was increased for ease of reading.
<p>Chapter 7 Cellular Respiration Pre-/Posttest Question #5: All work requires a source of _____.</p>	<p>A few student scores on this test question decreased from pre- to posttest. Students selected "ATP" from the answer choices, erroneously concluding that all work required ATP. This was most likely due to the chapter's strong focus on ATP.</p>	<p>Authors revised Chapter 7 to make clear that ATP was one source of energy.</p>
<p>Chapter 7, Concept 7.4 Electrons fall from food to oxygen during cell respiration. Online activity: <i>The Snowboarder</i></p>	<p>The keyboard controls were difficult to use and the snowboarder analogy wasn't a perfect one for the concept. Some student confusion.</p>	<p>Media team scrapped the activity. A new 7.4 interactivity was developed that more accurately presented the concept without using keyboard controls.</p>

Animations played through from beginning to end at the click of a "start" button.	Teachers and students expressed the need for more user control. Their concern came in the form of "speed control." Recommendations made to increase the user's control over the animations by segmenting animations into smaller components.	While developers could not offer varying speeds to play the QuickTime animations, they did adapt the standard QuickTime controller at the bottom of the animation window to show a content progress bar. This enabled the user to access relevant segments of a complex (or long) animation quickly when they wanted to replay it. See Concept 7.1 activity (<i>Bear in the Apple Tree</i>). Chapter 8 animations were developed with this revised format.
Animations were populated with teenagers to give the product a "high school" feel and a more personal, human touch.	Teachers pointed out that the animations looked too "young" and reminded us that teenagers think of themselves as older than they are. The inclusion of these younger-looking teens might make the material less interesting and attractive to them.	The developers removed the original characters, replacing them with photos for context-setting scenes. These contained adults or animals in areas where organisms needed to be animated.
Chapter 7, Concept 7.5 Cellular respiration converts food energy to ATP energy. A pinball animation showing the basic mechanisms of Glycolysis, Krebs Cycle, and Electron Transport	Teachers and students expressed the need for more user control. Participants' concern took the form of "this activity is too long, there's too much going on for the student to absorb everything."	The developers segmented the animation. Summaries of steps were provided to break the animation into manageable chunks and to slow it down.
Students and teachers noted they were frequently confused over the purpose of some activities, particularly the longer, multi-part interactivities.	The evaluation team suggested that each activity should contain a goal statement to make its purpose clearer to the learner. Furthermore, expected outcomes of the activity should be explicitly distinguished.	Goal statements were added to each concept activity.

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