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Implementing Web-based Scientific Inquiry in Preservice Science Methods Courses

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Abstract

This paper describes how the Web-based Inquiry for Learning Science (WBI) instrument was used with preservice elementary and secondary science teachers in science methods courses to enhance their understanding of Web-based scientific inquiry. The WBI instrument is designed to help teachers identify Web-based inquiry activities for learning science and classify those activities along a continuum from learner directed to materials directed for each of the five essential features of inquiry, as described in Inquiry and the National Science Education Standards (National Research Council, 2000). Implementations of WBI analysis activities in preservice science methods courses are discussed.

According to the *National Science Education Standards* (National Research Council [NRC], 1996), inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work. Inquiry also refers to activities through which students develop knowledge and understanding of scientific ideas and how scientists study the natural world. Inquiry-based teaching and learning activities can vary in the amount of structure and guidance they provide a learner, or the extent to which students initiate and design an investigation (NRC, 2000). Materials-directed inquiries are often highly structured and provide step-by-step instructions that present learners with a scientifically oriented question and then ask them to manipulate materials, make observations and measurements, record results, and formulate conclusions. In contrast, learner-directed inquiries are more open-ended, providing learners with opportunities to formulate a question or hypothesis to be investigated, design experimental procedures, and work according to their own designs.

As the NRC (2000) noted, both types of experiences are appropriate for classroom learning: While materials-directed inquiry activities can be used to focus learning on the development of particular science concepts, learner-directed inquiries can provide students with opportunities for cognitive development and scientific reasoning. Variations in the openness of the inquiry are based, in part, upon the goals for learning outcomes and upon the material developers' perceptions of how students learn in the context of school environments.

Although recent documents addressing reform in science education emphasize the importance of providing classroom students with opportunities to engage in learner-directed inquiries, it is important to note that learners will likely require practice with guided experiences before being able to engage in more open-ended activities (see for example, American Association for the Advancement of Science, 1993, and NRC, 1996).

An important goal of recent science education reform is to bring scientific inquiry experiences into pK-16 classrooms. These documents argue for de-emphasizing didactic classroom instruction that focuses on memorizing science facts. Instead, they contend, teachers should emphasize engaging students in inquiry-based learning to assist in their understanding of science. Participation in inquiry can help learners acquire scientific thinking skills while developing a deeper understanding of science content and processes (Glasson, 1989; Metz, 1995; White & Frederiksen, 1998). In actual classrooms, inquiry calls for students to exercise a wide range of skills, including formulating questions, making observations, collecting and analyzing data, using logical and critical thinking to formulate conclusions, evaluating alternative explanations, and communicating their findings.

Inquiry in today's science classrooms may take a variety of forms. For instance, a teacher might engage students with authentic questions for local and global investigations, ask them to learn through project-based science activities, or participate in role-playing debate simulations. An authentic activity is one that is coherent and meaningful, and its purpose is to help the learner acquire the culture and practices of those active in the real-world practice of the field under study (Brown, Collins, & Duguid, 1989). The key common components here are that each activity involves students with meaningful questions about everyday experiences, emphasizes using investigation to evaluate evidence critically, and engages learners in social discourse to promote knowledge construction. Thus, such inquiry-based approaches allow students to learn scientific practices through implementing and testing those practices realistically. Learners who experience inquiry-based activities and instructional methods may, therefore, have a

better chance of developing a broad understanding of science, along with the critical reasoning and problem solving skills involved in scientific reasoning.

Given the emphasis on incorporating inquiry teaching and learning in science specified in current science education reform initiatives, I have developed a method to help preservice science teachers in both my elementary and secondary science methods courses gain a theoretical and practical understanding of how to take advantage of Web-enhanced instructional materials to promote inquiry learning with classroom students. The activity described in this paper illustrates how I help preservice teachers understand the variations of inquiry and how they align with the learning goals of classroom students by analyzing what the Web has to offer and determining how to use such materials in the classroom to enhance the use of classroom scientific inquiry. This entails exploring when implementing materials-directed inquiries is appropriate, when using more learner-directed approaches is better, and how best to take advantage of the Web to support inquiry learning in differing classroom contexts.

The Science Methods Courses

I teach two science methods courses in Lehigh University's Technology-Based Teacher Education (TBTE) graduate program. One course is an elementary science methods course for students seeking teacher certification for grades K-6. The other course is a secondary science methods course for students seeking certification in general science, biology, chemistry, physics, and earth and space science. The science methods course is usually one of the first courses students take in the TBTE program, and it is often taken concurrently with a the course, Tools for K-12 Teaching and Learning. In this course students develop artifacts integrating Web design, video production, and concept mapping into K-12 instructional activities.

Inquiry-based pedagogical practices infused with a technology-integrated approach are emphasized in both science methods courses. Technologies such as Web-based resources, real-time data collection with probeware, simulations, and Geographic Information Systems are used to model the implementation of curricular activities with inquiry-based pedagogical strategies. The first five class sessions primarily focus on implementing instructional models in curricular contexts, understanding the inquiry continuum, developing lesson plans, and investigating the Lehigh River watershed (<http://www.leo.lehigh.edu/envirosci/watershed/>). The Lehigh River watershed is investigated using Web-based GIS, a virtual photojournal, a water quality data collection field trip to the Monocacy Creek, data analysis with a PHP server database of tributary data, real-time and archived USGS flow rates, and curricular activities designed to assist learners in understanding environmental issues in the watershed (<http://www.leo.lehigh.edu/envirosci/enviroissue/>).

The main objective of the sixth class session is to help students understand the instructional design of Web-based inquiry materials. The entire class session is spent analyzing and discussing Web-based inquiry (WBI) activities using the *WBI Instrument and Manual* (Bodzin & Cates, 2002). The WBI instrument is a tool designed to identify Web-based inquiry activities for learning science and to classify activities along a continuum from learner-directed to materials-directed for each of the five essential features of inquiry, as described in *Inquiry and the National Science Education Standards* (NRC, 2000).

Although individual teachers may hold different opinions about the desirability of the positions along this continuum, the instrument is neutral. That is, it classifies where the activity falls, rather than making a value judgment about the desirability of that position

on the continuum (Bodzin, Cates, & Vollmer, 2001). A copy of the WBI instrument manual is available online at http://www.lehigh.edu/~amb4/wbi/wbi-v1_0.pdf.

To confirm that the instrument helped preservice teachers produce predictable and consistent analyses of scientific Web sites, we calculated internal reliability for the instrument's use by 14 students in one of my elementary science methods courses. The instrument proved highly reliable, producing a Cronbach alpha of +.811 ($p < .001$) across 25 categorical assignments for the 14 student raters involved.

Many instructional materials and activities that are used in my courses are available online at <http://www.lehigh.edu/~amb4>. My course syllabi are available online at <http://www.lehigh.edu/~amb4/courses>.

Description of the WBI Instrument

A copy of the WBI instrument is provided in [Appendix A](#). It is a matrix made up of five rows and four columns. The five rows describe the five possible essential features of inquiry. The four columns describe the degree to which the WBI is either learner directed (left two columns) or materials directed (right two columns). A column descriptor is located at the top of each of the four columns. These statements summarize the guiding philosophy for all cells in that column. Each cell in the matrix contains a sentence or two that describes what WBIs falling into that cell would exhibit as properties. To qualify as a science WBI, the activity must meet six criteria, which are listed in Table 1.

Twenty-nine classification rules (see [Appendix B](#)) are provided to guide users in making placement decisions on the instrument. The manual provides a detailed description of each rule, accompanied by examples. Users are instructed to work methodically row by row, classifying the WBI into the cell that best matches how it addresses that essential feature of inquiry. Users are to write the exact words from the Web site that most closely match the descriptive sentence or sentences for the properties of that cell. If exact words cannot be provided, then a brief written description describing a rationale for placing the WBI into a particular cell of the row should be provided.

Implementation in Preservice Methods Courses

In my science methods courses, students read the WBI manual prior to a class session. During the next class session, the WBI activity is conducted. Learners are provided with a list of Web site addresses that contain both (a) large Web sites with multiple science activities consisting of WBIs and non-WBIs and (b) Web addresses to specific WBIs. (Links to selected sites that have been used in my courses are available online at <http://www.lehigh.edu/~amb4/wbi/>).

Students work in pairs to complete the instrument for five WBIs using a unanimous consensus analysis, with all students agreeing on all decisions and classifications. This consensus forces them to discuss what they see, what they know, and how scientific inquiry is facilitated by the Web site. After completing an instrument for a specific WBI, students discuss each placement with me before moving on to the next WBI.

Table 1
WBI Qualification Criteria

Criteria	Title	Descriptor
1	Three Inquiry Essentials	<p>A WBI must contain at least the first three essential features of classroom inquiry described in Inquiry and the National Science Education Standards:</p> <ol style="list-style-type: none"> 1. Learners are engaged by scientific ally oriented questions that are stated explicitly or implied as a task. 2. Learners give priority to evidence, which allows them to draw conclusions and/or develop and evaluate explanations that address scientifically oriented questions. 3. Learners draw conclusions and/or formulate explanations from evidence to address scientifically oriented questions.
2	Learner Centered	The WBI should be phrased in such a way that learners would perceive it as directed at them. The majority of the wording used in the WBI should be directed at the learner (“you”), not at the teacher (“your students”).
3	Student Learning Science Concept or Content	The WBI must support student learning of a science concept or science content. Science WBIs must fall into a recognized science discipline (biology, chemistry, physics, environmental sciences, astronomy, oceanography, and the like).
4	Web-Based	The WBI must be Web-based. A WBI is more than reformatted text from printed sheets placed on the Web, describing how an inquiry activity may be completed. Instead, it should be enhanced or customized to take advantage of the features of the Web to deliver instruction.
5	Scientific Evidence	Evidence used in a WBI should be of the same type an actual scientist would use.
6	Conclusions or Explanations Involve Reasoning	Conclusions and/or explanations in WBIs should be more than simple data analysis and reporting. They must involve reasoning.

After this one-day, in-class activity, the preservice teachers develop a Web-based science activity to engage classroom learners in a science-specific curricular topic of interest, thus

applying what they have learned immediately to design of their own instruction. As part of the assignment, they develop an assessment handout for the activity. The resultant Web site is tested out with a target learner, and the preservice teacher prepares a brief report on its effectiveness in bringing about science learning. This step, in turn, helps to lock in the knowledge on how WBIs promote learning with intended learners. (A description of my Web-based Science Activity assignment is available as part of my science methods courses syllabi available online at <http://www.lehigh.edu/~amb4/courses/>).

The WBIs created by my preservice students are of high quality and are well-designed to promote inquiry with K-12 students. Evidence of this is provided by the fact that many of my students' exemplary WBIs (see Figure 1, for example) are indexed in the [U.S. Department of Education's Gateway to Educational Materials](#) and are listed in [Appendix C](#). (**Editor's note:** See the Online Resources section at the end of this paper for URLs of Web sites mentioned in this paper.)

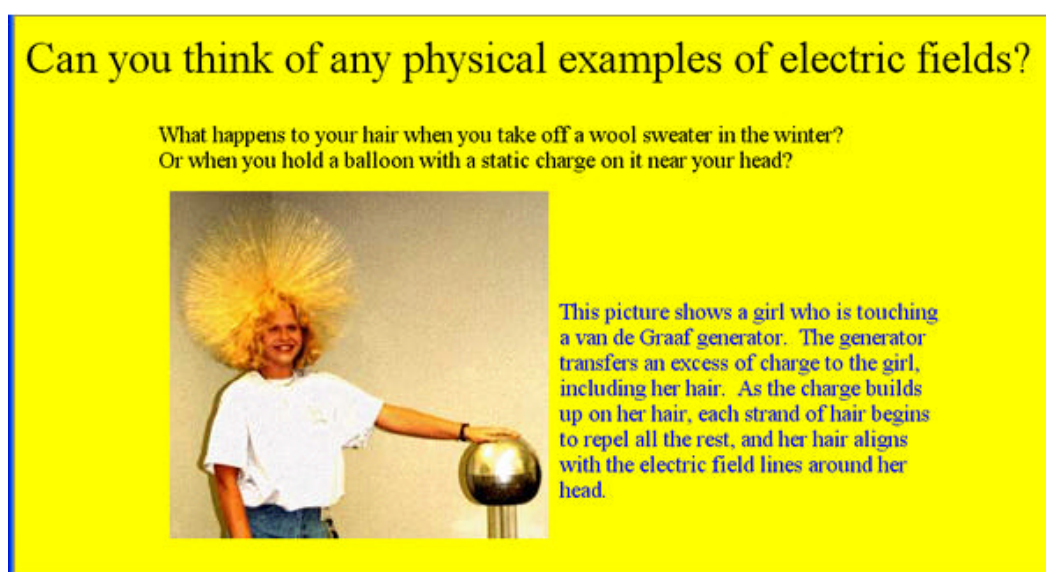


Figure 1. Screen capture from a WBI developed by preservice teacher Aran W. Glancy © 2002. (<http://www.lehigh.edu/~amb4/wbi/aglancy/efield1.htm>) .

I selected specific Web-based activities for WBI analysis to help preservice teachers understand the variations of inquiry and how they align with the learning goals of classroom students. Exemplary WBIs are selected, as well as others that are not as commendable to help preservice teachers see how they differ. The WBIs selected also provide students with opportunities to see how both learner-directed and materials-directed inquiries are appropriate forms of inquiry learning. Specific WBIs are select to promote understanding of the variations of each essential feature of inquiry. The selected WBIs also illustrate advantages a Web-enhanced activity may have over traditional text-based classroom instruction. In addition, I include at least a few WBIs that engage learners in authentic learning tasks that mirror the work of scientists. Examples of how some sites are used are discussed below.

[WhaleNet](#), [Athena - Earth and Space Science for K-12](#), and [Carolina Coastal Science](#) are examples of Web sites containing multiple activities. Large Web sites with multiple activities allow students to review many different types of science activities to see if they met the six WBI qualification criteria. Students come to realize that locating WBIs in a

large Web site with multiple activities is a time-consuming process. In addition, these sites provide students with opportunities to view activities that fail to qualify as WBIs in their present form. Certain activities are examined later to identify ways to augment them and make them qualify as WBIs.

Other WBIs are selected to provide students a chance to analyze collaborative experiments. These include the WBIs on the CIESE (Center for Improved Engineering and Science Education) [Online Classroom Projects](#) and [Walking with Woodlice](#) sites. Collaborative experiments represent a subsample of WBIs that illustrate two ways to utilize evidence. First, the learner is provided with a protocol to collect certain data. These data are contributed to a collective database. Next, the WBI provides learners with cumulative data from remote geographical placements and instructs the learner in how to analyze the cumulative data. In each of these collaborative experiments, there is first a learner-directed component that is then followed by a materials-directed component. Such experiments take advantage of distributed information sources to promote inquiry. Discussion of these sites in my courses concentrates on the role of collaboration to enhance knowledge of all participants.

The selected CIESE WBIs include two collaborative projects and a real-time data project. Two WBIs—[Human Genetics: A Worldwide Search for the Dominant Trait - Do You Have It?](#) and [The Stowaway Adventure](#)—are highly structured, materials-directed WBIs that provided learners with step-by-step detailed instructions and procedures to follow. Another CIESE WBI, [Sun Times: Global Sun Temperature Project](#), exhibits a more learner-directed philosophy, especially in the use of evidence. In each CIESE WBI, drawing conclusions and formulating explanations is little more than verification because learners' attention is directed (often through questions) to specific pieces of evidence leading them to a predetermined conclusion/explanation. Therefore, these activities merely measure the experimental and methodological proficiency of learners. In class, I contrast these activities with the *Walking With Woodlice* WBI, in which the conclusion/explanation cannot be predicted in advance and learners must analyze evidence to reach their own conclusions/explanations, thus helping preservice teachers understand how each approach develops different skills and processes.

The Carolina Coastal Science Web site contains a science-technology-society (STS) issues-based approach simulation, in which students are presented with a real-world controversial issue: Should a hard structure be built to stabilize a migrating inlet? Students investigate the issue from differing perspectives using online primary sources. After students complete their investigation, they participate in a public forum to debate the best course of action on the issue. This role-playing simulation provides a motivating context that engages learners in solving an authentic problem. Classroom debates on STS issues offer students a forum for communicating evidence and conclusions to an audience (NRC's fifth essential feature of scientific inquiry). In class, we discuss how an authentic scientific problem with no known solution frames a motivating context for learners to engage in a scientifically oriented question. Once again, this is contrasted with classroom use of a verification-type activity, in which a conclusion or explanation is already well established in the scientific community.

WBIs from the [WISE \(Web-based Inquiry Science Environment\)](#) Web site are included in the secondary methods course. The WISE Web site contains a variety of secondary science projects that use a Scaffolded Knowledge Integration Framework design (Linn & Hsi, 2000). In this framework, students are encouraged to question, criticize, analyze, reflect upon, and interpret the explanations they encounter. Many of the activities model effective use of instructional technologies including simulations, visualizations, and Internet materials to promote inquiry learning.

Inclusion of the WISE WBIs facilitates discussion of how scaffolding affects the placement of a WBI on the continuum from learner-directed to materials-directed. WISE WBIs provide scaffolding (support to help one know how to complete an activity) in the form of learner-selectable hints. In the WBIs, an avatar (a helpful character) is used to provide hints and suggestions to reduce the complexity of a task. Often the avatar's presence changes the activity to a more materials-directed activity. In class, I discuss how avatars may support the learning needs of students who require additional guidance and structure to complete activities. Students with learning disabilities or learners without much prior experience using inquiry methodologies are likely to require more task structuring to complete an inquiry. In addition, the use of the site's customization features are discussed in terms of design challenges teachers face as they tailor existing curricular materials to the educational needs of their students.

To assist learners in thinking about design process of a WBI for their assignment to create a Web-based science activity, I discuss how partial WBIs may be enhanced to become full inquiries. Many partial WBIs contain only the first three essential features of inquiry. In many cases, adding a sentence to an existing WBI that states, "*Can you think of other reasons that might cause this?*" would prompt learners to think about alternative explanations. In addition, various forms of classroom presentations, such as poster sessions and oral presentations can be discussed as ways learners can communicate and justify their proposed conclusions and/or explanations.

I also talk about the way a teacher's philosophical beliefs about inquiry affect how learner-centered or teacher-centered his or her class activities may be. I discuss how WBIs may be modified to be more or less learner centered. Often the wording of an activity may be modified in a few sentences to transform the activity from one design intent to another.

Finally, I discuss how sites that do not currently qualify as WBIs may be modified or utilized to become WBIs. The Web offers many good resources and activities, including authentic data sets, simulations, scientific visualizations, virtual reality, animations, and video clips that can be used to assist students in learning science. I discuss with my students how they can take advantage of these resources to create their own Web-based inquiries using the framework offered by the WBI instrument.

Summary

The critical analysis of WBIs using the instrument in my preservice science methods courses promotes student awareness of important characteristics of WBIs typifying the intent of recent science reform initiatives. My instructional methods enable preservice teachers to analyze what the Web has to offer and determine how to use such materials in the classroom to enhance classroom scientific inquiry. Analyzing WBIs provides many opportunities to discuss instructional, curricular, and technological supports that may aid students in the inquiry process.

These discussions address the nature of Web-based collaborative inquiry, the role of using scientific visualizations to promote learning, provisions in the instructional design of materials to motivate learners, the role of scaffolding in reducing the complexity of a task, and design features for promoting autonomous learning. Analyzing the instructional design of WBIs provides opportunities to discuss curricular customizations to meet the needs of diverse types of learners and provides a context for considering practical constraints of the classroom learning environment, such as time restrictions imposed by fixed schedules.

I believe my instructional methods have had an impact on my student understanding of how to use Web-based materials appropriately to promote inquiry-based learning. During intern teaching field placements, some of my preservice teachers have facilitated a Web-based inquiry process by presenting their students with a driving question to investigate a particular phenomenon. They provide their students with available Web-based data to analyze. Data sources have included elephant seal migration maps to investigate where elephant seals spend their time, drifter buoy data to investigate ocean currents, satellite images to investigate changes in land areas, and monarch butterfly migration data to investigate the monarch life cycle. In each of these cases, activity handouts were developed to assist learners in examining evidence to formulate conclusions.

Often, classroom learners were prompted by the preservice teacher to think about alternative explanations and communication has occurred in various formats including mini-poster sessions and brief classroom presentations. These examples illustrate that incorporating WBI methodologies in my science methods courses may have assisted preservice teachers with understanding a design process for using appropriate Web-based resources to promote inquiry-based learning with classroom learners.

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Online Resources

Athena - Earth and Space Science for K-12 - <http://vathena.arc.nasa.gov/>

Carolina Coastal Science - <http://www.ncsu.edu/coast/>

CIESE Online Classroom Projects - <http://k12science.org/currichome.html>

Gateway to Educational Materials - <http://www.thegateway.org>

Human Genetics: A worldwide search for the dominant trait - Do you have it? - <http://k12science.org/curriculum/genproj/>

The Stowaway Adventure - <http://k12science.org/curriculum/shipproj/>

Sun Times: Global Sun Temperature Project - <http://www.k12science.org/curriculum/tempproj3/en/>

Walking with Woodlice - <http://www.nhm.ac.uk/interactive/woodlice/>

WhaleNet - <http://whale.wheelock.edu>

WISE - The Web-based Inquiry Science Environment - <http://wise.berkeley.edu/>

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**Appendix A
WBI Instrument**

Web site Name:

Web site URL:

Specific Activity Name:

Specific Activity (Root) URL:

Essential Feature of Inquiry	Learner Directed		Materials Directed	
	L2: Learner-driven with much initiative and independence.	L1: Decisions to make, but support & scaffolding, particularly with process.	M1: Much selecting from provided materials. Limited choices.	M2: Materials-driven. Few choices and much direction given.
Learners are engaged by scientifically oriented QUESTIONS .	Prompts learner to formulate own question or hypothesis to be tested.	Suggests topic areas or provides samples to help learner formulate own question or hypothesis.	Offers learner lists of questions or hypotheses from which to select.	Provides learner with specific stated (or implied) question/hypothesis to be investigated.
Learners give priority to EVIDENCE , which allows them to draw conclusions and/or develop and evaluate explanations that address scientifically oriented questions.	Learner determines what constitutes evidence and develops procedures and protocols for gathering and analyzing relevant data (as appropriate).	Directs learner to collect certain data, or only provides portion of needed data. Often provides protocols for data collection.	Provides data and asks learner to analyze.	Provides data and gives specific direction on how data to be analyzed.
Learners formulate CONCLUSIONS and/or EXPLANATIONS from evidence to address scientifically oriented questions.	Prompts learner to analyze evidence (often in the form of data) and formulate own conclusions/explanations.	Prompts learner to think about how analyzed evidence leads to conclusions/explanations, but does not cite specific evidence.	Directs learner attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to draw conclusions and/or formulate explanations.	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).

<p>Learners evaluate their conclusions and/or explanations in light of ALTERNATIVE CONCLUSIONS/ EXPLANATIONS, particularly those reflecting scientific understanding.</p>	<p>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.</p>	<p>Provides hypertext links to relevant scientific knowledge that may help identify alternative conclusions and/or explanations. May or may not direct learner to examine these links, however.</p>	<p>Does not provide hypertext links to relevant scientific knowledge to help learner formulate alternative conclusions and/or explanations. Instead, (1) identifies related scientific knowledge that could lead to such alternatives or (2) suggests or implies possible connections to such alternatives.</p>	<p>Explicitly states specific connections to alternative conclusions and/or explanations, but does not provide hypertext links to support formulating such alternatives.</p>
<p>Learners COMMUNICATE and justify their proposed conclusions and/or explanations.</p>	<p>Reminds learner of general purpose of communication and/or need for communication, but gives no specific guidance.</p>	<p>Talks about how to improve communication, but does not suggest content or layout.</p>	<p>Suggests possible content to include and/or layout that might be used.</p>	<p>Specifies content to be included and/or layout to be used.</p>

Appendix B
WBI Classification Rules

Row Topic	#	Rule
General Classification	1	When in doubt, use philosophy column description located at top of each column to make decisions. These descriptions guide your cell selections.
	2	When several activities are presented in clear sequence leading to final activity that is dependent upon completing those earlier activities, treat full set of activities as one WBI.
	3	When WBI consists of multiple activities and these activities fall into different cells, note each activity's URL in appropriate cell when completing instrument.
Question	4	Place in L2 if learners are prompted to formulate their own explanation or hypothesis.
	5	Place in L1 if suggests topic areas or provides samples that help learners formulate own explanation or hypothesis.
	6	If offers lists of questions or hypotheses from which to select, goes in M1 cell.
	7	When provides learner with specific stated (or implied) question/hypothesis to investigate, goes in M2 cell.
Evidence	8	If the learner collects data outside Web site, then WBI placed on L side of instrument. If WBI provides learner with data, WBI is placed on the M side of the instrument.
	9	When learner determines what constitutes evidence and develops procedures and protocols for gathering relevant data (as appropriate), classified as L2.
	10	When WBI directs learner to collect certain data or only provides a portion of needed data, classified as L1.
	11	WBIs that provide data and ask learners to analyze them classified as M1.
	12	If provides data and gives specific direction on how data are to be analyzed, classified as M2.
Conclusions and	13	Amount of direction WBI provides learner is main

Explanations		determinant of whether placed on L or M side in this row.
	14	Classified as L2 if prompts learner to analyze data and formulate own conclusions/explanations.
	15	Classified as L1 if prompts learner to think about how evidence leads to conclusions/explanations, but does not cite specific evidence.
	16	<p>What distinguishes M1 and M2 WBIs from one another is whether are verification-type activities or not:</p> <p>If directs learner attention (often through questions) to specific pieces of evidence to draw own conclusions or formulate explanations, classified as M1.</p> <p>If directs learner attention (often through questions) to specific pieces of evidence to lead learners to predetermined correct conclusion/explanation, classified as M2.</p>
Alternative Conclusions and Explanations	17	WBIs that provide a “catalyst” to prompt learners to examine other resources and form connections to alternative conclusions/explanations independently (without guidance) are classified as L2. Catalysts designed to encourage learner to think about possibilities, but L2 alternative conclusions/explanations WBIs provide no hypertext links to sources of information for alternative conclusions/explanations.
	18	If WBI contains hypertext links to relevant scientific knowledge useful in formulating alternative conclusions/explanations, classified as L1. WBI may or may not refer to the provided links.
	19	When identifies relevant scientific knowledge that could be useful or suggests/implies possible connections, but does not provide hypertext links , classified as M1.
	20	If explicitly states specific connections, but does not provide hypertext links , classified as M2.
Communications	21	Intent of communication is to share explanations and conclusions to permit fellow scientists to "ask questions, examine evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations for

	the same observations" (NRC, 2000, p. 27).
22	Simply sharing data on Web-based form does not constitute communication. Communication is of conclusion/explanation, not data.
23	Communication requires learner justify conclusions and/or explanations and that information be shared with "audience," not simply submitting that information to teacher for assessment. Audience might consist of fellow students, other users of Web site, Web site's developer(s), or scientist.
24	Using right-sounding words not enough; WBI must actually solicit communication.
25	Communication is determined by what WBI solicits , not what learners submit.
26	If instructions in WBI about communication do not address content and/or layout, classified as L1 or L2. If instructions focus on content and/or layout, classified as M1 or M2.
27	WBIs that are very open-ended in terms of learners making decisions about techniques to use in presenting results fall into L2 cell. These WBIs remind learner of general purpose of communication and need for communication, but do not provide specific guidance.
28	When WBIs talk about how to improve communication , but do not suggest specific content or layout approaches to be used, classified as L1.
29	Distinguishing between M1 and M2 WBIs in this row based on how directive about learner's presentation: WBIs that suggest possible content and/or layout for presentation classified as M1. WBIs with clear specifications for content and/or layout classified as M2.

Appendix C
Preservice Teachers' WBIs Indexed in the Gateway to Educational Materials

Shark Report

http://www.lehigh.edu/~amb4/wbi/clemon/home_1.htm

The Design Challenge

<http://www.lehigh.edu/~amb4/wbi/kwardlow/sciwebquest.htm>

What's Wrong With Dave's Door?

<http://www.lehigh.edu/~amb4/wbi/sanderson/index.html>

Plant Nutrition

<http://www.lehigh.edu/~amb4/wbi/bcurran/index.htm>

Understanding Electric Fields and Field Lines

<http://www.lehigh.edu/~amb4/wbi/aglancy/efield1.htm>

Free-fall Acceleration

<http://www.lehigh.edu/~amb4/wbi/jphile/index.htm>

To See or Not to See....Inheritance of Color Blindness

WBIs for Elementary Learners

<http://www.lehigh.edu/~amb4/wbi/mcastronova/index.htm>

How Do You Design an Awesome Roller Coaster?

<http://www.lehigh.edu/~amb4/wbi/aporawski/rollercoasters.html>

Bald Eagle Migration

<http://www.lehigh.edu/~amb4/wbi/apriester/index.htm>

Nutrition and Exercise

<http://www.lehigh.edu/~amb4/wbi/rrohn/index.html>

How Does a Shark Survive in Its Environment?

<http://www.lehigh.edu/~amb4/wbi/cmichalerya/problem.htm>

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