Designing a Flexible Web-based Instructional System for Watershed Exploration and Inquiry

Alec M. Bodzin, Lehigh University


Abstract
Recent reform documents, including the National Science Education Standards (NRC, 1996), the National Educational Technology Standards for Teachers (NETS, 2000) and the National Geography Standards (GESP, 1994), emphasize the importance of teaching environmental science in K-12 classrooms and incorporating instructional technology into curricular contexts. In response to these initiatives, we developed a flexible Web-based instructional system called LEO (Lehigh Earth Observatory) EnviroSci Inquiry (http://www.leo.lehigh.edu/envirosci/) to provide K-12 teachers and students with a variety of technology-based materials to learn environmental science. Current research theory and best practices of teacher implementation of the SERVIT Group Web-based projects including Carolina Coastal Science and Water What-Ifs have guided the development of the LEO EnviroSci Inquiry curricular innovations. These activities have been developed in a partnership between science teacher educators, K-12 teachers, scientists, and informal science educators. The activities actively engage learners in data collection, analyzing data, working with Web-based Global Information Systems (GIS) databases, and learning in interdisciplinary contexts. Activities emphasize student-directed scientific discovery of their local environment as well as global contexts. This paper, presented as part of this SCALE symposium, describes how the Website has been designed to support curricular customization across primary and secondary grade levels. The paper describes how three classroom teachers have adapted the Web-based instructional system to meet the needs of their classroom setting. It also depicts how researchers and teachers are working together to design new curricular materials.

LEO EnviroSci Inquiry Website Description

The LEO EnviroSci Inquiry Web site is a K-12 outreach project from LEO - the Lehigh Earth Observatory and the SERVIT (Science Education Research in Visual Instructional Technologies) Group in the College of Education at Lehigh University. EnviroSci Inquiry enables teachers, students, and the public to learn about environmental science content knowledge from Lehigh University LEO scientists and interns. Learning activities actively engage participants in data collection, analyzing data, working with Global Information Systems (GIS) databases, and engaging in science-specific pedagogical practices that incorporate Web-based and other technologies to be implemented into the science classrooms. Environmental science curricular activities enable students to use Calculator-based laboratory (CBL) probeware, Web-based telecommunication tools, QuickTime Virtual Reality (QTVR), and other Internet resources to learn about environmental issues. Curricular activities emphasize student-directed scientific discovery of their local environment aligned to the National Science
Education Standards, National Educational Technology Standards, and the National Geography Standards.

The key goals of the LEO EnviroSci Inquiry are:

- Actively engage K-12 students in authentic scientific inquiry that will enhance existing classroom curricula.
- Enable K-12 students to learn scientific content, concepts, and processes by integrating a variety of instructional technologies into science curricular contexts.
- Create an innovative Web-facilitated project linking together research scientists, university students, science educators, inservice teachers, preservice teachers, and students to translate current scientific knowledge and practices into teaching practices.

Curricular Format

The LEO EnviroSci Website project is a Web-based instructional system that has been designed to be “customizable” by the individual user. Primary and secondary learners with different levels of ability can use LEO EnviroSci Inquiry as an instructional tool to learn environmental science concepts. To meet the needs of diverse teaching and learning styles, LEO EnviroSci Inquiry provides many different types of activities ranging from very structured guided inquiry investigations to open-ended activities where students generate their own questions for investigations. We recognize that one instructional model does not accommodate every learner, classroom teacher’s pedagogical style, or classroom learning environment. The Website’s primary function is to serve as a resource for an in-depth study of the Lehigh River watershed. However, many learning activities are designed to be used by learners who reside in other geographical locations. The Website’s Educator’s Guide (http://www.leo.lehigh.edu/envirosci/guide/index.html) provides instructional strategies for incorporating the Web-enhanced activities into the classroom.

Activity structures vary depending on the target audience of each learning activity. Many activities are interdisciplinary in nature and based on the local ecological region of the learner as well as global contexts. Many curricular activities emphasize student-directed scientific discovery of their local environment. Selected activities and Website sections include:

- **Fish Kills!** (http://www.leo.lehigh.edu/envirosci/watershed/riverexp/fishkills.html) is an open-ended inquiry activity designed for secondary school learners. This activity gives students the opportunity to formulate their own research questions explore and locate information, assess their findings, and present their information.

- The **Water Quality** (http://www.leo.lehigh.edu/envirosci/watershed/wq/index.html) section contains background information and protocols that assist learners using Vernier CBL (Calculator-Based Laboratory) units and graphing calculators to collect water quality data. Data reporting forms are provided on the Website that enable learners to submit collected data to the LEO water quality database. This data can then be compared to other water quality data located on the Website. Web-based data links to the Lehigh...
River’s USGS (US Geologic Survey) monitoring stations provide river flow data and real-time discharge data.

- The *Environmental Issues* area (http://www.leo.lehigh.edu/envirosci/enviroissue/) contains Science-Technology-Society (STS) issues-based approach simulations developed by our research group and partner organizations. These simulations provide learners with the experience of learning science and technology in the context of human experience involving real-life controversial issues. In these simulations, learners investigate a real-world controversial issue from different perspectives. After they complete their investigation, a public forum or debate is conducted to determine the next course of action on the issue.

- The *Geology* area (http://www.leo.lehigh.edu/envirosci/geology/) contains interactivities for learners to use virtual reality in their science investigations. *Which Way Is North?* is an activity that allows learners to develop skills in understanding location by exploring a variety of unique geological formations using QuickTime Virtual Reality (QTVR) panoramas and topographic maps. *Dino Inquiry* allows learners to explore a variety of dinosaur fossil bones from the Dinosaur National Monument quarry using panoramas and digital still imagery. *Geologic Explorations* allows one to explore a variety of unique geological formations through the use of QTVR.

### Curricular Implementation Examples

Three classroom teachers described below currently use the LEO EnviroSci curricular materials to assist in their students’ study of the Lehigh River watershed. Each teach in the same urban school district. This section provides a description of each teacher, their students, and their curricular goals. The section also describes how the teachers have adapted the Web-based instructional system to meet the needs of their classroom settings. Data was obtained through classroom observations, an interview protocol (see Appendix 1), and informal conversations.

**Dave.** Dave has been a science teacher for twenty-six years. He is comfortable with using instructional technologies that include the implementation of computers and the Internet for instructional purpose. Dave teaches a semester long environmental science course on a block schedule. The environmental science course contains 11th and 12th grade students. Most students are Hispanic and read at a 6th grade reading level. For many years, Dave has emphasized stream ecology in his curriculum. Usually he devotes one full week to the topic of water quality. Each year, his students go on a water quality sampling field trip to measure physical, chemical, and biological parameters of a stream. Lamotte test kits are used to obtain chemical nutrient data and a macroinvertebrate sample is conducted to obtain biological parameter data. Instructional goals include having students understand how to contrast different types of collected data and interpret data analysis on different temporal scales. Dave also wants his students to have an understanding of the environmental factors that produce observed data:
“I want them to understand when they find various, when they do these various tests, I want them to understand what that might mean. If you have high nitrate levels, what might be the reason that you have high nitrate levels? When you have..., or high phosphate levels or if you have low dissolved oxygen, what might be the reasons for these kinds of things? Or if you have no stone flies and may flies in the stream, what might that tell you? Those kinds of things, I want them to understand the data they’re collecting.”

In addition, Dave wants his students to understand the “bigger picture” of how ecosystems work including “how they impact ecosystems and how that impacts them.” He develops his instructional units with this over-arching goal in mind.

Dave maintains a strong belief that it is important to expose his students to local examples of environmental issues. Dave contends that using local examples motivates his students to learn the content. This assists the learners in making connections of environmental science content to real-life applications:

“One of the places where you can really clearly see those connections. You know, they can see how if they’ve got their backyard right next to the Monacacy and then it rains, it’s going to wash a lot of sediment into the stream. You know, I mean, they can see how their impact. Or if you have a farm and the cattle are wading around the stream, why is there going to be a nutrient low there and things like that. So, I think this is one place where they can really see those connections.”

In the summer of 2000, Dave assisted in providing feedback to the development team on the Lehigh River Watershed Explorations area of the Website. The main goal of this Website section is to present science to K-12 learners in a historical perspective by engaging them in a detailed study of the Lehigh River watershed. This watershed has a very rich history, presenting learners with a unique opportunity to observe how the American industrial revolution impacted a watershed over time. Stories are presented in the History of the Lehigh Watershed section that enable learners to explore science from a historical perspective and to observe how science and technology may impact society over time. The Lehigh River Watershed Photojournal provides learners with the opportunity to explore the Lehigh River watershed virtually. The photojournal contains MPEG movie watershed flybys that provide the learner with a graphical overview of the topography of the area. GPS (Global Positioning System) coordinates index the photojournal. In addition to digital images of the area, the photojournal Web pages contain short MPEG video clips and QuickTime Virtual Reality panoramas that allow learners to zoom in on specific physical features.

Dave places emphasis on presenting his students with a historical perspective of issues affecting the Lehigh River watershed during his classroom instruction, including many topics presented in the History of the Lehigh Watershed section of the Website. However, due to curricular time constraints, Dave has not yet been able to incorporate these sections of the Website as part of his in-class instruction.

In June 2000, Dave used CBL probeware for water quality data collection for the first time with his students. Dave stated that he was very comfortable using these tools for data collection, but noted that it took a lot of work and instructional time out of the
curriculum to get his students familiar enough with the equipment to ensure that calibrations were made accurately. Students used the Water Quality section of the LEO EnviroSci Website to learn water quality background information and obtain the protocols for collecting data using the Vernier CBL with TI-83 plus graphing calculators. Students compared their data obtained from the Lamotte chemical test kit with data obtained from the CBL probeware. Collected data was submitted to the LEO water quality database using a Web-based reporting form that was provided on the Website. The submitted data was marked with a low quality control index by the LEO staff since quality control assurances were in question. Because of the time involved with calibrating the probes, Dave decided to use only Lamotte water quality test kits during his sampling field trip in the following year.

In order to meet the needs of teachers with curricular time constraints and to ensure a higher quality control on the water quality data taken by students, LEO provided funding for a graduate student to support classroom teachers and students with gathering water quality data. This school year, Dave will not have to spend as much time instructing his students on the proper calibration of the probeware. Instead, the LEO graduate student will perform the necessary calibrations and be present during the field trip ensuring that sampling protocols are followed to ensure that a high quality control index can be assigned to the data.

George. George has been a classroom teacher for twelve years. He teaches an alternative integrated program under a common theme of wilderness education that uses adventure-based instruction and experiential education as tools to reach students’ potential in leadership skills, group problem solving, and academic achievements. His class is composed of fifty-eight heterogeneously grouped seventh graders, including learning support and gifted students. The program is co-instructed with one other teacher. The curriculum covers skills and concepts through an interdisciplinary, thematic combination of classroom and on-site learning experiences. The skills and concepts taught in traditional disciplines are integrated and focus on the comprehensive examination of a specific wilderness theme. Elements and processes from reading, language arts, related arts, technology, science, and social studies are included in curricular units. Students participate in a series of day trips to nature centers, field research areas, museums, historical sites, state parks, an indoor rock climbing gym, streams, and other ecosystems. The students also participate in three to four extended overnight fieldtrips.

George is comfortable using computers and the Internet in his instruction. His students create artifacts that are placed on a class Website to communicate their activities to the public. In the past, George has used Hach water quality kits for data collection with his students. For two years prior to being involved with the LEO materials, George did not conduct a water quality sampling field trip. He felt that going to a stream or lake to collect data was not as meaningful to the students as it could be since the data was just being stored on a school computer and not being used by anyone. Currently, George’s instructional goals for watershed studies include having his students gain experience using technology tools in science while engaging in an authentic research context in which the student data will contribute to monitoring efforts. It is also important to
George that his students connect science to other curricular disciplines including language arts and reading.

In summer 2001, George received training from LEO on the use of CBL probeware with TI 83 plus calculators for water quality data collection. This school year, George took his students on seasonal sampling field trips to the same location. The Water Quality section of the Website was used to provide students with content background on different chemical parameters. The water quality data collection protocols on the Website were used in the classroom to prepare for the sampling trips. The students submitted their data using the Web-based data report form. A LEO graduate student performed the necessary calibrations on the instruments and was present on each field trip to ensure that all sampling protocols were followed ensuring that the data would be assigned a high quality control index.

George will spend four weeks at the end of the school year to use water quality as a “culminating unit.” In the past, he spent only two weeks on this topic. He uses the theme of water quality to tie together previously introduced topics such as reptiles, amphibians, insects, mammals, birds, and forestry. He intends to use additional activities and resources on the Website at the end of the school year.

Debbie. Debbie has been a classroom middle school teacher for fourteen years. She currently spends half of her school day teaching three classes of a gifted seminar, one class each for 6th, 7th, and 8th graders. The school is an urban school with a very large Hispanic population of students. Debbie uses a project-based approach to teaching. Her students engage in four large-scale interdisciplinary projects during the school year. Her curriculum states that the projects completed by the students must include a debate, a simulation, a design construction, and a video production activity. She has curricular flexibility to select the content that will be incorporated within these projects. Debbie is very comfortable teaching with computers and the Internet in her instruction. Debbie also serves as the technology curriculum integration specialist for her school. She maintains her school’s network and has experience over the past decade incorporating technology-based projects into her classroom instruction. She is currently completing an Ed. D. in educational technology at a local university. Her students often engage in activities that include creating and utilizing large databases, working with spreadsheets, and creating project-based Websites. She also uses decision-making software simulations in her instruction. Debbie considers her ability to use hand-held data collection devices “a little weak.” She also views her prior experience using water quality chemical kits as “pretty weak.” Prior to her involvement with LEO, she had very little content knowledge in the areas of biological and chemical parameters used for water quality data collection and had not previously conducted a watershed study with her students.

Debbie’s instructional goals for watershed studies include engaging her students in hands-on science that has a real-world world application to their daily lives. She wants her students to be able to “do real science” using hand-held data collection tools. She wants her students to be able to make sense of collected water quality data and understand how it is relevant to their daily lives and the environmental decisions that they and others make. Debbie also wants her students “to see how databases are used in the real-world.” She believes that the LEO databases will provide her learners with
opportunities to observe trends and patterns in authentic data sets. In using the LEO materials, she believes that her students will be able to see integrated applications of science and mathematics.

In summer 2001, Debbie received training from LEO on the use of CBL probeware with TI 83 plus calculators for water quality data collection. Debbie took groups of students on sampling trips to the same location to obtain seasonal readings. The Water Quality section of the Website was used to provide students with content background on different chemical parameters. The water quality data collection protocols on the Website were used for practice in the classroom to prepare students for data collection in the field. A LEO graduate student performed the necessary calibrations on the instruments and was present during each field trip to ensure that all sampling protocols were followed. This ensured that the data would be assigned a high quality control index. The students submitted their data using a Web-based data report form.

At the end of the school year, Debbie is planning to spend seven weeks to use water quality as a theme to her last unit. She intends to modify the intended use of the Pine Creek WISE activity to meet her curricular requirement of engaging her students in a debate and a simulation. She believes this activity will reinforce previously introduced concepts of water quality and further her students’ understanding on how to analyze a water quality data set. She intends to have students carry out data analysis activities using the LEO hydroprobe data. During these activities, she intends to have her students compare the hydroprobe data to their sampled data in the watershed.

Designing New Curricular Materials

This section describes the collaborative process between the researchers and classroom together to design new curricular materials for the LEO EnviroSci Inquiry Website.

Procedure

Two researchers conducted three separate collaborative design meetings, one each with Debbie, George, and Dave, to discuss how to best guide the development of a new Web-based inquiry activity that uses the LEO hydroprobe data. A modified version of the SCALE design interview protocol (Appendix 1) was used to gather information. The goals of the interview included:
• Capturing information about the teacher’s needs and goals, available time, etc. to help shape the activity.
• Presenting the SCALE curricular framework for water quality projects (Appendix 2) and the Web-based Inquiry for Learning Science (WBI) framework (Appendix 3) to serve as a starting point for discussing designs of activity structures.
• Capturing the teachers’ views of purpose and value of the elements of the frameworks and their curriculum.

The structure of the design interview was to be an interactive discussion about the customization of specific LEO curricular materials, focusing on the use of the LEO hydroprobe data. The interview protocol allowed both the designers and the teacher to
explain their goals for coming together to customize the existing school’s curriculum by integrating LEO activities. Each collaborative design meeting was audio-taped. Written transcriptions of each design interview were transcribed. Transcriptions were analyzed for themes that could be used to guide the development of a new activity.

Findings

Motivating contexts.
The SCALE curricular framework made sense to the teachers. Each teacher felt that they could implement this framework in his or her classroom. They noted that providing a motivating entry point would be important for engaging their students into learning environmental science content. Dave noted that he incorporates motivating contexts within his instruction. He believed that incorporating this into a Web-based activity would assist him in his classroom instruction since using the Internet appears to motivate his students:

“I generally try to use some kind of locally relevant problem that I know of, but, or sometimes I’ll give them a fictional scenario. But it would be really helpful to have a really well developed one that I could sit them down on a Web site and have them start there, so that it would give them a reason to want to learn more about water quality and to, and we’re ultimately going out there and testing this water quality but if we start there, I try to do that but a good Web site would help me do that better. So, I think that’s a great starting point.”

A variety of motivating scenarios were described. George stated that a scenario connecting a real-life experience such as “getting sick on a camping trip” and relating that to the importance of purifying water would work well for his students. Dave provided many examples of locally relevant problems that could serve as motivating contexts for learning environmental science content. He noted that providing learners with a variety of examples from the watershed would help them to understand anthropomorphic interactions:

“The Lehigh River has a lot of little things, you know a lot of scenarios that could be used. I think the Lehigh River is a good one because it’s such an important body of water in this area. Any number of things from acid mine drainage to toxic waste up there in Palmerton to whatever could be used there. But also, the siltation of the Monacacy from runoff from the development is another good one. I think because the Monacacy is such a great little stream and the development here, I mean I see that Monacacy running brown and that’s just is disturbing to me. It’d be nice if there were several of these types of scenarios that they could look at because there is no one example that’s going to pull it all in for them. So maybe several of these that they could go through and look at and see as the entry point. Because then when we go out they’ll have some ideas about what kinds of things can go wrong and also be able to see if things are right. If you go out and test everything and it’s all right, there’s nothing, it’s like they didn’t get any results, if it’s all right. If the stream is perfect
water quality, it’s like they didn’t get any results. So somehow they need to see the bad stuff, so if that they do go out and test a good stream they know that it’s a good stream and then that’s a wonderful results and that they’re not disappointed because they didn’t find pollution or something.”

Divergent philosophies.
The World Wide Web provides opportunities to learn science through inquiry-based activities. Just like classroom-based science inquiry activities, Web-based inquiry activities (WBIs) for learning science fall along a continuum from learner-directed to materials-directed. Learner-directed activities tend to focus on individual decisions and a large amount of learner involvement in making decisions on how to complete the inquiry. Materials-directed inquiries tend to be very specific about what learners should do in order to complete the inquiry and often lead the learner towards expected conclusions and explanations.

The interviewed teachers hold different opinions about their instructional philosophy positions along this continuum. Debbie noted that her students were “top end students” and it was important for these students to be engaged in activities that are learner-directed. George noted that he would like to implement activities that were more learner-directed, since it aligned to his own style of learning. In addition, he commented that usually he does provide his students with questions in which to engage. Dave noted that since the students in his school district receive little experience with inquiry, a materials-directed approach would be needed to provide his learners with a structured experience before they could engage in a more learner-centered activity:

“Unfortunately our kids have had so little experience with inquiry...um, and I don’t think [our school district] is unique. I think that, it’s just really tough to design things that are really good inquiry based learning experiences. The kids don’t have much experience with it so they, especially the lower levels, they throw up their hands if you tell them to come up with a question. They can’t do it. They need you to give them the question. And even the, even our better students have very little experience in this. So what goes through my mind when you say this, and this takes a little more time for me in the classroom, is to have a materials directed example for them to work through, and then, say now you design a problem, you ask a question and you try to figure it out. I think they need that. You know, I think we want to have them do science, but I think we sometimes, when we say that, I think we sometimes forget that...that they don’t have experience doing science unfortunately, and they need to, they need to see how to do science first if we want them to actually really do it themselves. So I think that it would be great to have on this Website both so that ah...that they can get the experience first and then design their own ideas and so forth.”

Authentic data.
The idea of developing a Web-based inquiry activity with the LEO hydroprobe data was of interest to each teacher. All commented that they would want to use this type of activity with their students. George noted that the data set and background presented on
the LEO Website would interest his students since it shows scientists engaged in the same types of activities that his students are conducting:

“That’s real valuable. It’s taking data from the... Yeah absolutely, especially if the kids have already gathered their own data from the area and stuff like that from the area. It’s neat to see somebody else that’s doing it to. Like they need to see professionals that are doing it.”

Furthermore, George noted that his students become more interested in participating in an activity if it means something to them personally.

Dave contended that although it was important for students to be aware of what authentic “messy” data looks like, it was unlikely that he could implement an activity with “messy” data due to the time constraints that he has in teaching his curricular content. He recommended developing a materials-directed activity that would use a “clean” subset of data taken from the hydroprobe database that students would be able to observe both daily and seasonal patterns. Dave recommended using dissolved oxygen data from the hydroprobe to illustrate these patterns. He noted that “although dissolved oxygen is fairly complex in some aspects, it often produces data patterns that students can grasp.”

Each teacher noted that materials would need to be developed to provide learners with explanations about the hydroprobe data. Learners would also require explanations about data units and possible reasons that explain gaps in the data collection.

**Concluding Remarks**

In the development of the LEO curricular materials, we employ a user-centered design strategy that focuses simultaneously on interface issues, students and teachers’ subjective experiences in using Web-based interactivities, and student learning outcomes. Our design process begins with a needs assessment conducted jointly between the development team and the target users (classroom teachers). The findings described in this paper illustrate that there are differences among users of the LEO materials with regards to classroom implementation. The paper described contextual factors that contribute to these differences, including curricular time constraints, comfort level with content, prior experience with inquiry, and teaching styles. Given these different factors, it is important that materials be designed to support curricular customizations to fit the needs of diverse learners in diverse classroom settings. We continue to collaborate with classroom teachers to improve on the design and development of the LEO curricular activities. It is our intent to continue to provide a Web-based environment designed to enhance student learning of environmental science.
Appendix 1. Design Interview Protocol

Outline the main goals you have for implementing your curriculum.

**Introduce the framework**
Present the SCALE generic framework (vanilla model) first. Walk through each step and explain why SCALE thinks it’s important.
Introduce the WBI framework. Explain the differences between materials-directed and learner directed.
Reaction and discussion: Does this framework make sense?
Do you think we’ll be able to do something similar to this in your classroom?

**Walk through the materials**
Begin walking through the LEO EnviroSci Website, making sure that teachers see what it looks like as well as focusing on the material. Let teachers ask questions throughout if they’re not sure of things.

**Design discussion**
Show the LEO hydroprobe data. Discuss ideas of creating a materials-centered and a learner-centered WBI for this activity.

Once everyone has a sense of the scope of the project, start into the important design issues. Prompt teachers for their reactions to the material: Could you use something like this? Would it help you to meet your goals?

What changes are necessary to customize the watershed context of LEO EnviroSci? For example, focusing on data, threats to water quality, local issues, etc. to meet your curricular context?
What needs to be modified to do this?

Discuss the activity sequence for your curricular implementation. Focus on what you would normally do in the classroom and how the EnviroSci materials could enhance what you do?

Agree on a set of bullet points, perhaps organized by activity, for what needs to happen to adapt the materials to the teacher’s needs.

**Reflecting on goals**
Once you’ve been through the materials, take a few minutes to revisit the goals the teachers laid out up front.
Do you feel that the materials will address the goals?
How will you be able to tell if each goal is met?
Appendix 2. SCALE curricular framework for water quality projects

Effective water quality projects typically contain the following elements, which follow (with the exception of longitudinal scaffolding, which is always present) more or less in order.

Each of these elements can be implemented in different ways, and indeed each of the research groups associated with SCALE has addressed these elements in its own fashion. However, it is important to note that all of the SCALE research groups agree that these elements constitute critical features of a water quality project.

A motivating entry point
An activity or story that introduces the project and motivates student interest. This could be a fictional story, or an introduction to a locally relevant problem, or something else.

Opportunities to make sense of the setting
Students have an opportunity to demonstrate that they understand the problem and what they need to do to solve it. This could include background information about the problem, or about the physical setting.

Access to authentic data
Students have the opportunity to explore authentic data about the watershed. This data could come from a canned data set, students’ own data collection, historical data, or elsewhere. However, the data is authentic in that it relates directly to the problem at hand.

Opportunities to make sense of the data
Students have access to materials and activities that help them to understand what the data means. This includes background information about different kinds of tests, guides that document safe levels of different chemicals or pollutants, and tools that help students to organize data and identify patterns.

Goal of developing an explanation for the data
Students have a goal of developing a scientific explanation, grounded in the data, for what’s going on in the watershed. This explanation could address whether or not the water is safe to use in different ways (drinking, swimming, for livestock, etc.) or could explain historical trends in the data (evidence that pollution is getting better or worse). The explanation is generally rooted in the causal mechanisms that drive water quality (e.g. eutrophication), and uses data to support its claims.

The development of some kind of final artifact or culminating experience
Tied to the explanation, students create some kind of final artifact as a culminating activity in the project. This could be participation in a debate, or development of a causal model explaining what’s happening in the watershed, or something else entirely.

(Longitudinal scaffolds)
Many curricula provide different kinds of support for student learning throughout the project – we call these longitudinal scaffolds. These scaffolds can include guiDavece for what to do next, tools to help organize notes and data, prompts to help students articulate their thinking, and other methods.
<table>
<thead>
<tr>
<th>Essential Feature of Inquiry</th>
<th>Learner Directed</th>
<th>Materials Directed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>L2</strong>: Learner-driven with much initiative and independence.</td>
<td>Prompts learner to formulate own question or hypothesis to be tested.</td>
<td>Offers learner lists of questions or hypotheses from which to select.</td>
</tr>
<tr>
<td><strong>L1</strong>: Decisions to make, but support &amp; scaffolding, particularly with process.</td>
<td>Suggests topic areas or provides samples to help learner formulate own question or hypothesis.</td>
<td>Provides learner with specific stated (or implied) question/hypothesis to be investigated.</td>
</tr>
<tr>
<td><strong>M1</strong>: Much selecting from provided materials. Limited choices.</td>
<td><strong>M2</strong>: Materials-driven. Few choices and much direction given.</td>
<td>Provides data and asks learner to analyze.</td>
</tr>
<tr>
<td><strong>L1</strong>: Decisions to make, but support &amp; scaffolding, particularly with process.</td>
<td><strong>M1</strong>: Much selecting from provided materials. Limited choices.</td>
<td>Provides data and gives specific direction on how data to be analyzed.</td>
</tr>
<tr>
<td><strong>L2</strong>: Learner-driven with much initiative and independence.</td>
<td><strong>L1</strong>: Decisions to make, but support &amp; scaffolding, particularly with process.</td>
<td><strong>M2</strong>: Materials-driven. Few choices and much direction given.</td>
</tr>
<tr>
<td>Learners are engaged by scientifically oriented QUESTIONS.</td>
<td><strong>M1</strong>: Much selecting from provided materials. Limited choices.</td>
<td><strong>M2</strong>: Materials-driven. Few choices and much direction given.</td>
</tr>
<tr>
<td>Learners give priority to EVIDENCE, which allows them to draw conclusions and/or develop and evaluate explanations that address scientifically oriented questions.</td>
<td>Learner determines what constitutes evidence and develops procedures and protocols for gathering and analyzing relevant data (as appropriate).</td>
<td>Directs learner to collect certain data, or only provides portion of needed data. Often provides protocols for data collection.</td>
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<tr>
<td>Learners formulate CONCLUSIONS and/or EXPLANATIONS from evidence to address scientifically oriented questions.</td>
<td>Directs learner to think about how analyzed evidence leads to conclusions/explanations, but does not cite specific evidence.</td>
<td>Provides learner with specific stated (or implied) question/hypothesis to be investigated.</td>
</tr>
<tr>
<td>Learners evaluate their conclusions and/or explanations in light of ALTERNATIVE CONCLUSIONS/EXPLANATIONS, particularly those reflecting scientific understanding.</td>
<td>Prompts learner to examine other resources and make connections to conclusions and/or explanations independently (Catalyst). Provides no hyperlinks to relevant scientific knowledge intended to help learner formulate alternative conclusions and/or explanations.</td>
<td>Directs learner attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to lead learner to predetermined correct conclusion/explanation (verification).</td>
</tr>
<tr>
<td>Learners COMMUNICATE and justify their proposed conclusions and/or explanations.</td>
<td>Reminds learner of general purpose of communication and/or need for communication, but gives no specific guidance.</td>
<td>Specifies content to be included and/or layout to be used.</td>
</tr>
<tr>
<td></td>
<td>Talks about how to improve communication, but does not suggest content or layout.</td>
<td></td>
</tr>
</tbody>
</table>