Formative Evaluation of the Exploring Life Curriculum: Year Two Implementation Fidelity Findings

Alec M. Bodzin Lehigh University
Ward Mitchell Cates, Lehigh University
Betsy Price, Westminister College

Abstract

This paper reports the second-year implementation findings of an NSF-supported formative evaluation study of a basal biology program for ninth and tenth grade students that integrates the World Wide Web with a short topic-oriented textbook. The program's curriculum is based on the *National Science Education Standards*; it uses a 4 E's learning cycle model, a modification of the 5 E's instructional model (Bybee, 1993). In this second year, we employed a user-centered design strategy that focused on program components, implementations in actual classrooms, and student learning outcomes. This paper addresses implementation fidelity, the degree to which instructional materials are being used in a classroom setting as intended by their developers. The findings suggest constraints on classroom teachers inhibit their ability to implement the intended curriculum as designed. The ways in which the developers revised those materials to accommodate these constraints are described.

Exploring Life (Pearson Education, 2003) is a basal biology curriculum for ninth and tenth grade students based on the *National Science Education Standards* (National Research Council, 1996 --henceforth, *Standards*). *Exploring Life* employs a 4 E's learning cycle model, a modification of the 5 E's instructional model (Biological Sciences Curriculum Study, 1993). The "E's" represent various phases of the constructivist learning cycle (***e**ngage, **e**xplore, **e**xplain, **e**valuate*). The product, whose prototyping was funded by the National Science Foundation, integrates a shorter (800-page), concept-oriented textbook, a collection of inquiry-based lab and field activities, and an extensive World Wide Web site that provides an interactive learning environment for students. These components are designed to work together to help teachers provide a more interactive classroom in which computers support and enhance delivery of the curriculum.

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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. **Interactive Concepts** – For each chapter concept, there is a companion Interactive Concept activity on the Web site. These Interactive Concepts animate biological processes and promote active learning through activities such as problem solving, drag-and-drop sorting, building a structure, predicting an outcome, playing a game, competing in a challenge, graphing data, or calculating a solution. Each activity concludes with several questions that probe students' understanding of the content. Answers are available online for self-assessment.
3. **Chapter Quizzes** – Each chapter concludes with a 15-25 multiple choice question assessment 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 explore an interesting aspect of that chapter.
5. **Laboratories** – Online laboratory companions that include 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.

6. **Closer Looks** – These optional activities provide a more in-depth exploration of a particular topic.
7. **Careers** – These activities allows a students to virtually explore the work of a professional pertaining to the content of that chapter.

Our second-year evaluation program focused 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 paper, we describe a study of *implementation fidelity*; that is, the degree to *Exploring Life*'s instructional materials were implemented in the classroom setting as originally envisioned by their developers. We identified not only how teachers implemented the materials, but also how the developer's <u>intended</u> curriculum compared with the <u>enacted</u> curriculum (what teachers actually did in their classrooms). Since this was a formative evaluation, we provided feedback to the developers and they modified the product to address identified differences. We discuss these modification later in this paper.

Design and Procedure

We have employed a user-centered design strategy throughout the development of *Exploring Life*. This approaches aims at improving the quality of the learning and teaching experiences and focuses on both students and teachers' subjective reactions to using program components as well as 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

(Champagne & Klopfer, 1974; Zuzovsky & Orpax, 1979). 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. During the second year of the formative evaluation, 61 high school biology teacher participants pilot-tested *Exploring Life* materials with a total of 3673 students.

The methods and instruments used to investigate the evaluation questions included:

1. *Implementation measures.* Biology teacher participants completed a post-implementation questionnaire consisting of open-ended questions and Likert-scale items after implementing a prototype chapter in the classroom. The instrument was designed to address our main formative evaluation questions. For example, Appendix A (available online at http://www.lehigh.edu/~inexlife/papers/narst2003/appena.pdf) displays the questionnaire used for Chapter 7.
2. *Site-based field observations*. Evaluation team members visited a sample of classrooms as observers, gathering open-ended observations. Eight classrooms of students were observed using the *Exploring Life* materials.
3. *Interviews with teachers*. Semi-structured phone interviews were conducted with arbitrarily selected *Exploring Life* teacher participants who had completed at least two chapters of the materials with their students. The intent of the phone interviews was

to acquire additional implementation information not likely to be included in survey responses.

4. *Content knowledge assessments*. The assessments were constructed by the *Exploring Life* developers with considerable input from members of the evaluation team. The quizzes were given to 9th and 10th grade biology students before and after using an *Exploring Life* chapter. Each question usually corresponds to a distinct learning objective. For consistent marking, these quizzes were multiple choice.

Findings

Although 61 teachers participated in the study, not all used all three available chapters with their students. Fifty-six of the 61 piloted-tested Chapter 7; 51 teachers pilot-tested Chapter 8; and 33 teachers pilot-tested Chapter 36 (one pilot-tested with two groups of students due to semester block scheduling). Paired *t*-test results of pretest to posttest performance on the three pilot chapters showed students' content knowledge increased significantly ($p<.001$) for each chapter at an alpha level of .05 (Ch.7: $t(2277) = 43.384$; Ch.8: $t(2376) = 43.689$; Ch.36 $t(1280)= 29.053$)

Teachers used a variety of instructional methods to implement *Exploring Life* chapter materials in the classroom. Table 1 summarizes the reported methods of instruction. Most instructional time was spent with computer-based concepts and interactivities, followed by textbook use, lecture, laboratories, and discussion. Demonstrations were used to a lesser extent. The amount of time teachers used a particular instructional method in their classroom varied substantially.

Table 1. Mean reported methods of instruction percentages.

Method of instruction	Mean Ch.7 (n=62)	Mean Ch.8 (n=54)	Mean Ch.36 (n=34)	Grand Mean
Exploring Life Website activities on computer	46.25%	52.84%	57.85%	52.31%
Textbook	27.08%	22.86%	25.74%	25.23%
Lecture	22.73%	23.50%	25.00%	23.74%
Laboratories	22.01%	17.69%	18.21%	19.30%
Discussion	18.94%	13.09%	13.21%	15.08%
Demonstration	8.33%	9.00%	7.50%	8.28%

There was also substantial variance in the amount of time teachers used chapter materials in their classroom. Teachers predominately had students use computers individually or within a group, while computers were used for whole classroom demonstrations to a lesser extent. Very few teachers reported using computers as learning stations or activity centers. Only one teacher reported that her students used a Smartboard to work through the Web-based materials.

Table 2 summarizes the percentage of use of each Web-based materials type.

Table 2. Web-based teacher use of chapter materials (percentage across all 3 chapters)

Web-based material type	N	Usage Mean	Usage Range
Interactive Concepts	14	97.2%	88.9 – 100.0%
Quiz	3	69.7%	64.7 – 75.8%
Closer Looks	3	67.8%	63.0 – 72.6%
Webquests	3	66.3%	59.3 – 73.5%
Laboratories	4	51.3%	30.6 – 66.1%
Explore!	2	50.6%	41.9 – 59.4%
Career	1	41.2%	41.2%

Most teachers implemented each Interactive Concept in their classroom. Each Interactive Concept is integrated with a concept presented in the text and such activities were completed by students in a shorter period of time than most other activity types. Open-ended survey responses indicated that teachers valued the integration of the Web and text components. Some open-ended responses noted that the guidance and feedback provided in the Interactive Concepts reinforced the information presented in the text and the simulations aided students in understanding biological processes. Interactive concepts not used by teachers were predominantly located at the end of the chapter sequence and the reasons usually given for not using them were that they were too complex or too detailed for the ability level of their students.

Appendix B, (available online at http://www.lehigh.edu/~inexlife/papers/narst2003/appenb.pdf) lists the reported reasons teachers did not use a specific Web-based material type in their classroom for all three chapters. Time constraints/lack of instructional time was predominantly listed as a reason the participants did not implement a laboratory, Webquest, Explore!, Closer Look, or Quiz with their students. In addition to time constraints, the following reasons for not using a Web-based material type appear noteworthy:

- Webquests: Technical problems and slow Internet connection.
- Laboratories: Difficulty with lab materials, did not have or receive lab materials, and experienced difficulty in getting the lab to work.
- Explore!: Concept covered in another topic.
- Quizzes: A written quiz was used instead.
- Closer Looks: Too advanced or detailed for students.

In response to Likert-scale items, a high percentage of teachers agreed that they found enough diverse activities to select what was needed in the chapter (Ch.7: 81.7%; Ch. 8: 72.2%; Ch. 36: 78.1%). In addition, a comparable proportion of teachers agreed that the modes of instruction were developmentally appropriate for their students (Ch. 7: 79.0%; Ch. 8: 70.4% for; Ch. 36: 81.8%).

Discussion

The findings suggest that time and other constraints on classroom teachers inhibit their ability to execute the intended 4 E's learning cycle model with the *Exploring Life* curriculum. Data from the implementation surveys and teacher interviews reveal that time was a major factor in determining which activities a teacher would use in the classroom. The teachers who did not use the laboratories, Webquests, Career, or the Explore! activities cited time constraints as being the main reason why those activities were not used in the classroom. Of particular note, over two-thirds of the teachers that pilot-tested Chapter 7 (69.4%) reported not using the *Fastplants Guided Research Laboratory*, a multi-day inquiry laboratory. Activities that required more than one classroom period to implement were less likely to be used. Those that required a single class period, might be implemented, but were less likely to be used than activities that took shorter amounts of time to complete (for instance, Interactive Concepts). Many school-based biology curricula are "very content heavy," requiring teachers to cover certain topics in a specified amount of time. This curricular time constraint plays a large role in influencing decisions by teachers about which activities to select. Many teachers feel the pressure of being held accountable to state-mandated end-of-course mastery tests for their students.

One set of standards for scientific inquiry lists five essential features. These include:

- Learners are engaged by scientifically oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.

- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Learners communicate and justify their proposed explanations. (National Research Council, 1996)

One of the developers' goals was to enhance teacher use of scientific inquiry activities with their students. In designing the Web-based activities, the developers sought to implement as many of these essential features in their activities as they could. Appendix C (available online at http://www.lehigh.edu/~inexlife/papers/narst2003/appenc.pdf) displays the placement of each prototype activity on the Web-based Inquiry for Learning Science instrument beta version 2 (Bodzin and Cates, 2002). It is based on *Inquiry and the National Science Education Standards (*National Research Council, 2000), an enhancement of the 1996 work that addresses learner-directed versus teacher-directed approaches. The WBI instrument is a tool designed to identify Web-based inquiry activities for learning science and classify them along a continuum from learner-directed to materials-directed for each of the five essential features of inquiry.

Unfortunately, implementation results in this area were less impressive than we might have wished: The more essential features of inquiry an activity contained, the less likely teachers were to use that activity with their students in our pilot test.

Implementing inquiry-based instruction demands a significant shift in what teachers typically do in a science lesson. Orchestrating this kind of nontraditional, inquiry-based instruction is complex, and many teachers have not embraced the essence of this mode of learning in which students begin to think scientifically (Fradd & Lee, 1999). It will likely take many teachers time to adjust their current pedagogical styles to incorporate inquiry-based approaches. It appears that many biology teachers may want or need training in how to incorporate inquiry-based science instructional materials effectively into biology curricular contexts. Therefore, it is important to provide teachers with professional development assuring that teachers have the appropriate skills, knowledge and instructional strategies to help students achieve "science as inquiry" standards. Furthermore, it is likely that biology teachers may require other kinds of support to implement inquiry-based instruction into the classroom.

Curricular Modifications

Notable product improvements were made in the design of the instructional and support materials as a result of the implementation fidelity formative evaluation of year 2. Table 3 summarizes the changes to *Exploring Life* as a result of the evaluation feedback. Further, the strategies employed in modifying the product have been used in the development of new materials for succeeding chapters, as well as teacher-support materials.

Table 3: Product improvements based on formative evaluation findings.

Design Issue/Component	Evaluation Feedback	Resulting Product Change
Online Activities and WebQuests had desired length goals with estimated time periods to complete.	Pilot testers expressed concern that some of the activities were too long. WebQuests designed for 25-30 minute execution were taking close to an hour to complete and some Online Activities were overly long and complex. Teachers wanted to be sure that students could accomplish an activity within a given class period and that the amount of time allocated per chapter was appropriate to the importance of the chapter.	Developers revised the estimate time required to complete each activity type. Specific goals were set (e.g., no more than five external links per WebQuest), complexity of the activity was re-scaled appropriately for the importance of the concept, and great care was given to streamline the activities. Suggestions for implementation are now included in the teacher support materials. Text within online activities has been significantly reduced to allow students quicker access to Web-based interactivities.
Laboratories	Some laboratories were not being implemented due to curricular time constraints. In addition, teachers had difficulty getting results with some of the laboratory procedures due to not having access to specific materials.	Laboratories were modified or additional laboratories were developed to accommodate curricular time constraints. Addition information in the teacher support materials has been included to assist teachers with implementing alternative materials in laboratories.
Teaching environments vary widely.	Field observations noted tremendous variability in the teaching environment (time allotted to cover concepts, school facility, classroom arrangement, available hardware, class size) and the resultant effects on teachers' ability to use the program.	The development team has worked hard to maintain the flexibility of the program. Teachers can selectively choose from among a chapter's resources to easily adapt the program to their particular teaching environment. Recommended implementation sequences have been developed in the teacher support material to assist teachers with imposed time constraints.
The *Exploring Life* Web site includes online self-assessments within each concept's activity as well as server-scored assessments at the end of each chapter.	Pilot testers constructed their own worksheets because they felt the need to track student progress through the activities. They expressed a desire for some type of written accountability from the student beyond the assessment tools already available.	Based on specific suggestions from the pilot teachers, the developers devised a print supplement (*Learning Log*) that consists of one worksheet for each concept in the book/Web. Teachers can assign these worksheets and collect them after class.
Building highly interactive multimedia may result in slow download time, depending on the user's hardware and Internet connection speed.	Teachers complained of slow download time, even on computers with broadband access including cable or T1 connections.	The developers devised a plan to retain the richness of the media while reducing download times. They (1) used smaller sized assets, (2) began to use multi-screen templates (which eliminated load time lags within activities), and (3) devised a loading scheme to load all directions first. This allows the student to read while the rest of the activity loads and provides the additional benefit that the directions get read before the student engages in an online activity.
Pilot testing with Web-based materials is a difficult undertaking requiring the procurement of hardware and software along with careful planning. Of the 87 pilot testing teachers, 29.9% dropped out.	The evaluation team analyzed the problems cited by "dropout" teachers and concluded that the teachers required additional advice on how to use computers flexibly, in a wide variety of ways and settings.	As a result, more information was given in the initial orientation meeting on the various possible configurations and uses of the computer (beyond just using a computer lab). This information was further developed into Chapter Planning Guides that will appear in the Teacher's Edition of the textbook. Plans are in discussion for teacher training and mentoring scenarios.

Implications for Developers

The *National Science Education Standards* defines curriculum as "the way content is delivered . . . the structure, organization, balance, and presentation of the content in the classroom." (National Research Council, 1996, p. 2). The Third International Study of Mathematics and Science identifies two major dimensions: the intended curriculum (goals and plans), and the implemented curriculum (practices, activities, and institutional arrangements) (Schmidt, et al., 1996). Well-prepared science teachers can plan, implement and evaluate a high quality, standards-based science curriculum that includes long-term expectations, learning goals and objectives, plans, activities, materials, and assessments. They must be able to customize existing curricular materials to be consistent with their school-adopted standards. Individual teachers selectively chose from a variety of instructional materials to meet their curricular objectives and accommodate the diverse learning needs of their students.

But the designers of intended curricula need to be aware of the time demands on teachers in the field. Implemented curricula –by their very nature—must conform to the local pressures and capabilities of the teachers who implement them. Thus, if developers wish to market strong science products based on a learning cycle model and incorporating a heavy focus on scientific inquiry, they need to look for ways to address time and training constraints those teachers encounter. This likely means a combination of shorter activities and greater flexibility, as well as wrapping training in both product use and scientific inquiry around the product. Addressing these teacher needs and equipping teachers to succeed should, however, increase implementation fidelity and enhance the extent to which products meet their developers' goals.

Notes

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