Formative Evaluation of the Design and Development of a Web-based Biology Curriculum: Year One Findings

Paper presented at the 2002 National Association of Research in Science Teaching Annual Meeting, April 7-10, 2002

Alec M. Bodzin, Lehigh University
Betsy Price, Westminister College
Ward Mitchell Cates, Lehigh University
Brad Williamson, Olathe High School East
Neil Campbell, University of California, Riverside

Abstract

This paper reports the first year s formative evaluation of a biology program for ninth and tenth grade students that integrates the World Wide Web with a short concept-oriented textbook. The curriculum is based on the *National Science Education Standards* and emphasizes an active, constructivist learning program using interactive Web-based instruction in concert with a textbook and a laboratory program. We employed a user-centered design strategy that focused simultaneously on interface issues, students and teachers' subjective experiences in using Web-based interactivities, and student learning outcomes. Our mixed method evaluation combined experimental methods and qualitative approaches to assess prototype materials in terms of their ease of use, pedagogical soundness, clarity in presentation and breadth and depth of content. This article describes the methods used during this formative evaluation and the results obtained.

Formative evaluation is defined as "the systemic collection of information for the purpose of informing decisions to design and improve the instructional product" (Flagg, 1991) and is usually conducted to provide developers of learning environments with information that is useful in improving an instructional program during its developmental stages. The techniques associated with formative evaluation of technology-based instructional materials have been the subjects of a much research over the past few years (see for example Jacobs, 1998; Mauldin, 1996; Northrup, 1995; Phelps & Reynolds, 1999). Interface and instructional design issues have received much attention from teams developing technology-based learning products. Unfortunately, such developers have sometimes focused less attention on evaluating the kinds and level of support needed to implement science curricula effectively in classroom settings.

In this article, we describe a user-centered design strategy that focuses simultaneously on interface issues, instructional support for classroom implementation, student learning outcomes, and students and teachers' subjective experiences in using Web-based interactivities. Our approach combines experimental methods and qualitative approaches to assess prototype materials in terms of their ease of use, pedagogy, program performance, and presentation and coverage of content. We describe how this approach led to notable improvements in the design of the instructional materials.

Theoretical Framework

The Call for Reform

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 (AAAS, 1989, 1993; Bybee, 1996; NRC, 1990; Schwab, 1958; Uno & Bybee, 1994; Yager, 1988). Most of these reform initiatives advocate a change in emphasis from students memorizing facts and terminology to students investigating nature through active participation (DeBoer, 1997; NRC, 1989; Uno, 1990; Welch, Klopfer, Aikenhead, & Robinson, 1981). Research on learning supports what many teachers have concluded from experience: students understand and apply concepts better when they construct their own understanding than when they are passive vessels in the educational process (Anderson, 1992; Bruner, 1962; Vygotsky, 1978). In 1996, the *National Science Education Standards* (henceforth, *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 developers of instructional materials free to determine the best "how to" for given contents, learners, and instructional settings.

Obstacles To Reform

There are a number of obstacles to the adoption of active science learning. The textbook persists as the focal point of curriculum in most science classrooms, but its inflexibility can act to inhibit teachers and school districts from embracing the core values of the *Standards.* The *Standards* "rest on the premise that science is an active process (Carley, 1988). Given the frequency with which printed textbook s are revised, they are unlikely to serve as the centerpiece of a curriculum reform that moves students from passive absorption to active participation (Chiappetta & Fillman, 1998; Groves, 1995; McInerny, 1986).

While active learning programs are available on the Internet, they are seldom embedded in a complete curriculum. Before the *Standards* validated investigative learning, it was already a priority for students of experienced teachers who are confident with their subject knowledge and comfortable with their authority in the classroom (McNeal & Avanzo, 1997). Such teachers may well be able to incorporate active learning into existing textbook-based science curricula. There are, however, many teachers who are not so experienced or comfortable and these teachers may have more difficulty incorporating individual investigative learning activities into the standard science curriculum. In addition, the demands of accountability measurements in the form of state mandated end-of-course mastery tests may make it even riskier to attempt to incorporate such activities piecemeal (Cohen, 1997; Costenson & Lawson, 1986; Feldman, Konold, & Coulter, 2000; Yager, 1992).

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 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 already been developed for use in K-12 science classrooms. Such materials can provide prompts for students to examine evidence (data), compare different viewpoints, and analyze and synthesize existing data sets to formulate conclusions. The Web allows for the use of various instructional resource types to enhance their value for student science learning. These include scientific visualizations, simulations, virtual reality, animations, video clips, still images, and distributed learning sources. Some of these resources have been described in the literature (see for example, Bodzin & Park, 1999; Cohen, 1997; Coulter & Walters, 1997; Feldman, Konold, & Coulter, 2000; Songer, 1998).

In addition, the Web may be able to provide supports for learning processes infused with constructivist principles. Constructivist conceptions of teaching and learning assign primary importance to the way in which learners attempt to make sense of what they are learning (Krajcik, Blumenfeld, Marx, & Soloway, 1994). In a Web-based environment, learning can be an active process where learners explore ideas, compare and synthesize resources, and revise ideas. The Web may provide a context for authentic learning by presenting learners with authentic real world tasks that require problem solving and reasoning to achieve a collaborative goal. Web-based conferencing and the sharing of student-created work can provide learners the opportunity to articulate their reasoning as they solve problems. Web-based activities can provide task structuring that requires learners to think about their own learning as they solve problems and seek out alternative explanations. Collaborative Web-based learning involves social interaction and a sharing of collective knowledge in which the peer dialogue involves learners in the social construction of knowledge. Thus, the World Wide Web, because of its interactivity, its accessibility, its customizability, and its sense of community, may present an opportunity to overcome the four obstacles identified earlier.

Initial Program Design

The overall project goals were to develop a biology curriculum designed to improve high school biology students' understanding of fundamental biological concepts; to improve their self-confidence and skill in scientific reasoning and inquiry; and to enhance their ability to apply biological knowledge and the methods of science to important social issues, consistent with the *Standards.* The two main project objectives were (1) to develop a general biology curriculum based on constructivist learning and focused on biological themes, and (2) to develop student-centered materials for active learning of biology.

The products that would be developed to directly facilitate student learning would include (1) a short, concept-oriented textbook, (2) inquiry-based activities and simulations presented over the World Wide Web, and (3) investigative "wet" laboratories and field studies. To provide the active involvement that supports effective learning, the developers would create inquiry-based activities and simulations to be delivered over the Web. A series of activity types for each chapter were developed for online delivery. These included:

1. **WebQuests -** Short activities that engage students in the chapter subject before they have even learned the key concepts.
2. **Concept Activities -** Each concept in a chapter would have an accompanying Website activity. Activities animate biological processes and promote active learning through self-assessment activities, such as problem solving, graphing data, drag-and-drop sorting, building a structure, predicting an outcome, labeling a diagram, playing a game, competing in a challenge or calculating a solution.
3. **Chapter Quizzes -** Learners would be able to take an online quiz of 25 multiple choice questions at the end of each chapter. Feedback on each answer directs students to appropriate places on the Website for review.

4. **Explore!** In contrast to the concept activities, which mainly reinforce the textbook concepts, Explore! activities are longer-range activities designed to enable students to apply and extend concepts through active participation.
5. **Laboratories -** Animated laboratory procedures for laboratories found in a printed laboratory manual. These procedures complement, not replace, real lab and field experiences. Thus, animated procedures on the Website provide students with background and practice to enhance their hands-on labs.

Evaluation Design

Our aim was to discover which factors and issues are important for biology teachers in successfully implementing *Biology: Exploring Life* with their students and to convey this information to the developers 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. *Content knowledge assessments*. Pre- and post-tests constructed by the *Biology: Exploring Life* developers with considerable input from members of the evaluation team were given to 9^{th} and 10^{th} grade biology students before and after using each chapter. Each multiple choice question corresponded with a distinct learning objective.
2. *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 *AAAS Benchmarks for Science*

Literacy and in the *Standards* (American Association for the Advancement of Science, 2000). Biology teacher participants who completed this instrument after each evaluation workshop reflected on the standards and their implications for curriculum content and instruction (Kesidou, 2001). Appendix A lists the criteria for this instructional analysis procedure.

3. *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).

    a. *Evaluation workshops*. Biology teachers were given Web-based and text materials to review prior to participating in an evaluation workshop. In each evaluation workshop, biology teachers were observed as they worked through the Web-based materials for 1.5 hours. After each biology teacher worked through the materials, he or she participated in a focus group session.

    b. *Site-based field observations*. Six classrooms of students were observed by evaluation team members who gathered open-ended observations.

    c. *Expert Analysis*. An instructional design expert (third author) reviewed the materials and provided analyses and recommendations at two major stages in the development of the Web-based materials.

4. *Attitude measures.* Biology teacher participants completed a post-implementation survey consisting of Likert-type and open-ended questions after using materials in their classroom (Appendix B) and submitted a journal to the evaluation team that

used open-ended questions (Appendix C). These instruments were designed to address our four main formative evaluation questions:

a. Do the materials address the important goals of biological science teaching and learning?

b. Are inquiry and activity the basis of the learning experiences?

c. Are the topics of the unit and the modes of instruction developmentally appropriate?

d. How are teachers implementing the materials?

5. *Interviews with students.* Semi-structured interviews (Borg & Gall, 1983, p.442) with a sample of students were conducted to initiate discussion about their perception of learning with the materials. A semi-structured interview allows the researcher to follow-up with respondents answers to a set of specific questions The students' comments acted as prompts for each other.

6. *Student response journals*. A sample of students were asked to write a student reaction paper about their experience.

7. *Interviews with teachers who did not use materials*. Structured phone interviews (Borg & Gall, 1983, p.442) were conducted with each teacher participant from the first two workshops who was unable implement the materials with their classroom students.

8. *Computer experience questionnaire*. This instrument asks about past and current computer and Internet training, use of technology, and perceived level of skill and confidence in using computers and Web-based learning.

Implementation

Three evaluation workshops were conducted at different developmental stages during the first year. Calls for participation were posted on national and state educational listservs and bulletin boards. Biology teachers that were interested in participating in the *Biology: Exploring Life* evaluation completed a 44-item computer experience questionnaire. The survey allowed us to select participants with varied demographics and background characteristics including: geographical area, socio-economic level of the school, years using the Internet for teacher planning/preparation, perceived preparation to use the computer and Internet in classroom activities, training to integrate instructional technologies into curricula, number of computers in the classroom and school, student-to-computer ratio, and extent of technology use in the classroom.

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 materials during this first year. The participants reported that they felt ready to use computers for their own professional use, as well as with their students. Most teachers were early adopters (88.1%), members of a social system of biology teachers that have embraced the use of computers and the Internet. All participants (100%) reported that they had assigned their students Internet research tasks. Furthermore, 92.9% reported they had assigned students data analysis and problem-solving tasks that involved using computers or the Internet. On average, 88.1% of the participants said they had used computers for three or more years in teacher planning and preparation and had attended professional development experiences in the past three years. Even with a notable level of reported professional development, most teachers (97.6%) stated that most of their knowledge of technology use was derived from their own independent learning and interactions among colleagues (83.3%). Only 35.7% reported that at least a moderate extent of their training came from college courses.

The participants reviewed the materials in various stages of development at one of three evaluation workshops. Workshops were held in August 2000, October 2000, and March 2001. Table 1 lists *Biology: Exploring Life* materials that were evaluated and the data-collection instruments that were used during each workshop.

Table 1. Evaluation Workshop Activities in Year 1

Workshop	**Materials Evaluated**	**Data Collection**
Workshop 1 August 2000 (18 participants -- included 1 preservice teacher and 1 science supervisor)	• Prototype Cell Respiration chapter • Conducted FastPlants laboratory	• Evaluator observations: Usability • AAAS criteria for evaluating the quality of instructional support instrument • Survey - program objectives • Focus groups
Workshop 2 October 2000 (11 participants)	• Revised prototype Cell Respiration chapter • Rapid prototypes for new interface (Traylor Media and Redhill Studios)	• Evaluator observations: Usability • AAAS criteria for evaluating the quality of instructional support instrument • Survey - program objectives • Focus groups • Rapid prototype responses
Workshop 3 March 2001 (15 participants)	• New interface • Revised Cell Respiration chapter, Photosynthesis chapter • Teacher Resource prototypes	• Evaluator observations: Usability • AAAS criteria for evaluating the quality of instructional support instrument • Survey - program objectives • Focus groups • Small group open-ended questions

A prototype is a test version designed to facilitate testing. A prototype chapter for Cell 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 interface directions for the Website. Rapid prototypes exhibit key properties of finished products but usually lack other superficial features of the later product. Rapid prototyping allows small-scale implementation of different design approaches in order to evaluate strengths and weaknesses of these approaches before full-scale production (Northrup, 1995). Participants in the October 2000 workshop evaluated both rapid prototypes. Participant feedback about the prototypes and the interface analysis reports led to the development of a new interface design for the Website.

The Cell Respiration and Photosynthesis chapters were implemented in the new interface design prior to the March 2001 evaluation workshop. The Biosphere chapter was developed in May 2001.

During the 2000-2001 school year, eighteen participants pilot-tested *Biology: Exploring Life* materials with 783 students. The evaluation team conducted five classroom field observations during the school year and findings of classroom field observations and evaluation workshops were discussed with the development team. These discussions led to modification of the materials that were, in turn, evaluated in each succeeding workshop and by our interface design expert. As noted above, students completed pre- and post-tests for biology content knowledge and concepts before and after using chapter materials, and each teacher submitted a post-implementation survey and a journal with open-ended responses for each chapter. Follow-up phone interviews were conducted with selected teacher participants. Throughout the first year of the project, almost daily contact over an e-mail listserv occurred among the evaluation team, the development team, and the teacher pilot testers.

Data Analysis

AAAS Criteria for Evaluating Instructional Support

Table 2 displays the results of the AAAS *Criteria for Evaluating the Quality of Instructional Support* instrument. Main findings on effectiveness of the materials reported below were based on responses from 43 teacher-participants.

Table 2. Results of the AAAS Criteria for Evaluating Instructional Support Instrument. [Rating scale: Excellent (3), Good (2.5-2.9), Satisfactory (2.0-2.4), Fair (1.5-1.9), Poor (0-1.4)]

Criteria for evaluating the quality of instructional support		Prototype (n=28)		New interface (n=15)	
		Mean	sd	Mean	sd
I.1	Conveying unit purpose	2.45	0.85	2.67	0.49
I.2	Conveying lesson purpose	2.43	0.50	2.67	0.62
I.3	Justifying activity sequence	2.71	0.46	2.80	0.41
II.1	Attending to prerequisite knowledge and skills	1.41	1.31	1.93	0.96
II.2	Alerting teacher to commonly held student ideas	1.29	1.24	2.27	1.03
II.3	Assisting teacher in identifying own students' ideas	2.04	0.94	1.67	1.11
II.4	Addressing commonly held ideas	2.11	0.88	2.20	0.86
III.1	Providing variety of phenomena	2.85	0.36	2.67	0.82
III.2	Providing vivid experiences	2.81	0.40	2.47	0.83
IV.1	Introducing terms meaningfully	2.81	0.40	2.60	0.63
IV.2	Representing ideas effectively	2.83	0.37	2.67	0.49
IV.3	Demonstrating use of knowledge	1.62	1.30	2.13	0.99
IV.4	Providing practice	2.77	0.43	2.67	0.49
V.1	Encouraging students to explain their ideas	2.27	0.83	2.47	0.52
V.2	Guiding student interpretation and reasoning	2.42	0.79	2.73	0.59
V.3	Encouraging students to think about what they've learned	2.00	1.10	2.07	0.96
VI.1	Aligning assessment to goals	2.21	1.02	2.33	0.90
VI.2	Testing for understanding	2.46	0.83	2.53	0.92
VI.3	Using assessment to inform instruction	1.91	1.08	1.73	1.03

Reported strengths of the materials tend to center around content delivery and suitability to intended learners. Respondents reported that the materials:

- Did a good job conveying an overall sense of purpose and direction that is understandable and motivating to students.
- Involved students in a logical or strategic sequence of activities.

- Provided a sufficient number and variety of phenomena, observable events in nature that can make scientific ideas real to students.
- Included activities that provide firsthand experiences with phenomena when practical and a vicarious sense of those phenomena when not practical. The experiences that were not firsthand (for example, text, pictures, animations, interactivities) provide students with a vicarious sense of the phenomena.
- Introduced technical terms in conjunction with an experience with the idea or with a process. Terms were introduced as needed to facilitate thinking and promote effective communication. The materials were effective in linking technical terms to relevant experiences rather than just having students learn definitions of terms.
- Included accurate and comprehensible representations of scientific ideas. The interactivities provided a sufficient number and variety of representations that were explicitly linked to the presented concept and comprehensible to the students.
- Provided a sufficient number of tasks in a variety of contexts, including everyday contexts. Furthermore, novel tasks were included.
- Encouraged students not only to express but also to clarify, justify, and represent their ideas. The Web-based materials included text that directly provides students with immediate feedback regarding their ideas.
- Included specific and relevant tasks and/or questions related to a specific experience or reading. There are examples throughout the material that use questions or tasks that have helpful characteristics. Examples include framing important issues, helping students relate their experiences with phenomena to presented scientific ideas,

helping students make connections between their own ideas and the phenomena observed, and helping students make connections between their own ideas and the presented scientific ideas.

- Offered assessment items that require application of ideas and avoids allowing students a trivial way out, such as using a formula or repeating a memorized term without understanding. Some assessment items included both familiar and novel tasks.
- Contained materials that appear able to help teachers create a classroom environment that welcomes student curiosity, rewards creativity, encourages a spirit of healthy questioning, and avoids dogmatism. Especially highly rated materials included the CalorieQuest, the Wisconsin Fastplants lab, and the Explore It! activities.
- Avoided stereotypes or language that might offend particular groups.
- Suggested alternative formats for students to express their ideas during instruction and assessment. This was evident where students reported their laboratory results in the form of mini-posters or were provided suggestions on how to give a report or to create a PowerPoint presentation.

Not all aspects of the materials were equally effective. In particular, participants cited a desire for stronger teacher support/guidance and help in implementing the materials most effectively. Respondents cited as weaknesses of the materials that they did <u>not</u>:

- Specify prerequisite knowledge (prior knowledge or understanding that learners need to be able to learn new content or concepts) or skills that are necessary to meet the benchmark(s) for learning.
- Alert teachers to commonly held student ideas (some of which are troublesome and some helpful).
- Demonstrate/model or include suggestions for teachers on how to demonstrate/model skills or how to use the knowledge that is presented in the chapter (*Teacher Resource* materials).
- Include specific suggestions to help teachers provide explicit feedback or include suggestions on how to diagnose student errors, give explanations about how these errors may be corrected, or how to further develop students' ideas.
- Specify ways students could/should express their initial ideas about the content and concepts presented in the material. Furthermore, the material did not engage (or provide specific suggestions for teachers to engage) students in monitoring how their ideas have changed periodically in the unit.
- Contain as great a variety of alternative assessment items as the teachers wished.
- Provide specific suggestions for teachers about how to use the information from the embedded assessments to make instructional decisions about what ideas need to be addressed by further activities.
- Suggest how to probe beyond students' initial responses to clarify and further understand student answers.

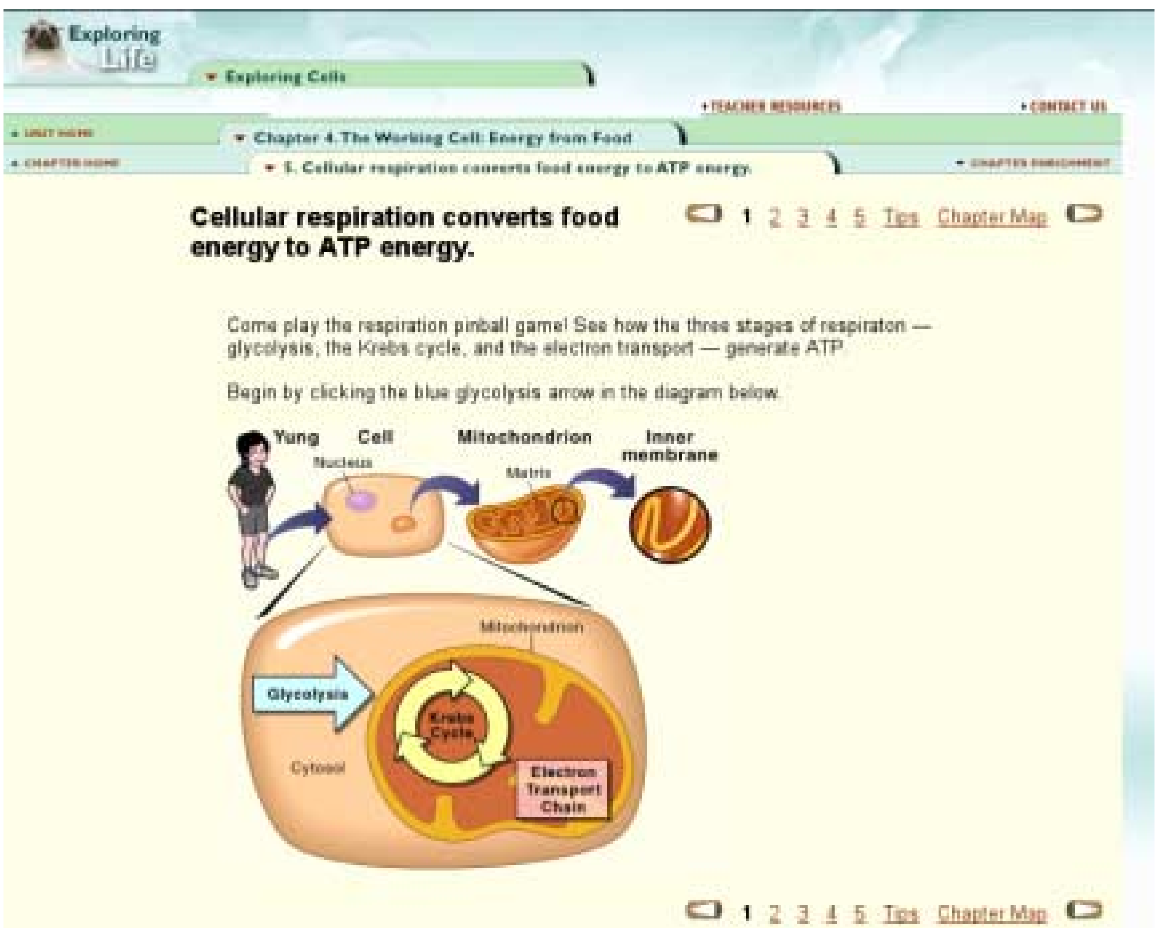
Usability Analysis

During the first evaluation workshop, many teacher participants had difficulty navigating throughout the initial prototype Website (Figure 1). They experienced high frustration levels with using these materials, especially with activities that contained hypertext links to external Websites that launched a second browser window. Participants had difficulty moving back and forth between the two browser windows, sometimes unaware that two browser windows were open. Further, a few participants lost data when they closed the primary browser window inadvertently. After the first evaluation workshop, we concluded that the Website needed a new user interface. The evaluation team, with considerable input from the instructional design expert, recommended providing site navigation on the left-hand side of the screen and a breadcrumb navigation trail to display the user's task on the top of the screen. Such a task trail would show where the user has been and where the user would be heading within the task. This would result in a more efficient use of the Website and reduce the use of the "Back" button on the browser. Further, it was recommended that the development team consider using a frames-interface or a Java-coded equivalent.

Students who used the prototype had difficulty understanding concepts presented in some of the animations. The speed of the animation did not give learners enough time to process the material presented. The evaluation team recommended that the animations be chunked into smaller sequences or segments to facilitate the learner's ability to process that information. This could be accomplished by reducing the speed of the animation at strategic places or programming the animation to pause briefly and present the learner with a summary of the information presented.

Participant observation and small group interviews with students revealed many positive aspects of the Website. The learners liked receiving immediate feedback to answers they submitted. They noted that Web-based graphics and animations helped them understand the content. WebQuests and Explore! activities were well received by students who noted that these activities related to their daily lives. The animations in the Fastplants lab helped learners understand what was occurring and also assisted with understanding the experimental procedure.

Figure 1. Screenshot of prototype.



Content Knowledge Assessments

Data interpretation.

Individual questions were designed to address biological content acquisition, concept application, and naive science conceptions. Percentage scores were calculated for each individual question on the pre- and posttreatment content assessments. A paired *t*-test was used to identify significant differences between the overall pre- and post-test scores at an alpha level of .05.

Results.

The scores of the pretests and post-tests for both interfaces of the Cellular Respiration chapters show that students' content knowledge increased significantly. (See Tables 3 and 4). Chapter 4 was the Cell Respiration prototype chapter. Chapter 7 was the revised prototype chapter that included the new interface design. The number change of the Chapter 4 prototype to Chapter 7 was due to the restructuring of the program s table of contents. Table 5 shows the percentage of items answered correctly on the content assessments for the Chapter 4 prototype. Table 6 shows the percentage of items answered correctly on *The Working Cell: Energy from Food* (Chapter 7) content assessments with the revised content and new interface. On the Chapter 7 content assessment, 11 of 12 items had increased correct response on the post-test. Performance on item question 6, however, decreased on the post-test (-12.21%). It appeared that students were having difficulty applying the concept of a calorie to an everyday situation. As a result, the evaluation team recommended the developers provide additional examples, perhaps through Web-based interactivities, to assist learners in understanding how caloric energy is used by humans in real life.

The scores in Tables 3 and 4 indicate that student learning from the materials was significant ($p<.001$). We cannot, however, assess performances with Web-based materials in comparison with performances of students who did not use the *Biology: Exploring Life* materials. During the second year of our study we will conduct such comparisons.

Table 3. Analysis of Content Assessment Item Scores from *The Working Cell: Energy from Food* Prototype. (n=478)

<table>
<tr><th>Question number</th><th>Ch.4
Pretest
% correct</th><th colspan="2">Ch.4
Post-test
% correct</th></tr>
<tr><td>1</td><td>58.85</td><td colspan="2">73.43</td></tr>
<tr><td>2</td><td>38.92</td><td colspan="2">71.16</td></tr>
<tr><td>3</td><td>46.25</td><td colspan="2">80.08</td></tr>
<tr><td>4</td><td>52.95</td><td colspan="2">63.19</td></tr>
<tr><td>5</td><td>70.18</td><td colspan="2">69.64</td></tr>
<tr><td>6</td><td>71.61</td><td colspan="2">68.12</td></tr>
<tr><td>7</td><td>35.09</td><td colspan="2">60.72</td></tr>
<tr><td>8</td><td>31.42</td><td colspan="2">49.72</td></tr>
<tr><td>9</td><td>17.86</td><td colspan="2">35.86</td></tr>
<tr><td>10</td><td>25.36</td><td colspan="2">46.30</td></tr>
<tr><td>11</td><td>60.45</td><td colspan="2">66.03</td></tr>
<tr><td>12</td><td>35.73</td><td colspan="2">60.15</td></tr>
<tr><td>MEAN</td><td>5.388</td><td colspan="2">7.441</td></tr>
<tr><td>t-TEST</td><td>t=18.639</td><td>df=477</td><td>p<.001</td></tr>
</table>

Table 4. Analysis of Content Assessment Item Scores from Revised *The Working Cell: Energy from Food* (n=213)

Question number	Ch.7 Pretest % correct	Ch.7 Post-test % correct	Change
1	63.38	73.24	+9.86%
2	33.80	77.93	+44.13%
3	43.66	85.92	+42.26%
4	56.81	66.67	+9.86%
5	69.01	72.77	+3.76%
6	67.61	55.40	- 12.21%
7	26.76	59.62	+32.86%
8	37.09	54.46	+17.37%
9	15.49	46.95	+31.46%
10	28.64	68.08	+39.44%
11	55.40	64.79	+9.39%
12	37.56	67.14	+29.58%
MEAN	**5.352**	**7.930**	**+21.2%**
***t*-TEST**	***t*=15.110**	**df=212**	***p*<.001**

Table 5. Analysis of Content Assessment Item Scores from Chapter 8 - *The Working Cell: Energy from Sunlight.* (n=86)

Question number	Pretest % correct	Post-test % correct	Change
1	32.56	62.79	+30.23%
2	36.05	68.60	+32.55%
3	51.16	60.47	+9.31%
4	33.72	54.65	+20.93%
5	36.05	60.47	+24.42%
6	23.26	43.02	+19.76%
7	33.72	63.95	+30.23%
8	13.95	31.40	+17.45%
9	11.63	32.56	+20.93%
10	18.60	20.93	+2.33%
11	26.74	46.51	+19.77%
12	30.23	48.84	+18.61%
13	34.88	41.86	+6.98%
14	29.07	38.37	+9.30%
15	16.28	45.35	+29.07%
16	25.58	19.77	-5.81%
17	26.74	43.02	+16.28%
MEAN	**4.810**	**7.826**	**+17.7%**
***t*-TEST**	***t*=9.940**	**df=85**	***p*<.001**

Table 6. Analysis of Content Assessment Item Scores from Chapter 36- *The Biosphere.* (n=78)

Question number	Pretest % correct	Post-test % correct	Change
1	82.05	85.90	+3.85%
2	64.10	71.79	+7.69%
3	60.26	67.95	+7.69%
4	52.56	55.13	+2.57%
5	35.90	61.54	+25.64%
6	14.10	10.26	-3.84%
7	7.69	15.38	+7.69%
8	71.79	76.92	+5.13%
9	29.49	24.36	-5.13%
10	20.51	43.59	23.08%
11	39.74	26.92	-12.82%
12	24.36	38.46	+14.10%
13	39.74	47.44	+7.70%
14	23.08	41.03	+17.95%
15	19.23	52.56	+33.33%
MEAN	**5.770**	**7.215**	**+21.6%**
***t*-TEST**	***t*=4.789**	**df=77**	***p*<.001**

Students' knowledge of Chapter 8 - *The Working Cell: Energy from Sunlight* content increased significantly (p<.001). Table 5 shows the percentage of items answered correctly on this chapter s content assessments. Percentage gains were observed on 16 of 17 assessment items.

- Only a modest post-test increase was observed for item 10. Item 10 addresses a common misconception pertaining to processes that occur during both respiration and photosynthesis. The evaluation team recommended to the developers that better teacher support materials be included to present strategies for teaching conceptual change for helping learners understand these processes.
- Students' performance decreased (-5.81%) on post-test item 16. This is a difficult application of the materials presented in Concept 8.4 of the Website. In the second

year of our evaluation, we will compare the distribution of scores for this item for students assigned this activity in their classroom and those not so assigned.

The content assessment scores for pretest and post-test items related to Chapter 36 - *The Biosphere* show that students' content knowledge increased significantly (p<.001). Table 6 shows the percentage of items answered correctly on content assessments. Percentage gains were observed on 12 of 15 assessment items.

- A post-test percentage decrease (-3.84%) was observed on item 6. It appeared that students did not understand the process of global air circulation. This topic was presented in Concept 36.2 on the Website. Field observations noted that students had difficulty understanding the animations in this concept. The evaluation team recommended that the developers modify the content in this section.
- A post-test percentage decrease of 12.82% occurred on item 11. It appeared that students were having difficulty applying the concept of the interrelationship of biotic and abiotic factors in an ecosystem. The evaluation team recommended that additional examples be included in the teacher support materials to assist teachers in teaching this concept.

Summary of Attitude Measures

Table 7 displays the results of the teacher-participants' post-implementation surveys for *Biology: Exploring Life* chapters. It should be noted that the *Biology: Exploring Life* teacher support materials were not fully developed during the implementation of these materials. In general, teachers reported that materials actively engaged students in learning biology. Materials utilized some features of inquiry in the delivery of content and they contained unit topics and modes of instruction that were developmentally appropriate for the majority of the sampled population of students. Finally, the materials were perceived to address important goals of biological science teaching and learning.

Table 7. Post-implementation Likert Item Survey Responses
Scale: 1-Strongly disagree, 2- Somewhat disagree, 3- Neutral, 4- Somewhat agree, 5-Strongly Agree

Item	**Ch.4 Avg.**	**Ch.4 SD**	**Ch.7 Avg.**	**Ch.7 SD**	**Ch.8 Avg.**	**Ch.8 SD**	**Ch.36 Avg.**	**Ch.36 SD**
The Exploring Life materials promote constructivist learning in the biology classroom	4.43	0.53	4.25	0.46	4.33	.52	4.25	.50
The Exploring Life materials encourage active learning for all students.	4.29	0.76	4.12	1.13	4.33	.52	3.75	1.26
The Exploring Life materials did **not** improve my students understanding of fundamental biological concepts.	1.86	1.07	2.00	0.93	2.50	.84	2.00	.82
The Exploring Life materials helped to increase my students self-confidence in and skill in scientific reasoning and inquiry.	3.57	0.79	3.50	0.76	3.83	.75	3.00	1.15
The Exploring Life materials enhanced my students ability to apply biological knowledge and the methods of science to important social issues.	3.71	0.49	3.25	1.39	3.33	1.03	3.00	1.15
The Exploring Life teacher support materials assisted me in implementing the materials in my classroom.	3.86	0.38	2.88	1.55	3.17	1.17	4.25	.50
Inquiry is the basis of the learning experience with the Exploring Life materials.	4.43	0.53	4.12	0.35	3.67	1.03	3.50	1.73
The topics of the Exploring Life chapter and the modes of instruction are developmentally appropriate for my students.	4.14	1.21	4.14	1.22	4.33	.82	3.33	1.15

Note. Number of respondents: Ch.4 = 7; Ch.7 = 7; Ch.8 = 6; Ch.36 = 4.

The animations were viewed as a major strength of the materials by both teachers and students. During the evaluation workshops, teachers responded that they felt animations would help students understand content presented in a chapter and help them learn concepts presented in the laboratory. Most teachers commented that the animations helped them to understand the laboratory procedures in *Biology: Exploring Life*. In interviews, students reported that animations and interactivities had, indeed, helped them to understand the biology concepts. Segmenting animations into smaller chunks appeared to help learners understand concepts presented.

Many learners responded that *Biology: Exploring Life* was interactive. They perceived *Biology: Exploring Life* as a better way of learning biology content than by learning biology with a textbook and "what the teacher normally does. As noted earlier, learners perceived a relationship between WebQuests and Explore! activities and their daily lives and felt that the immediate feedback of the Website helped them understand main points.

Preliminary data suggests that interactivities and graphics on the Website helped lower level students and low-level readers understand main concepts. In interviews, learners stated that being able to work through the materials at their own pace helped them improve their understanding of the biology concepts. However, some learners did note that certain interactivities such as watching the pinball animation and the "snow boarder" activity did not assist them in understanding the concepts being presented. Some teachers noted that lower level students and students with learning disabilities appear to be more "on-target" than with their regular biology program. One teacher noted substantial increases in her students' grades while they were pilot testing the cellular respiration and photosynthesis chapters.

Computer Use

Most participants used computers for over 50% of their class time when they taught with the materials. Teachers used computers in different ways to deliver instruction. Most teachers reported having their students use the materials with one student per computer, while group work was the second most common way students worked with computers. The computer was used as a learning station in four classrooms and for whole class demonstrations in three classrooms.

Teachers experienced technology implementation issues when they used the materials in their school. Participants encountered a variety of problems including crashing computers, slow network connections, using the wrong Web browser, and difficulties in loading helper applications and installing browser plug-ins. Many participants had difficulty scheduling tightly reserved computer labs.

Teachers reported difficulty structuring student use of computers. Most participants apparently did not adapt the program for use in a one-computer classroom. Rarely did teachers report using the computer as a classroom learning station or with a projection device in the classroom.

Revision of Product Materials to Improve Learning

Substantial product improvements have been made in the design and content of the instructional materials since the original prototype chapter was developed. Table 8 summarizes the design and content improvements made to the prototype chapter of *Biology: Exploring Life* as a result of the evaluation feedback. The resulting modifications were used in the development of additional media for succeeding chapter development.

A comparison of the original prototype with the current version of *Biology: Exploring Life* reveals many improvements in the evolving design of the materials. Figure 2 shows a screenshot of the new interface of the Website. As noted earlier, novice computer user participants had difficulty navigating within the prototype Website during the first evaluation workshop and experienced confusions related to multiple browser windows being open. In contrast, in the third evaluation workshop with the new design, participants appeared able to navigate efficiently and with little confusion.

Figure 2. Screenshot of new *Biology: Exploring Life* interface.

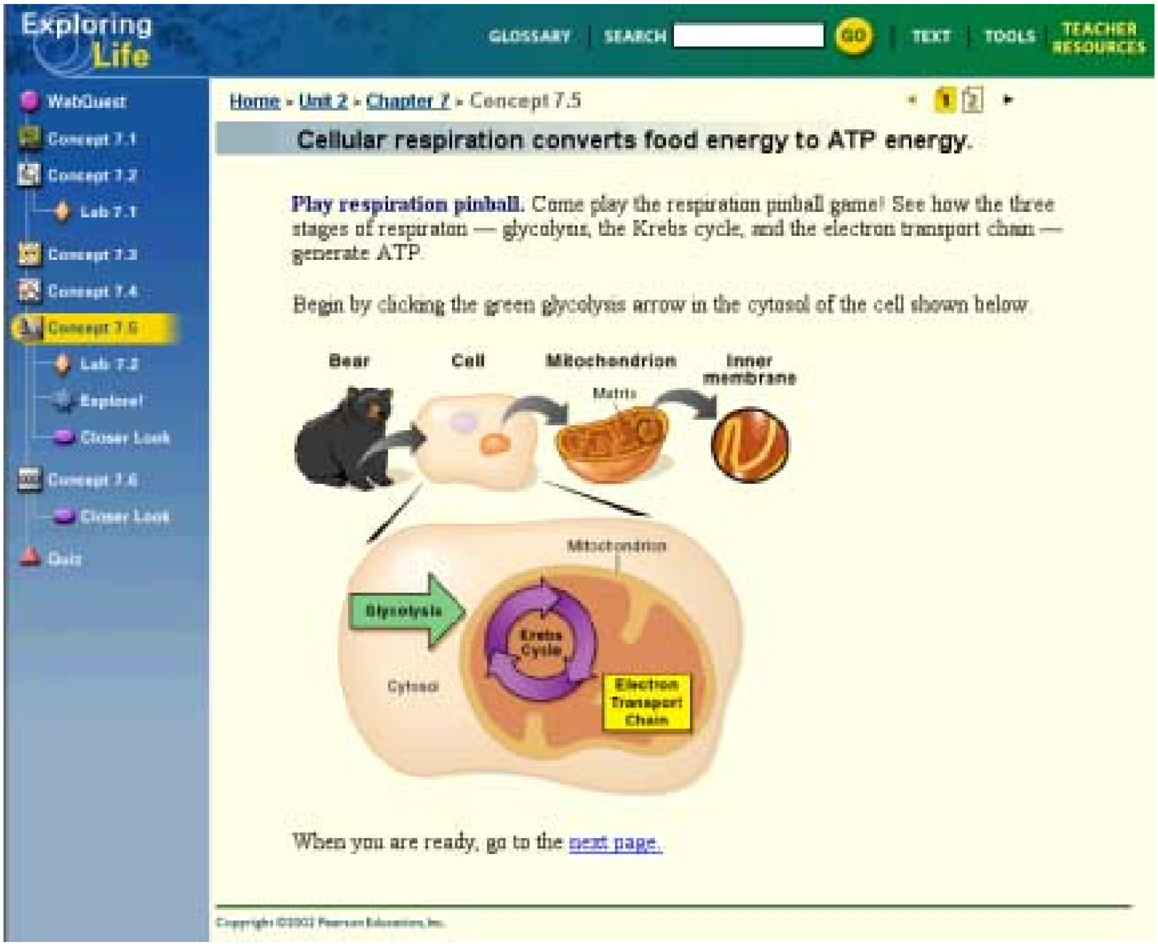


Table 8: *Biology: Exploring Life* Product Improvements as a Result of the Formative Evaluation.

Problem	Evaluation Feedback	Resulting Product Change
The prototype chapter did not have adequate "teacher resources" available to assist teachers in using Biology: Exploring Life with their students.	1. 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. 2. Pre- and post-test content assessments revealed students' misconceptions.	1. 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. 2. A "teaching for conceptual change" section of the teacher resources currently under development.
User interface issues: 1. The concept backbone structure unclear. 2. Relationship between labs/explores and their parent concepts unclear. 3. Color scheme not optimized. 4. Confusion over how to page forward within an activity and the function of the breadcrumb (navigation trail) feature. 5. Difficulty finding and reading instructions for the activities.	1. Teachers had trouble understanding how each Website component related to the entire site. User interface recommendations made. 2. Teachers expressed confusion over the different types of activities and how they all fit together. User interface recommendations made. 3. Teachers expressed concern that the screen looked too bland. Color scheme recommendations made. 4. 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. 5. Learners would scan the text for specific instructions, not bothering to read carefully. User interface recommendations made.	See new user interface on the Website: 1. New concept backbone as it appears on the chapter table of contents and on each activity page. 2. New concept backbone. 3. New color scheme. 4. 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. 5. Developers added a blue instruction box to each activity to house specific interactive instructions. The type size was increased for ease of reading.
Chapter 7 Cellular Respiration Pre-/Post-test Item #5: All work requires a source of _______.	A few student scores on this test item decreased pre- to post-test. Students selected ATP from the available responses, erroneously concluding that all work required ATP. This was most likely due to the chapter s strong focus on ATP.	Authors revised Chapter 7 to make clear that ATP was one source of energy.
Chapter 7, Concept 7.4 Electrons fall from food to oxygen during cell respiration. Online activity: *The Snowboarder*	The keyboard controls were difficult to use and the snowboarder analogy wasn t a perfect one for the concept. Some student confusion.	Media team scrapped the activity. A new 7.4 interactivity was developed that more accurately presented the concept without using keyboard controls.

Animations played through from beginning to end at the click of a start button.	Teachers and students expressed a desire for more user control of pacing. 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 users to access relevant segments of a complex (or long) animation quickly when they wanted to replay it. See Concept 7.1 activity (*Bear in the Apple Tree*). 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. The activities now contain adults or animals in areas where organisms need 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 a desire for more user control of pacing. Participants said, 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.

Discussion

Our concurrent integrative formative evaluation process was extremely useful in producing Web-based instructional materials for learning high school biology in an active learning environment. In our iterative evaluation process, teacher and student feedback played a major role in decisions about what changes to make in the instructional materials. Since the evaluation occurred at different stages of the development work, it was relatively easy to modify interactivities and alter instructional design features based on recommendations from the evaluation team. The resulting modifications were then tested during the next phase of the evaluation.

While we were able to improve the materials and make them easier to use, teaching high school biology using a Web-based curriculum does not appear to be an easy task for many classroom teachers. Our data reveal that many teacher participants, despite their years of technology experience, are not accustomed to using computers with their students with learner-centered materials. Teachers predominantly used the computer materials for content knowledge acquisition through use of the concept activities (tutorials designed to provide the learner with immediate feedback).

Materials that were not used by some classroom teachers included the laboratory activities, the Webquests, and the Explore! activities. These participants noted they did not have enough time to incorporate the labs into their prescribed district curriculum or that their school contained poor network connections, making use of these activities difficult.

It will likely take many teachers time to adjust their current pedagogical styles to teaching with learner-centered Web materials. Many have little training in how to incorporate technology into leaner-centered instructional contexts using constructivist approaches. In particular, it appears that many biology teachers may want or need training in how to incorporate Web-based science instructional materials effectively into curricular contexts. To meet these needs, the development team is presently designing professional development experiences for teachers who will use *Biology: Exploring Life*. In addition, the product will include material for the teacher on tips for use and specific suggestions on how to use computers in different classroom contexts.

The next stage of this three-year 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 investigate implementation of a Web-integrated program in diverse educational settings.

Notes

1. The preparation of this article was funded by a grant from the National Science Foundation (NSF), Grant IMD-9986610. The opinions expressed are those of the authors and do not necessarily reflect the position of NSF.

2. The authors would like to thank Dawn Bothwell, Michelle Heist and Sherrie Moore for their assistance with data collection and analysis preparations.

References

American Association for the Advancement of Science. (1989). *Science for all Americans: Project 2061 report on literacy goals in science, mathematics, and technology.* Washington DC: AAAS

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

American Association for the Advancement of Science. (2000). *High school biology textbooks evaluation*. Retrieved June 30, 2000, from http://www.project2061.org/newsinfo/research/textbook/hsbio/

Anderson, O. R. (1992). Some interrelationships between constructivist models of learning and current neurobiological theory, with implications for science education. *Journal of Research in Science Teaching, 29*, 1037-1057.

Borg, W.R., & Gall, M. D. (1983). Educational resaerch: An introduction (4th ed.). New York: Longman.

Bodzin, A. M., & Park, J. C. (1999, July). An online inquiry instructional system for environmental issues. *Meridian, 2*(2). Retrieved July 30, 1999, from http://www.ncsu.edu/meridian/archive_of_meridian/jul99/coastal/index.html

Bruner, J. S. (1966). *Toward a theory of instruction*. New York: W. W. Norton.

Bybee, R. B. (1996). The contemporary reform of science education. In J. Rhoton, and P. Bowers (Eds.), *Issues in science education*, (pp. 1-14) Arlington, VA: National Science Teachers Association.

Carley, W. W. (1998). A fundamental challenge: How do we reform the system. *American Biology Teacher, 60*, 242-244.

Chiappetta, E. L., & Fillman, D. A. (1998). Clarifying the place of essential topics and unifying principles in high school biology. *School Science and Mathematics, 98*, 12-18.

Cohen, K. C. (Ed.). (1997). *Internet links for science education: Student-scientist partnerships*. New York: Plenum Press.

Costenson, K., & Lawson, A. E. (1986). Why isn't inquiry used more in classrooms? *American Biology Teacher, 48,* 150-158.

DeBoer, G. (1991). *A History of ideas in science education: Implications for practice*. New York: Teachers College Press.

Dougherty, M., & Miller, J. (1998). BSCS biology: A human approach and insights in biology. *American Biology Teacher, 60*, 98-115.

Feldman, A., Konold, C., & Coulter, B. (2000). *Network science, a decade later: The Internet and classroom learning*. Mahwah, NJ: Lawrence Erlbaum Associates.

Flagg, B. (1991). *Formative evaluation for educational technologies.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Groves, F. H. 1995. Science vocabulary load of selected secondary science textbooks. *School Science and Mathematics, 95,* 231-235.

Jacobs, G. (1998). Evaluating courseware: Some critical questions. *Innovations in Education and Training International, 35*(1), 3-8.

Kesidou, S. (2001). Aligning curriculum materials with national science standards: The role of Project 2061's curriculum-materials analysis procedure in professional development. *Journal of Science Teacher Education, 12*(1), 47-65.

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., & Soloway, E. (1994). A collaborative model for helping middle grade science teachers learn project-based instruction. *Elementary School Journal, 94*, 483-497.

Mauldin, M. (1996). The formative evaluation of computer-based multimedia programs. *Educational Technology, 36*(2), 36-40.

McInerney, J. (1986). Biology textbooks -- Whose business? *American Biology Teacher, 48,* 396-400.

McNeal, A. P., & Avanzo, A. D. (Eds.). (1997). *Student-active science*. Philadelphia: Saunders College.

National Research Council. (1989). *High school biology today and tomorrow*. Washington, DC: National Academy Press.

National Research Council. (1990*). Fulfilling the promise: Biology education in the nation's schools*. Washington, DC: National Academy Press.

Northrup, P. T. (1995). Concurrent formative evaluation: Guidelines and implications for multimedia designers. *Educational Technology, 35*(6), 24-31.

Owston, R. D. (1997). The World Wide Web: A technology to enhance learning and teaching? *Educational Researcher, 26*(2), 27-33.

Phelps, J., & Reynolds, R. (1999). Formative evaluation of a web-based course in meteorology. *Computers & Education, 32*, 181-193.

Schwab, J. J. (1958). The teaching of science as inquiry. *Bulletin of the Atomic Scientists, 14*, 374-379.

Songer, N. B. (1998). Can technology bring students closer to science? In B. J. Frasier & K. G. Tobin (Eds.), *International handbook of science education* (pp. 333-347). Dordrecht, The Netherlands: Kluwer Academic.

Uno, G. E. (1990). Inquiry in the classroom. *Bioscience, 40*, 841-843.

Uno, G. E., & Bybee, R. W. (1994). Understanding the dimensions of biological literacy. *Bioscience, 44*, 553-560.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Welch, W. W., Klopfer, L. E., Aikenhead, G. S. & Robinson J. T. (1981). The role of inquiry in science education: Analysis and recommendations. *Science Education 65*, 33-50.

Yager, R. E. (1988). Achieving useful science: Reforming the reforms of the 60s. *Educational Leadership, 46(1)*, 53-54.

Yager, R. E. (1992). Viewpoint: What we did not learn from the 60s about science curriculum reform. *Journal of Research in Science Teaching, 29*, 905-910.

Appendix A.

Criteria for Evaluating the Quality of Instructional Support

Category I. Providing a Sense of Purpose

Conveying unit purpose. Does the material convey an overall sense of purpose and direction that is understandable and motivating to students?

Conveying lesson purpose. Does the material convey the purpose of each lesson and its relationship to others?

Justifying activity sequence. Does the material involve students in a logical or strategic sequence of activities (versus just a collection of activities)?

Category II: Taking Account of Student Ideas

Attending to prerequisite knowledge and skills: Does the material specify prerequisite knowledge/skills that are necessary to the learning of the benchmark(s)?

Alerting teacher to commonly held student ideas: Does the material alert teachers to commonly held student ideas (both troublesome and helpful).

Assisting teacher in identifying own students' ideas: Does the material include suggestions for teachers to find out what *their* students think about familiar phenomena related to national science education standards and frameworks before the scientific ideas are introduced?

Addressing commonly held ideas: Does the material attempt to address commonly held student ideas?

Category III: Engaging Students with Relevant Phenomena

Providing variety of phenomena: Does the material provide multiple and varied phenomena, observable events in nature that can make a scientific idea real to students (this includes the use of technology to extend the senses, e.g., using a microscope), to support ideas presented in national science education standards and frameworks?

Providing vivid experiences: Does the material include activities that provide firsthand experiences with phenomena when practical or provide students with a vicarious sense of the phenomena when not practical?

Category IV: Developing and Using Scientific Ideas

Introducing terms meaningfully. Does the material introduce technical terms only in conjunction with experience with the idea or process and only as needed to facilitate thinking and promote effective communication?

Representing ideas effectively. Does the material include accurate and comprehensible representations of scientific ideas?

Demonstrating use of knowledge. Does the material demonstrate/model or include suggestions for teachers on how to demonstrate/model skills or the use of knowledge?

Providing practice. Does the material provide tasks/questions for students to practice skills or using knowledge in a variety of situations?

Category V: Promoting Student Thinking about Phenomena, Experiences, and Knowledge

Encouraging students to explain their ideas. Does the material routinely include suggestions for having each student express, clarify, justify, and represent his/her ideas?

Are suggestions made for when and how students will get feedback from peers and the teacher?

Guiding student interpretation and reasoning: Does the material include tasks and/or question sequences to guide student interpretation and reasoning about experiences with phenomena and readings?

Encouraging students to think about what they've learned. Does the material suggest ways to have students check their own progress?

Category VI: Assessing Progress

Aligning assessment to goals. Assuming a content match between the curriculum material and the national science education standards and related frameworks, are assessment items included that match the same standards and frameworks?

Testing for understanding. Does the material include assessment tasks that require application of ideas and **avoid** allowing students a trivial way out, like using a formula or repeating a memorized term without understanding?

Using assessment to inform instruction. Are some assessments embedded in the curriculum along the way, with advice to teachers as to how they might use the results to choose or modify activities?

Category VII: Enhancing the Science Learning Environment

Providing teacher content support. Would the material help teachers improve their understanding of science, mathematics, and technology necessary for teaching the material?

Encouraging curiosity and questioning. Does the material help teachers to create a classroom environment that welcomes student curiosity, rewards creativity, encourages a spirit of healthy questioning, and avoids dogmatism?

Supporting all students. Does the material help teachers to create a classroom community that encourages high expectations for all students, that enables all students to experience success, and that provides all students a feeling of belonging in the science classroom?

Appendix B. Post-implementation Survey

I. Using the Likert scale below, please indicate to what extent you agree or disagree with the following statements.

1	2	3	4	5
Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree

- The *Exploring Life* materials promote constructivist learning in the biology classroom.
- The *Exploring Life* materials encourage active learning for all students.
- The *Exploring Life* materials did not improve my students' understanding of fundamental biological concepts.
- The *Exploring Life* materials helped to increase my students' self-confidence in and skill in scientific reasoning and inquiry.
- The *Exploring Life* materials enhanced my students' ability to apply biological knowledge and the methods of science to important social issues.
- The *Exploring Life* **teacher support** materials assisted me in implementing the materials in my classroom.
- Inquiry is the basis of the learning experience with the *Exploring Life* materials.
- The topics of the *Exploring Life* chapter and the modes of instruction are developmentally appropriate for my students.

II. Open-ended questions. Please respond to the questions below.

- How do the *Exploring Life* materials help you implement constructivist learning in your biology classroom(s)?
- Which *Exploring Life* materials promoted active learning of biology?
- How did the *Exploring Life* materials improve your biology students' understanding of fundamental biological concepts?
- How did the *Exploring Life* materials improve your students' self-confidence and skill in scientific reasoning and inquiry?
- How did the *Exploring Life* materials enhance your students' abilities to apply biological knowledge and the methods of science to important social issues?
- How did the teacher support materials assist you with implementing the *Exploring Life* materials in your classroom?
- How is inquiry the basis of the learning experience with the *Exploring Life* materials? Provide a few examples.
- How are the topics of the chapter and the modes of instruction developmentally appropriate?

Appendix C. Web-based Journal

Number of classroom days you used the chapter materials.
Length of classroom period in minutes.

Amount of time (in days) students are in front of computers

Whole class demonstration
One student using one computer
Group using one computer
Learning station or activity centers use
Other _________________

Method of instruction. Please assign a percentage to your use of the *Exploring Life* chapter materials in your classroom. For example, for 90%, enter 90.

Lecture
Hands-on activities
Discussion
Demonstration
Other_________________
Other ________________

Which *Exploring Life* activities did you use in your classroom?

Which *Exploring Life* activities did you not use with your students?
Describe in detail why you did not use these activities?

Briefly describe other activities you used with the *Exploring Life* materials?
Why did you incorporate these materials?

Describe the assessments you used.

Describe in detail your students' reactions to the *Exploring Life* materials.