ENHANCING PRESERVICE TEACHERS' UNDERSTANDING OF WEB-BASED SCIENTIFIC INQUIRY

Alec M. Bodzin and Ward Mitchell Cates, Lehigh University

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). Recommendations for using the WBI instrument in preservice science methods courses are discussed.

According to the *National Science Education Standards* (National Research Council, 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 (National Research Council, 2000). Material-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 National Research Council (2000) noted, both types of experiences are appropriate for classroom learning: While material-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

Paper presented at the Association for the Education of Teachers of Science Annual Meeting, St. Louis, MO. January 29 - February 2, 2003.

developers' perceptions of how students learn in the context of school environments. While recent science education reform documents (for example, American Association for the Advancement of Science, 1993 and National Research Council, 1996) 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.

An important goal of recent science education reform documents is to bring scientific inquiry experiences into 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. 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 allows 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.

Learning Science in a Web-Enhanced Classroom

Learning science in today's classroom need not be restricted to text-based curricular resources solely under classroom teacher guidance and the World Wide Web offers teachers and students access to more resources. The literature describes many Web-based K-12 science curricular resources for the classrooms (see Berenfeld, 1994; Cohen, 1997; Feldman, Konlold, & Coulter., 2000; and Gordin, Gomez, Pea, & Fishman, 1996 as just a few examples).

Web-based materials may encourage students to learn independently. Materials can provide prompts for students to examine evidence (data), compare different viewpoints on issues, analyze and synthesize existing data sets to formulate conclusions, and communicate findings to others across large geographical distances. The Web also offers rich instructional resources to enhance student science learning unavailable in many traditional classrooms. These resources include:

- Scientific visualizations - Rich representations that present scientific relationships as visual patterns and provide data-intensive descriptions of phenomena.
- Simulations - Interactivities used to simulate and explore complex phenomena.
- Virtual Reality - Technology that enables a user to interact with and explore a spatial environment through a computer.
- Animations, video clips, or still images – Multimedia sources that illustrate science content, concepts, or processes.

- Distributed information sources - Real-time data, online databases, peer groups, and mentors/experts in many locations.

In addition to a wealth of rich sources usually not available in many classrooms, the Web also offers some advantages over traditional text-based science instruction. These include:

1. *Information is current.* Many different kinds of science information are online and new scientific discoveries occur each day. Thus, the Web provides learners access to the latest data and interpretations.
2. *Data may be richer.* Web-based data are often more diverse than data presented in curricular text materials. For instance, data may come from scientists' labs or from active scientific data-collection tools in the field, like drifter buoys in the ocean or seismic sensors placed in the earth. Data can even take the form of a digital image or a 360-degree panorama that can be explored interactively. Students may explore remote geographic locations they would otherwise not be able to view.
3. *Access to data is greater.* Learners can access large amounts of current and archived scientific data from both near and remote geographical locations. Learners can use the Web to question scientific experts.
4. *Collaboration may be more widely distributed in time and space.* The Web enables authentic student collaboration with scientists using Web-based discussions and group tasks. Classes in different regions may work together to collect and analyze data, to interpret and share their findings, and to discuss both processes and interpretations.
5. *There can be a real audience.* The Web facilitates sharing inquiries with an authentic audience with which to communicate.

6. *Teachers have access to richer repertoires of tested activities.* Many teachers have posted lesson plans, materials, and even self-contained activities to the Web. A teacher can access these materials and determine which are best suited to his or her students.

Web-based technologies are receiving increased attention from the science education community because of their potential to provide supports for new types of inquiry learning. Such supports include tools for synthesizing primary sources (Linn, Bell, & Hsi, 1998), sharing data and ideas across distances (Feldman et al., 2000), visualizing and analyzing large amounts of data (Edelson, Gordin, & Pea, 1999), and providing scaffolds to promote knowledge integration (Linn & Hsi, 2000). When properly designed, such supports may be used to promote autonomous classroom learning, thus decreasing the amount of teacher guidance needed in a classroom.

Implications for Science Methods Courses

Given the emphasis on incorporating inquiry teaching and learning in science specified in current science education reform initiatives, as well as the opportunities described above, preservice science teachers will want to gain a theoretical and practical understanding about how to take advantage of Web-enhanced instructional materials and approaches to promote inquiry learning with classroom students. One way to accomplish this might be to help preservice teachers understand the variations of inquiry and how they align with the learning goals of classroom students. Done properly, activities that involve analyzing what the Web has to offer and determining how to use such materials in the classroom might help preservice teachers enhance their use of classroom scientific inquiry. This would entail exploring when it is appropriate to implement materials-directed inquiries, when it is better to use more learner-directed approaches, and how best to take advantage of the Web to support inquiry learning in differing classroom contexts. Learning to make informed and wise decisions likely requires that preservice teachers have critical experience with a wide range of scientific Web sites while thinking hard about what those sites offer in terms of classroom needs, instructional approaches, and the demands of scientific inquiry.

Classifying Web-based Inquiry

There have been attempts to classify Web-based learning in general. These classification systems have focused on different models of instruction (Collins & Berge, 1995; Harasim, 1993), social aspects of Web-based interactions (Riel, 1993), cognitive features (Teles, 1993), and general factors for evaluating Web-based instruction (Khan & Vega, 1997; Nichols, 1997; Ravitz, 1997). In an attempt to improve the design of science-related educational Websites, two teams of researchers formulated classification schemes for analyzing the Websites properties (Nachmias, Mioduser, Oren, & Lahav, 1999; Sarapuu & Adojaan, 1998).

Despite such Website analyses and proposed general classification schemes, it remained unclear to what extent the World Wide Web provides scientific inquiries for students. Further, it was unclear what form such inquiries take or how one should categorize Websites offering scientific inquiries. We began the process of clarifying these key issues. In a recent study (Bodzin Cates, & Vollmer, 2001), we identified 34 Web-based inquiry activities (WBIs) from the Eisenhower National Clearinghouse *Digital Dozen* awards list (http://www.enc.org). A multi-pass unanimous consensus analysis of characteristics and classifications of this sample identified how WBI activities reflected the essential features of scientific inquiry as described in *Inquiry and the National Science Education Standards (*National Research Council, 2000). From the results of this study, we created a categorization system for analyzing science Websites across the five essential features of inquiry.

To confirm that the instrument covered the right content and did so in appropriate ways, both the instrument and its manual underwent a national external validation with three science educators with expertise in both inquiry-based science learning and Web-based activity development. As a result of their analyses and suggestions, both the instrument and its manual were revised to enhance both their reliability and ease of use.

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 fourteen students in one of the courses discussed later in this article. The instrument proved highly reliable, producing a Cronbach Alpha of +.811 (p<.001) across 25 categorical assignments for the 14 separate raters involved.

Description of the WBI Instrument

The WBI instrument is a tool designed to identify Web-based inquiry activities for learning science and 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 (*National Research Council, 2000). While 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.

A copy of the 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. These are listed in Table 1.

INSERT TABLE 1 ABOUT HERE

Twenty-nine classification rules (see Table 2) are provided to guide users in making placement decisions on the instrument. The manual provides a detailed description of each rule accompanied with 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 Website 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 why one feels the WBI falls into that particular cell of the row should be provided.

INSERT TABLE 2 ABOUT HERE

Implementation in Preservice Methods Courses

In summer 2001, the *Web-Based Inquiry for Learning Science* (WBI) instrument and manual (beta version 1.0 -- http://www.lehigh.edu/~amb4/wbi/beta/beta1.pdf) were used in an elementary science methods course. As a result of this use, the instrument and manual were revised, producing a second beta version (http://www.lehigh.edu/~amb4/wbi/beta/beta2.pdf). The second beta version was used in a secondary science methods course in Fall 2001. Subsequent revisions were made to the instrument and manual, resulting in a final version (http://www.lehigh.edu/~amb4/wbi/wbi-v1_0.pdf). This final version was then used in Spring 2002 in an elementary science methods course. In all cases, when the instrument was used in preservice science methods courses completing assigned analyses was a course requirement.

In the first two courses using the WBI instrument (Summer and Fall 2001), students were instructed to read the manual prior to a class session. During the class session, learners worked in pairs to complete the instrument for three WBIs using a unanimous consensus analysis. In all cases, the students had to agree on all decisions and classifications. After completing an instrument, students had to discuss each placement with the course instructor before moving on to the next WBI. In the third course use (Spring 2002), students were assigned to read the instrument manual and complete the WBI instrument independently for five WBIs outside of class over a one-week period. A class discussion about the placements of the WBIs occurred during the next class session.

Summer 2001: Elementary Science Preservice Teachers

Students in this science methods course were provided with a list of Website addresses that contained both (1) large Websites with multiple science activities consisting of WBIs and non-WBIs, and (2) Web addresses to specific WBIs. Table 3 lists the Websites that were selected for use in the first semester. *WhaleNet*, *Athena - Earth and Space Science for K-12* and *Carolina Coastal Science* were Websites that contain multiple activities. Providing large Websites with multiple activities allowed students the opportunity to review many different types of science activities to see if they met the six WBI qualification criteria. Students learned that locating WBIs in a large Website with multiple activities is a time-consuming process. In addition, these sites provided students with opportunities to view activities that failed to qualify as WBIs in their present form. Such sites could then be examined later to identify ways to augment them and make them qualify as WBIs.

INSERT TABLE 3 ABOUT HERE

Two WBIs, *Down the Drain* and *Walking with Woodlice* were selected to provide students the opportunity to analyze collaborative experiments. Collaborative experiments represent a subsample of WBIs that illustrate a twofold way to deal with 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. These collaborative experiments take advantage of distributed information sources to promote inquiry. Discussion of these sites in a science methods class concentrated on the role of collaboration to enhance knowledge of all participants.

The *Biological Timing Online Science Experiment* Website was selected to illustrate that a Website might imply that it was providing authentic communication to learners, but in actuality may not deliver on that promise. This site stated on the opening page that learners will "share conclusions with other scientists from all over the world." However, this did not appear to be the case. The site implied communication by using terms such as “communicate,” “e-mail,” and “talk to” throughout. Yet students did not communicate conclusions or explanations on the Website and e-mail appeared to be used solely to ask scientists questions about the data themselves. This Website also provides learners access to scientific visualizations called actograms. The actograms provide learners with graphical display of large amounts of data about hamster activity that learners must analyze to formulate their conclusions. This helped them to see how the Web might offer diverse data representations they and their students might wish to use.

The *Carolina Coastal Science* Website 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 or debate to determine the next course of action on the issue. This role-playing simulation provides a motivating context by engaging learners in an authentic problem. Classroom debates on the STS issues offer students a forum to communicate evidence and conclusions to an audience. Discussion of the use of this Website in a science methods course focused on how an authentic scientific problem with no known solution frames a motivating context for learners to engage in a scientifically oriented question. This was contrasted with classroom use of a verification-type activity where a conclusion or explanation is already well established in the scientific community.

The *WhaleNet* Website provides WBIs that use authentic marine mammal data sets for learners to study migration patterns. Learners may access a variety of Web-based tools including map generators, real-time drifter buoy data, and visualizations of maps containing sea surface temperatures to help analyze the migration data sets. The site also provides opportunities for students to communicate their findings to marine mammal scientists and takes advantage of using current scientific information to engage learners in real-world questions alongside scientists studying similar problems. In addition, the site provides access to the same tools that marine scientists use for their data analysis.

The *Athena - Earth and Space Science for K-12* Website provides learners with many materials-directed WBIs. In contrast to the other WBIs previously discussed, *Athena* WBIs are designed to be completed in a short period of time, usually one classroom period. A comparison between the design of the *Athena* WBIs and more learner-directed WBIs highlighted time-allocation issues involved in completing inquiries in science classrooms. In general, the more learner-directed a WBI is, the more time it will take a learner to complete. Allocating sufficient curricular time to complete a more learner-directed inquiry is a critical issue for teachers who worry about curriculum coverage. Discussions with preservice teachers focused on trade-offs between using learner-directed WBIs to cover content more in-depth over a longer period of time versus the more efficient, but perhaps less deep, materials-directed approaches to instruction.

Fall 2001: Secondary Science Preservice Teachers

The students in this course analyzed WBIs from the *WISE – The Web-based Inquiry Science Environment* Website (http://wise.berkeley.edu/). The WISE Website 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. The *WISE* site was selected to provide students with a variety of science content WBIs to select from that could be accessed from one location and to expose students to curricular materials supported by the National Science Foundation. The *WISE* site also contains many interdisciplinary science activities that can be used in multiple curricular content areas.

The use of the *WISE* WBIs facilitated discussion about how scaffolding hints in a WBI affects the placement of the inquiry on the continuum from learner-directed to materials-directed. In the WBIs, an avatar is used to provide hints and suggestions to reduce the complexity of a task. Often the use of the avatar changes the activity to a more materials-directed activity. In the methods course, the use of the avatar was discussed in terms of the learning needs of students who may 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. The use of additional scaffolds may promote knowledge integration for these learners. In addition, the use of the site's customization features was discussed in terms of design challenges teachers face as they tailor existing curricular materials to the educational needs of their students.

Spring 2002: Elementary Science Preservice Teachers

Table 4 lists the five WBIs that were assigned to preservice elementary science students in the third course. In contrast to consensus approaches used in the previous two courses, students were instructed to use the WBI instrument independently to analyze and classify the five WBIs. The main purpose of using this sample of sites was to demonstrate to students how the philosophy of the Website designer appears to drive how that site approaches inquiry. In addition, this sample was purposely selected to include (1) some WBIs that were full inquiries, containing each of the five essential features, and others that were partial inquiries, and (2) different types of WBIs that included collaborative experiments, real-time data projects, and activities that could be conducted in a home environment.

INSERT TABLE 4 ABOUT HERE

Three WBIs were selected from the *CIESE* (Center for Improved Engineering and Science Education) *Online Classroom Projects* (http://k12science.org/currichome.html) site. The *CIESE* site is widely recognized as outstanding by national science education organizations including the Scilinks Project of the National Science Teachers Association, the Eisenhower National Clearinghouse's Digital Dozen, and the American Association for the Advancement of Science's Science NetLinks. The selected WBIs included two collaborative projects and a real-time data project. The *Human Genetics: A worldwide search for the dominant trait - Do you have it?* and *The Stowaway Adventure* were highly structured, materials-directed WBIs that provided learners with step-by-step detailed instructions and procedures to follow. The other *CIESE* WBI, *Sun Times: Global Sun Temperature Project,* exhibited a more learner-directed philosophy, especially in the use of evidence. In each *CIESE* WBI, drawing conclusions and formulating explanations was little more than verification because learners' attention was directed (often through questions) to specific pieces of evidence that led them to a predetermined conclusion/explanation. Therefore, these activities merely measured the experimental and methodological proficiency of learners. In our science methods course, we contrasted 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.

The three collaborative experiments were also used in this course to discuss how Web-based communication may be used for sharing information. Each WBI invited learners to share their conclusions on the Web. The *Walking With Woodlice* WBI is very learner-directed with respect to how learners communicate their conclusions and offers no specific guidance on how to structure communication. In contrast, the *CIESE* WBIs contain specific questions to guide learners in communicating and justifying their explanations and include a student *discussion area* for sharing reports. In general, the WBIs that were more materials-directed with respect to communication contained richer explanations than the more learner-directed WBI. However, even providing specific guidelines for what the reports should contain did not assure effective sharing in all cases. Some previously submitted student reports did not articulate their data analysis or justify their conclusions despite clear instructions. This comparison led to a discussion on the importance of providing structure for students and the role the classroom teacher must play in ensuring effective communication.

Suggestions For Effective Use With Preservice Teachers

When using the WBI instrument in a science methods course, instructors will want to take great care in selecting Websites for student analysis. Selecting exemplary WBIs, as well as others that are not as commendable, helps preservice teaches see how they differ. The WBIs selected should also provide opportunities to see how both learner-directed and materials-directed inquiries are appropriate forms of inquiry learning. Selections should also promote understanding of the variations of each essential feature of inquiry. The WBIs used should illustrate advantages a Web-enhanced activity may have over traditional text-based classroom instruction and instructors may wish to insure that they include at least a few WBIs that engage learners in authentic learning tasks that mirror the work of scientists.

While the *Web-based Inquiry for Learning Science* instrument has proven to be valid and reliable, our experiences suggest several instructor techniques that may enhance your students' use of the instrument in shared analyses in the methods classroom.

1. Tell preservice teachers in advance that an activity may be classified in more than one cell in an *essential feature* row. This is especially true for collaborative experiments that make use

of a dual nature of evidence. In a collaborative experiment, a learner-directed data-collection component is followed by a materials-directed database data-analysis component. Students need to understand, therefore, that they would classify this activity in two cells in the *evidence* row on the instrument.

2. When preservice teachers have difficulty making a placement decision between adjacent cells on the instrument, have them reread the philosophy column descriptions located at the top of the column.

3. Discuss the *communication rules* from the manual before they begin analyzing and classifying WBIs. Often, preservice teachers perceive communication to be between the teacher and the student when in fact the intent of communication in an inquiry is to share explanations and conclusions in order to permit one's 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" (National Research Council, 2000, p. 27). Simply completing an online worksheet or stating one's conclusion in a blank or field does not qualify as communication unless there is sharing with an audience other than the teacher. An audience might consist of fellow students, other users of the Website, the Website's developer(s), or a scientist.

4. Help preservice teachers recognize that collecting data outside the Website with a hands-on protocol places the WBI on the learner-directed side of the *evidence* row. If learners are provided with data from the Website, then the WBI is placed on the materials-directed side of the *evidence* row.

5. 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 that learners can communicate and justify their proposed conclusions and/or explanations.

6. Talk about how a teacher's philosophical beliefs about inquiry affect how learner-centered or teacher-centered his or her class activities may be.
7. 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.
8. 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. Preservice teachers can use these resources to create their own Web-based inquiries using the framework offered by the WBI instrument.

Summary

As Owston (1997) contended, the World Wide Web may well change the way science education content is delivered in K-12 classrooms. By having students analyze WBIs using the instrument in preservice science methods courses, instructors can promote student awareness of important characteristics of WBIs typifying the intent of recent science reform initiatives. Analyzing WBIs provides many opportunities to discuss instructional, curricular, and technological supports that may aid students in the inquiry process. These discussions can 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 learner, 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.

In a Web-based inquiry, learning can be an active process where one may explore ideas, compare and synthesize resources, and revise ideas. Web-based conferencing and the sharing of student-created work can provide learners the opportunity to articulate their reasoning as they solve problems. WBIs may provide task structuring that requires learners to think about their own learning as they solve problems and seek out alternative explanations. Collaborative WBIs may involve social interaction and a sharing of collective knowledge in which the peer dialogue involves learners in the social construction of knowledge.

We are still in the process of researching how using the WBI instrument affects preservice science teachers' view to apply scientific inquiry in the classroom and the role of WBIs in enhancing student scientific understandings. We hypothesize, however, that such research will demonstrate that analyzing WBIs helps preservice science teachers gain a better understanding about the essential features of inquiry along a continuum from learner-directed to materials-directed. In turn, we suspect this will lead them to use WBIs more effectively with their classes and explore a wider range of inquiry activities with their students.

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Table 1. WBI Qualification Criteria

Criteria	Title	Descriptor
1	**Three Inquiry Essentials**	A WBI must contain at least the first three essential features of classroom inquiry described in *Inquiry and the National Science Education Standards*: **1.** Learners are engaged by scientifically 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.

Table 2. 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 Website, 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 Explanations	**13**	Amount of **direction** WBI provides learner is main 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	What distinguishes M1 and M2 WBIs from one another is whether are **verification-type activities** or not:
		If directs learner attention (often through questions) to specific pieces of evidence to draw own conclusions or formulate explanations, classified as M1.
		If directs learner attention (often through questions) to specific pieces of evidence to lead learners to **predetermined correct conclusion/explanation**, classified as M2.
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 Website, Website'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.

Table 3. List of elementary Websites containing WBIs provided in first semester.

Website	**Web Address**
WhaleNet	http://whale.wheelock.edu
Athena - Earth and Space Science for K-12	http://vathena.arc.nasa.gov/
Down the Drain	http://k12science.stevens-tech.edu/curriculum/drainproj/
Walking With Woodlice	http://www.nhm.ac.uk/hosted_sites/woodlice/
Carolina Coastal Science	http://www.ncsu.edu/coast/
Biological Timing Online Science Experiment	http://www.cbt.virginia.edu/Olh/

Table 4. List of elementary WBIs provided in third semester.

Website	**Web Address**
Sun Times: Global Sun Temperature Project	http://k12science.org/curriculum/tempproj/
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/
Walking With Woodlice	http://www.nhm.ac.uk/interactive/woodlice/
Find out why - Why does chocolate melt in your hand?	http://www.nsf.gov/od/lpa/events/fow/fowtfkv2n3/htm/melt.htm

Appendix A. WBI Instrument

Website Name:______________________ Website URL:______________________

Specific Activity Name:______________________ Specific Activity (Root) URL:______________________

	Learner Directed		Materials Directed	
Essential Feature of Inquiry	**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).
Learners evaluate their conclusions and/or explanations in light of **ALTERNATIVE CONCLUSIONS/ EXPLANATIONS,** particularly those reflecting scientific understanding.	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.	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.	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.	Explicitly states specific connections to alternative conclusions and/or explanations, but does not provide hypertext links to support formulating such alternatives.
Learners **COMMUNICATE** and justify their proposed conclusions and/or explanations.	Reminds learner of general purpose of communication and/or need for communication, but gives no specific guidance.	Talks about how to improve communication, but does not suggest content or layout.	Suggests possible content to include and/or layout that might be used.	Specifies content to be included and/or layout to be used.

