Investigating Life NSF Final Report
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1. Major Research and Education Activities

Biology: Exploring Life (*ELife*) is a new kind of integrated high school biology program for 9th and 10th grade teachers and students. *ELife* consists of four main components: (1)!a relatively short textbook, (2)!the *ELife* Web site, (3)!lab and field experiments, and (4)!online and printed resources designed to help teachers make the program work in their classrooms. The integration of these components should enable all students to explore biology content actively, instead of limiting them to passive exposure to that content.   This biology program provides a rich set of resources that can be selectively integrated into the curriculum to accommodate a wide range of teacher and student needs. *ELife* uses a three-stage learning cycle model for each major concept: (1)!Engage, (2)!Explore/Explain, and (3)!Evaluate.

The main goal of the funded project is to guide the development of the *ELife* biology program designed to improve high school biology students' understanding of fundamental biological concepts. The students' self-confidence and skill in scientific reasoning and inquiry and their ability to apply biological knowledge and the methods of science to important social issues should also be enhanced, consistent with the National Science Education Standards.

Objectives of the *ELife* curricular program include developing:

1. A general biology program focused on a few key concepts for each major topic (chapter).

2. Student-centered materials for active learning of biology.

3. Tools to support teachers as they test out new ways to teach biology in the classrooms

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. The aim of the summative evaluation was to measure the project's success in meeting its goals and objectives.

A battery of methods and instruments was used in the three-year evaluation. Each instrument can be viewed at http://www.lehigh.edu/~inexlife/evaluation/.

Ninety high school biology teachers selected from a stratified sample of thirteen distinct geographical regions participated in the evaluation of the *ELife* materials during the first two years of the grant implementation period. The participants reviewed the *ELife* Web-based and text prototype materials at one of six evaluation workshops. Feedback and recommendations resulting from the evaluation workshops were reported back to the development team. A complete list of these reports is available at: http://www.lehigh.edu/~inexlife/evaluation/.

During the first year of the grant implementation period, eighteen participants pilot tested *ELife* materials with 783 students. During the second year of the grant implementation period, sixty-one participants pilot tested the materials with 3673 students. The evaluation team conducted five field observations in year 1 and eight in

year 2. Field observations and data summary reports are available at:
http://www.lehigh.edu/~inexlife/evaluation/.

      Significant product improvements were made in the design of the instructional materials since the original prototype chapter. Appendix A summarizes the changes made to the prototype materials of *ELife* as a result of the NSF evaluation feedback. The resulting modifications were used in the development of additional media for succeeding chapter development.

      Sixteen biology teachers field-tested *ELife* materials with 1040 students during the third year of the grant implementation period during an 18-week period from January 20 to May 23, 2003. Six rural, 5 urban, and 5 suburban teachers were selected as field-testers from a sample of sixty-one participants who pilot-tested the *ELife* materials in their classrooms during the 2001-02 school year. Responses to the *Teacher Technology Adoption* instrument classified 4 teachers as innovators, 3 as early adopters, 7 as early majority, and 2 as late majority users of technology. Ten participants had their students use computers primarily in the classroom, while six mainly used computers with students in a computer lab setting. Additional information about the participants from the *Exploring Life Teacher Questionnaire* is available online at
http://www.lehigh.edu/~inexlife/nsfreport3/a.pdf.

2. Major Findings

Student Measures

      It appears use of the *ELife* materials produces significant gains in learning of biology content even within a single semester. These improvements in biology content knowledge hold regardless of type of community and whether the learner is assigned an IEP.

Teacher implementation

      Individual teachers selectively chose from a variety of Web-based and text instructional materials to meet their curricular objectives and accommodate the diverse learning needs of their students. The results of the *Curricular Implementation Survey (end of the field test)* is available online at http://www.lehigh.edu/~inexlife/nsfreport3/b.pdf. The reported reasons teachers did or not use a specific *ELife* material type with their students is included in this appendix.

      Table 1 summarizes the percentage of teachers who reported using each *ELife* material type "almost always" (used for all or almost all chapters) or "often" (used for most chapters). Data from the *Curricular Implementation Survey (end of the field test)* reveal that time was a major factor in determining which activities a teacher would use in the classroom. Many school-based biology curricula are "very content heavy," requiring teachers to cover certain topics in a specified amount of time. Curricular time constraints play a large role in which activities get selected. Teachers who reported that they did not use *laboratories* or *Online Features* cited time constraints as the main reason those activities went unused in the classroom. In general, activity types that required at least an entire classroom period to implement were used to a lesser extent than other activity types.

Table 1. *ELife* material use summary

ELife material type	Percent teacher reported using "almost always" or "often"
Online Activities	100.0%
WebQuests	93.8%
Textbook Concept Checks	62.5%
Textbook Reviewing Concepts	62.5%
Textbook Applying Concepts	56.2%
Online Chapter Assessments	50.0%
Online Features	50.0%
Lab Online Companions	31.2%
Laboratories	25.0%

Teacher perceptions of *Exploring Life*

Field test teachers identified active learning, interactivity, and helping to develop improved thinking skills as the greatest strengths of ELife. Use of technology was also recognized as a very strong component of the program. Teachers noted that the Web components helped students visualize difficult concepts and addressed a variety of learning styles. Teachers rated the reading level of the materials as appropriate for the level of their students and noted *ELife* contained relevant examples of biological science that are applicable to students' lives. In addition, they rated materials as highly motivating for students. Other important findings pertaining to teacher perceptions include:

Teachers noted that using the program was easier than they expected and reported becoming more confident in using technology in their classrooms.

Teachers perceived their students becoming more self-reliant in their learning and felt, consequently, that they could require more of them.

Teachers viewed *ELife* as a program that made doing inquiry with students easier.

Teachers responded that *ELife* is better aimed at special populations than a traditional textbook program.

Exploring Life Expert Review Panel

A three-member review panel of scientists, science educators, and biology educators reviewed the *ELife* materials independently with the *Biology: Exploring Life Materials Review Instrument*. This instrument was designed to ascertain how well the *ELife* curricular program has met the grant goals and objectives. The current strengths of the *ELife* program as indicated by the review panels findings include:

ELife includes learner-centered activities that involve "active learning."

Many online activities including *Features* (*Science-Technology-Society* and *Careers*) and *WebQuests* provide learners with activities to help them connect the biological sciences to current issues and events at the personal, community and global levels.

The *ELife* materials provide opportunities for students to develop deep understanding of biological concepts.

The online activities should help different types of learners understand particular concepts that are presented in the text.

The majority of laboratory activities included in the lab manual that are labeled as "investigative" are better developed than what is typically seen in the laboratory manuals of commercially published text programs.

The *Teacher's Edition* contains some anecdotal misconceptions and misunderstandings that students may possess.

The instructional materials are likely to be interesting, engaging and effective for all populations of students (for example, of both genders, of varying ethnicity, regular as well as disability students, urban and rural, and the like).

ELife provides appropriate assessment opportunities for students in both online activities and in the textbook.

The *Teacher's Edition* contains useful implementation information, including background information, time frames, suggested uses for concepts, and suggestions for using the materials in different levels of technology-equipped classrooms.

The format of the Web site, textbook, and other printed materials are easy to use.

ELife accommodates everyone. Teachers that are innovators and early adopters should be able to use materials with new pedagogical practices. Teachers that are not comfortable with technology or with using student-centered approaches can use the program while employing more traditional teaching approaches.

Appendix B lists recommendations for strengthening future revisions of the product.

Concluding Remarks

ELife is a technology-rich product that shows much promise for being used to promote innovative biology teaching and learning if utilized as envisioned by the developers. The program takes advantage of interactive exercises on the Web to assist learners in understanding biological content and concepts. Having the online materials integrated into a comprehensive biology curriculum is likely to promote technology use by classroom teachers who have not, in the past, incorporated technology into their instruction very extensively. This program has opened the door for innovators and early adopters of technology to envision how more "cutting-edge" types of learning experiences might be used to promote biology learning. While *ELife* does contain some innovative simulations and virtual demonstrations, more can be done to promote more learner-centered experiences in the online activities.

In order for *ELife* to be implemented as envisioned by the developers, it should provide teachers in schools more professional development experiences to help them adopt *ELife*. Appendix C provides recommendations to address such experiences.

Clearly there seems to be evidence that *Biology: Exploring Life* has potential to make a difference. Unfortunately, the demands of a tight publication schedule, the normal sorts of delays incurred in bringing technology-based components online, and the ramp-up in professional development and support materials made it difficult to determine in this summative evaluation exactly to what extent this innovative product can produce lasting, long-term enhancement of the teaching of biology. We suggest that the publisher be allowed a year to bring all materials online, to acquire textbook adoptions across the country, and to resolve any minor problems with the online components. Then we

propose that NSF fund a two-year evaluation in which to investigate with a new nationwide sample the extent to which *ELife* helps to effect change in real biology classrooms with real teachers and real students.

The present project has developed many new instruments that could be applied to that sample to collect rich data sets for detailed analysis. Such a study with a broader sample would augment the strong existing findings from this project and help to illuminate what we know about both technology implementation in biology teaching and use of student-centered scientific inquiry.

Appendix A. Exploring Life Product Improvements as a Result of NSF Formative Evaluation.

Instance Prior to Feedback	Evaluation Feedback	Resulting Product Change
The prototype chapter did not have adequate "teacher resources" available to assist teachers in using 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 posttest 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 is currently under development.
User interface issues: 1. The concept backbone structure. 2. Showing the relationship between labs/explores and their parent concepts. 3. Color scheme 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.
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 (*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. These contained adults or animals in areas where organisms needed to be animated.
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. See any activity on the current version of the site.
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.
The *Exploring Life* Website 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 multiscreen 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.
Students have diverse learning styles.	Not all pilot testing students liked everything in the program.	Suggestions to teachers in the support materials were added on ways to implement the program to accommodate diverse learning styles.
Teaching environments vary widely.	Field observations noted tremendous variability in the teaching environment (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.

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 of the program, not completing their pilots.	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.
The computer is used on a regular basis with this program.	Teachers were having hardware and software problems. The evaluation team analyzed the problems reported by the participants and found that all teachers were experiencing similar technical problems. They concluded this was inevitable given today's computing equipment and the technical support structure of many schools.	New information was added to the teacher support materials. An *EL Community Website* (www.usingexploringlife.com) was developed and contains an area designed to help teachers solve basic implementation and technical issues. These include: (1) Suggested ways to connect with the technical support staff at each school. (2) Ideas and suggestions to include the school technical support staff as stakeholders in the adoption process. (3) Cultivating a network of systems people to serve in an advisory capacity for new users. Alerted Prentice Hall technical support and sales people to most common issues and encouraged them to bring the school's systems people into the adoption process.
Teachers were having problems determining if they had appropriate hardware and software configurations and identifying technical support staff at their own schools. Many teachers found that their "technical support staff" was not actually staffed with technologically sophisticated technicians.	The quality of school-based technical support systems organization, management, and skill level was compared with a sub-sample of schools.	The results showed that some teachers are better supported than others. Teacher support and training is necessary for all teachers but particularly for those poorly supported in their own institutions. Currently, the Prentice Hall technical support is receiving training on the range of hardware and software issues that arose during the pilot tests. Teacher training and ongoing professional development opportunities will be considered.
The Digital Divide.	Field observations revealed there are schools that acquired computers with funds from granting agencies.	The *EL Community Website* includes a list of granting agencies and philanthropy organizations.
Addressing student misconceptions.	Feedback from the AIBS/Packard and *AAAS Criteria for Instructional Support* instruments noted that the materials did not address common misconceptions of students.	The Chapter Planning Guide for each chapter in the Teacher's Edition contains a section called "Addressing Naïve Conceptions."

Assessments.	Feedback from the AIBS/Packard and *AAAS Criteria for Instructional Support* instruments noted that the materials did not contain a wide range of assessments that could be used for diagnostic and formative purposes.	The Chapter Planning Guide for each chapter in the Teacher's Edition contains a section called "Assessment and Remediation" that provides alternative assessments for teachers to use.

Appendix B. Recommendations for Strengthening Future Revisions of *Exploring Life*.

Laboratories**:**

Laboratory activities should be developed to move learners through more open, and less guided inquiry approaches as the school year progresses. The developers should assume that it might be likely that students using *ELife* may not have had any prior experience using inquiry-based laboratories or activities. We recommend *ELife* provide structured, guided inquiry laboratories or activities in the beginning chapters or in those chapters teachers are most likely to implement in the beginning part of the school year. As chapters progress, gradually increase learner-centered features of the laboratories and activities. By the end of the school year, activities should be predominantly learner-centered activities that show a large degree of open-ended activity.

Some wet laboratories labeled "investigative lab" are not investigative, but rather structured and guided hands-on learning activities. These labs could be customized to be more investigative. Provide teachers with suggestions or options to enhance the level of student-centered inquiry in these laboratories.

Include more complex simulation activities that allow learners to change parameters and conduct multiple runs. These simulations could be used in addition to wet laboratories or to replace certain laboratories where there is much preparation time and learning may be minimal.

Support:

Create a *Professional Development Web site* that focuses on pedagogical concepts. This Web site might include a series of short online "mini-course modules" to support teachers in pedagogical practices with *ELife*. Modules would link to specific examples of *ELife* components. Suggested modules would include:

- ✓ Using *ELife* with diverse learner subgroups (gifted students, lower ability students, students with disabilities, etc.). This module would address different learning modalities and would be explicit about how teachers would use program materials to accommodate learning needs.

- ✓ How to use different Web-based activity types most effectively in the classroom. This module would provide information on how a teacher could use online activity types in the classroom. For example, it could provide descriptions and examples of how to use animations in a classroom with questioning strategies.

- ✓ How to use assessment data to inform instructional decision-making.

- ✓ How to treat prior knowledge in the classroom (for example, identify and address student misconceptions).

- ✓ How to enhance wet laboratories to be more inquiry-based.

- ✓ How to use a textbook (for example, leaving a textbook at home instead of carrying back and forth).

Assessment:

Online assessments are currently multiple-choice and are predominantly *knowledge* and *comprehension* questions (lower-level category-types of questions, as classified by Bloom's taxonomy). Online summative assessments should <u>also</u> include *application*, *analysis*, *synthesis*, and *evaluation* questions.

There is a lack of sufficient background information on common student misconceptions related to each chapter topic. Include pretests for diagnostic purposes that analyze common misconceptions. Provide instructions on how to use the data to customize instruction.

To assess critical thinking and deeper understanding, include open-ended response items in the online summative assessments.

Online Activities:

Provide support for improved use of online activities in the classroom. A variety of online activity types serve as an *animated textbook* (for example, online concept 23.2) or a *user-directed simulation* that often appears like an *animated transparency* (for example, online concept 13.3). Include ideas for teachers to use these <u>activity types</u> in their lessons beyond using online activities only as Web-based computer-assisted instruction modules.

Students should be allowed to make mistakes in online activities and be able to try again before being provided with the correct answer.

Include more higher levels of activity types in the materials.

- ✓ Provide open-ended simulations that provide learners with complete control. This would allow learners to explore a concept beyond a teacher-mediated or pre-determined track. The sheep-breeding lab (10.2) could be developed into such a simulation.

- ✓ Provide additional activities that would qualify as Web-based inquiry activities (WBIs) for learning science. Such activities could take advantage of authentic biological science data sets available on the Web.

Diverse Learners:

Materials in the *Teacher's Edition's* "Meeting Diverse Needs" sections should be made more explicit to help teachers understand how different sub-groups of students would gain from using the activities.

The Spanish glossary should also have audio pronunciations (as is true now for the English glossary).

The glossary should be more integrated with the Web site concepts and activities. Hyperlinks can be used to link Web site concepts and activities to the glossary.

Activate Prior Knowledge Section:

Include resources or alternative activities for students who might be lacking in foundational knowledge. This section should refer teachers to other sections of *ELife* if the missing foundational knowledge is available elsewhere.

Offer strategies in this section for eliciting common student misconceptions.

Teaching Strategies:

The "Best Practices" section of the *Teacher's Edition* could provide more useful information. An online section could be devoted to providing a more detailed vignette that provides an example of best practices (for example, a video clip or lesson plan).

"Reteach" sections in the *Teacher's Edition* (for example, p. T197) need further elaboration.

"Teaching Tips" in the online *Teaching Guide* need further elaboration in order to be useful in the classroom.

WebQuests:

It should be made clearer to teachers how the Webquest fits into each chapter.

Need to make better connections between the material in the Webquest and the rest of a chapter.

Features (STS, Careers, History of Science):

The content of the features should be more integrated into the online concepts and WebQuests, rather than set off by itself.

The Web as a Rich Resource:

One of the strengths of the Web is the ability to access current scientific knowledge including news articles, journal articles and data and findings from laboratories. *ELife* should consider becoming part of the NSTA *SciLinks* program. (*SciLinks* is a partnership between NSTA and commercial textbook publishers that provides students with a variety of current science sources including science news, reviewed Web sites that contain additional content and access to content experts.)

The Web-based materials need to be more integral to the program and not additive if the program is truly innovated.

Orienting Teachers to *ELife*:

Create a twenty-minute video to orient teachers to the philosophy of the program. The video can include pedagogical strategies for using various program components.

Appendix C. Professional Development Recommendations.

1. *Video orientation.* Provide a video orientation to show an overview of the program. The video should present the philosophy of the program and illustrate how the program components (textbook, web site and laboratories) work together within the learning cycle model. Videos of classroom implementation would also be helpful.

2. *Inquiry-based instruction.* 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. Thus many biology teachers may want or need training in how to incorporate inquiry-based science instructional materials effectively into biology curricular contexts. Professional development should assure that teachers have the appropriate skills, knowledge and instructional strategies to help students achieve "science as inquiry" standards.

3. *Learner-centered approaches.* Professional development may need to focus more on helping teachers and administrators understand how best to implement learner-centered approaches. Our findings suggest that many teachers (and perhaps administrators) may not have as broad an understanding of learner-centered approaches to teaching biology as they might. Professional development focused on acquiring a diverse repertoire of pedagogical approaches may prove useful.

4. *Diverse computer configurations.* Teachers wishing to implement technology-rich materials may need to rely on a more diverse set of computer configurations than just using the computer lab. It would benefit biology teachers to see how *ELife* Web materials can be used effectively in a one-computer classroom settings and how wireless classroom configurations might provide additional flexibility for biology instruction.

5. *Support network.* Create a vehicle for sharing by experienced teachers. Have experienced teachers available online to help with implementation issues.

6. *Responsibility for change:* Few would define textbook publishers as agents of instructional change. While it is certainly appropriate for textbook publishers to provide implementation supports for teachers to use program materials effectively, the responsibility of providing systemic professional development for science instructional pedagogical practices lies with schools that adopt an innovative curricular program.