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Challenges and issues in designing inquiry on the Web

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Abstract

The purpose of this study is to discuss major issues in designing inquiries on the web. Instructional designers face a lot of difficulties and challenges to deal with in the course of designing inquiry experiences for learners in the online environment, a complex and ill-structured learning environment. Facilitating inquiry or using an inquiry-based learning approach on the web has both advantages and disadvantages. Instructional designers need to acknowledge the design issues arising in each and every phase of the design process. Utilising appropriate design strategies, instructional designers can provide positive learning experiences for their online learners. For this purpose, three representative cases in the context of teacher professional development were examined and six major issues were identified as follows: (1) seeking a balance between a system-generated guide and human facilitator, (2) visual representation of the inquiry process, (3) motivating learners with the right question, (4) engaging learners in various learning activities, (5) guiding the inquiry process with various scaffolds, and (6) maximising learning by coordinating resources, tools and the community of inquiry. This study explains each issue in great detail and provides possible guides for instructional designers to handle the issue.

Introduction

For a long time, educators have been committed to finding a way to make learning more meaningful, more transferable to various situations out of a specific context, and more conducive to self-directed, life-long learning. Inquiry-based learning (IBL) is a recent manifestation of this long-term desire (Benson & Bruce, 1998). Since the last century,

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IBL has been addressed by many researchers such as Dewey, Massialas, Fenton, Griffin, Metcalf, Bruner, Suchman and Beyer, to name a few. Also, they have defined IBL from a variety of perspectives. Some stress the active nature of the learner's involvement, associating inquiry with hands-on experience. Others connect inquiry with the discovery approach or development of scientific inquiry skills. Still others emphasise promoting higher-order thinking skills and self-directed learning (Looi, 1998).

This study defines IBL as an instructional approach in which inquiry functions as a main vehicle for teaching and learning. In this approach, students learn about inquiry and learn through inquiry, and develop their higher-order thinking skills and self-directed learning skills. It is not important what might lead the inquiry—the project, case, or problem—and what might be the result, product, case analysis, or problem solution. IBL induces learners to represent problems, develop their own hypothesis or designs, come up with evidence, conduct self-directed investigations, assess their own progress and finally reflect on their inquiry process. This inquiry process is the most important factor which characterises IBL and has been considered beneficial in augmenting meaningful learning (Brown & Campione, 1994; Collins, Brown & Holum, 1991; Cognition & Technology Group at Vanderbilt, 1997; Linn & Hsi, 2000; Slotta, 2002; White & Frederickson, 1998).

Inquiry is not a context-free activity. It is driven by a specialised language, law and theories, methodologies of the disciplines like arts, science, and humanities and specific areas like classroom instruction, teacher professional development, scientist community, and so on. For example, scientific inquiry process is adopted to reveal the unusual natural phenomenon under study in science. Scientists formulate hypotheses, organise experiments, collect data, and analyse the findings in order to test the hypothesis. Another example is mathematical inquiry which starts with complete abstraction and emphasises discovering relationships between quantitative ideas and inventing new perspective (Martinello & Cook, 2000).

Each and every academic discipline and specific area has its own language, theories, and methodologies to conduct inquiry. Applying IBL to disciplines and areas helps learners appropriate its unique language and theory and apply their own methodology to posing questions and doing inquiry in its own unique context. In the science classroom, for instance, IBL helps learners get involved with diverse ideas and knowledge integration processes and they make connections between their existing ideas, information, observations, and diverse perspectives with the goal of developing more coherent and generative scientific knowledge (Martinello & Cook, 2000). In professional teacher development, a case or cases are presented to learners as a way of implementing IBL. Cases can be used to convey issues in teaching because they capture the richness and the complexity of the real world in classroom situations (Marx, Blumenfeld & Krajcik, 1998). Cases establish a framework for inquiry and discussion among learners and lead their inquiry process.

While there are many ways to implement IBL, online education or e-learning has the potential to augment inquiry. In combination with a constructivist point of view, e-

learning ensures students' positive participation, on-task behaviour, and rich collaboration. According to researchers, e-learning can empower students' ownership and self-directed learning by increasing student involvement and responsibility for their own learning. It provides resources for inquiry which are free for anyone with Internet access to use (Bonk & Dennen, 1999). In this regard, asynchronous conferencing systems and hypermedia are outstanding tools that learners can utilise to collaborate and inquire more efficiently. The asynchronous conferencing system facilitates inquiry through collaborative brainstorming, reflective writing, peer feedback, record keeping, and interactive dialogue. Hypertext or hypermedia enables learners to perform self-directed inquiry through remote access to many types of resources including library catalogues and topical databases (Bonk & Dennen, 1999; Chong, 1998; McLellan, 1998; Pierce, 2000). Also, students can design hypertext documents (web pages) with ease. Learning-by-design activities help learners develop search skills and improve design skills, and enhance appreciation of data as well as ownership (Lim, Plucker & Bichelmeyer, 2003).

Well-designed IBL on the web can provide learners with cognitive tools and procedural guidance for their inquiry and helps them form a learning community wherein teachers and learners interact to solve complex problems (Slotta, 2002). A WISE project is one example. It provides an Internet-based platform for students to work collaboratively on an inquiry project. WISE helps learners organise their ideas and understand scientific advance. Students harness note-taking tools, cognitive hints, editing tools, web searches and project maps that the WISE project provides and they view controversial aspects of science, visualise their inquiry process, engage in developing arguments, support debates and reach a successful conclusion. Students should predict outcomes, test their ideas, and reflect on their progress to increase learning (White & Frederikson, 1998; Chi, 1996).

On the contrary, an e-learning environment has some drawbacks in facilitating inquiry (Bonk & Dennen, 1999). First of all, it is time-consuming. Considerable time might be spent on course design and development, adjusting to new forms of tasks and activities. Effective structuring of student work is not easy in online situations. Second, the abundance of information can be a barrier for some learners and instructors alike. For example, some learners find it hard to manage the abundance of data in a conferencing system, which also causes significant challenges to the instructor in giving timely and appropriate feedback and assessing student progress. Third, students tend to be nice to one another and students' comments to each other tend to be opinion rather than inquiry. Lastly, communication between students and instructor and among students may be difficult without visual cues and physical presence. It is difficult to form communities of learners and instructors.

While the technology might facilitate a dynamic and interactive educational experience, making it happen depends on many factors beyond the technology (Bullen, 1998). The attributes of e-learning like time- and place-independence, many-to-many communication, computer mediation, and interactive communication, do not ensure

active an inquiry on the web. There are many critical issues to be considered when one tries to implement IBL on the web. In other words, designing IBL on the Web is to build online inquiry-based learning environments (OILEs) and it is fairly complex and ill-structured. Instructional designers continue to encounter new, challenging issues beyond the technical problems during the design process.

This study introduces the key issues and challenges that instructional designers should consider when they try to build OILEs, which actually used to be neglected (or ignored) in traditional instructional design practices. Currently, however, the knowledge base for IBL is not firmly established. In accordance with Kearsley's remark, 'It is likely that case and problem-based approaches will be more popular strategies in the online courses' (Kearsley, 2000, p. 69) on the future use of the IBL approach, which is not yet present. Through this study, small efforts were exerted to more meaningful learning on the web.

Methods

To identify issues in designing inquiry on the web, three representative cases were selected especially in the context of teacher professional development. They are WebQuest, Inquiry Page, and Learning to Teach with Technology Studio (LTTS), approaches which are inquiry based learning on the web. Selection criteria for cases were as follows:

- design proposed in the case should assist learners in inquiry: the case should include some kinds of inquiry tools, components, and mechanisms to facilitate inquiry;
- design in the case should have its own visual representation for the inquiry process. It ought to display the inquiry as a main vehicle for teaching and learning;
- in the case, self-directed learning and learner-centered approach should be encouraged.

Examining the cases and analysing the design elements revealed key issues in design case by case (for the full description of the case, see Lim, 2001). For example, the WebQuest case pointed out the importance of design activities and various types of scaffolding (http://edweb.sdsu.edu/WebQuest/). Inquiry Page showed the significance of a community of inquiry, giving a good example of a structure for inquiry (http://www.inquiry.uiuc.edu/). In the LTTS case, an inquiry module was noticeable as a core learning process and a vision of developing an integrated learning system (http://ltts.org).

Based on the findings, the issues were listed, categorised, and cautiously examined. Again, the issues and categories were sent to several renowned researchers for review. Reflecting on their review, the initial issues were refined and finally grouped into six main categories as follows: (1) seeking a balance between a system-generated guide and human facilitator, (2) visual representation of inquiry process, (3) motivating learners with the right question, (4) engaging learners in various learning activities, (5) guiding the inquiry process with various scaffolds, (6) maximising learning by coordinating resources, tools, and community of inquiry.

Issues

Issue 1: Seeking a balance between a system-generated guide and human facilitator

Attempting to design inquiry on the web, instructional designers ought to ponder on how to structure learners' experiences and make them meaningful under limited resources and time constraints. They can consider two aspects: the system designing method and the human facilitator's intervention. In other words, they can ask questions like 'How should the system be designed to help a learner's inquiry' and 'To what extent and in what ways should the human facilitators intervene in a student's inquiry for guidance?'

As for the first question, the system or learning environment created by the system is essential since everything in an e-learning course is done through a human–computer interface. Learners only see the computer screen and follow the directions suggested by the computer. The computer provides menus to be followed, scaffolding, resources, lesson sequences, and so on. Computer-based tools can provide conditions for learning that are unique and conducive to the comprehension of what the data is, how it can be collected, manipulated, visualised, transformed, and eventually examined for clues to understanding the world (Windschitl, 2000). Usually a team of designers or an instructor determines the design elements. Whoever designs it, the system creates some sort of learning environment, providing some mechanism to guide a learner's inquiry, give feedback, and make recommendations for the learning sequence. Some systems may have more advanced mechanisms to assess the learner's progress and to direct the learners to additional resources. Sometimes, a computer system acts like an instructor without any human facilitator.

As for the second question, the human facilitator's role varies widely depending on many factors such as the subject area, teaching style, learner characteristics, etc. He or she can provide more direct guidance for learners with minimal reliance on the system. The facilitator may direct students' inquiry using the dialogue-inquiry method. Also, in coordination with the system, he or she may provide specific, individualised guidance and resources beyond the scope of the programme. He/she can reply to email messages, review test scores, assess participation, and proactively contact learners (Driscoll, 1998). The challenge for online facilitators is to determine how to coordinate system elements and their facilitation under certain circumstances.

In order to ensure meaningful learning, the following design elements need to be considered (Bonk & Dennen, 1999; Bonk & Reynolds, 1997; Bonk & Smith, 1998; Hara & Kling, 1998):

System-generated guide

- Data and visual organisers can be used to support learner inquiry, such as timelines, taxonomies, flowcharts, Venn diagrams, categorisation schemes, and comparison and contrast matrices.

Human facilitator

- For developing creative thinking skills, instructors can use various tactics such as telling, exploring the web, brainstorming, role play, metaphorical thinking, free association, semantic webbing, asking what-if questions, and improvisation.
- For critical thinking skills, instructors may use structured debates, rebuttals, reading reactions, guided reflection logs, case analyses, discussion summaries, reflection or minute papers, and other critical thinking types of writing activities.
- To deepen discussion and further inquiry, instructors may guide students to identify main points, discuss pros and cons, rank or vote on ideas, find patterns and relationships, and examine cost-benefits.

Issue 2: Developing visual representation of inquiry process

Visual representations help instructors and learners see where they are in the complex inquiry process. In online situations, students and even instructors oftentimes feel lost (Barron & Ivers, 1995). They do not know how activities fit together in particular or how activities would contribute to their overall understanding of the problem or to their ability to complete the inquiry (Schwartz, Lin, Brophy & Bransford, 1999). Visual representations are instrumental in helping students develop a map of their own learning. Through visual representations, learners can view errors they made in the process of reasoning or inquiry as a natural part of learning. At the same time, they understand that learners' active participation in the inquiry process is critically important for learning.

To be successful in developing inquiry on the web, visual representation in the inquiry process is critical since it helps learners to see where they are in their learning process. By providing visual representations, instructional designers can help online learners to overcome this difficulty and to draw a mental map of their own learning. Therefore, visual representations in the inquiry process should be designed to help online learners understand where they are in their inquiry.

Also, the visual representation can provide a mental model for inquiry-based learning and make it easy to reflect on the inquiry process. In an online learning environment where inquiry is facilitated, learners may see a series of images that show the inquiry process. As they relate images to one another, they discuss each image: how and what they achieve. In this way, the visual representation plays an important role in developing inquiry and building a community. Schwartz *et al* (1999) indicated that the visual representation of the STAR LEGACY helped learners to talk easily with their team partners who teach other disciplines because they all shared a common structure of inquiry.

The issue here is what kind of structure might be effective in developing inquiry among learners. The structure should capture the circular, recursive, and continuous notion of inquiry when building a structure of inquiry. In this sense, a model of the inquiry cycle might be more appropriate than a linear structure. The visual structure in Figure 1 may facilitate the circular notion of inquiry process: to try out, to come back

and to revise. Notice that in Figure 1, each element of the inquiry process interacts with each other through 'sharing activities' (discussion and collaboration) and the whole process of inquiry is continuously evolving. This represents the openness of the inquiry process, showing the scientific inquiry process as well.

Here is a brief description of each element of the inquiry process shown in Figure 1:

- Ask—An overarching question/problem or case scenario is provided as a springboard. The springboard should be connected to the learners' lives and stimulate their curiosity. It consists of an overarching problem/question or case scenario for this module, grade level, author/co-author, and keywords and description for a search engine. Learners may be allowed to articulate their own problem/question;
- Plan—Learners design their own learning plans and problem solving strategies within a certain time frame. In a team environment, learners discuss roles and tasks for each member. It may include a project management plan or K-W-L (ie, what you Know—what you Want to know—what you have Learned) sheet;
- Explore—Exploring is a systematic way of carrying out an investigation. This is a stage for carrying out the learning plan to solve the problem. Learners use their background knowledge, readings, web sites, resources, and open directories to solve the problem. The system or facilitators provide just-in-time help if necessary;
- Construct—Learners make meaning out of the data, synthesise what they found, and construct new knowledge or create an artifact;
- Reflect—Learners reflect on their conclusion and on their own inquiry process. They apply their conclusion to a new situation and prepare new questions for a next cycle of inquiry. It includes evaluation rubrics, new questions for the next inquiry learning cycle, responses from others, learners' note, and so on.

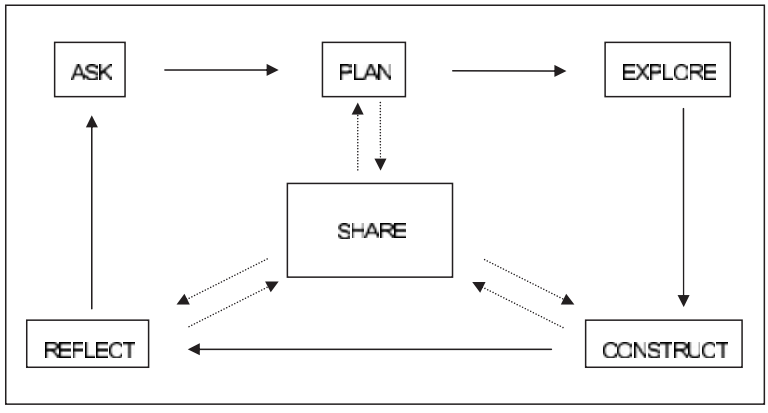

Figure 1: Visual representation of the inquiry process

Issue 3: Motivating learners with the right question

A successful IBL rests upon a higher level of motivation on the part of learners. When students are not sufficiently motivated or extrinsically motivated, they tend to fail to become engaged in inquiry activities (Edelson, Gordin & Pea, 1999). Identifying meaningful motivating factors and context for inquiry also influences the nature and sequencing of the activities and determines the contents of the scaffoldings (Edelson *et al*, 1999). Despite its importance, it is true that there are only few empirical data describing students' interests which could provide useful implications on the design of online inquiry-based learning environments (OILEs) (Blumenfeld, Soloway, Mark, Krajcik, Guzdial & Palincsar, 1991; Hannafin, Land & Oliver, 1999).

OILEs are capable of cultivating a learner's inquiring mind only if they ask the right questions relevant to the learner's life. In the initial phase of the inquiry process (*ASK* shown in Figure 1 above), learners are usually given a problem, question, or case scenario as a springboard for their inquiry. Meanwhile, asking the right question can be a very challenging task to instructional designers.

Here are several strategies available for determining a question to motivate learners. The first strategy is to use a brainstorming session to determine a topic. It might be helpful to have the initial brainstorming with a peer or human facilitator to select a topic. This generally brings up many fresh ideas and gives learners a chance to explore their areas of interest. Brainstorming is a good step because they can reflect on their current situation: what I know, what I need to know, and what I need to learn about this subject matter.

A second strategy is to start with a familiar topic instead of creating a new 'great' one. When determining a topic, it is important to start at the interest areas of the designer him/herself. Concerning the content of a topic, a final strategy is to consider an ill-structured, provocative, and authentic one. Ill-structured, authentic tasks seem to improve learners' inquiry skills and inquiring minds. While well-structured problems can be solved correctly with certainty and requires a few inquiry skills and methods to solve problems without further defining the problems, ill-structured problems often have undefined goals and pose multiple solutions as well as multiple methods to solve them. The problems present 'uncertainty about which concepts, rules, and principles are necessary' for the solution (Jonassen, 1999, p. 219). To solve ill-structured problems, students need more resources than those already given and need to develop ways to solve the problems. Even the problems themselves change as new information is found. Based on their data, learners make decisions and provide solutions to the problems.

On the other hand, instructional designers need to consider a motivation strategy of providing learners with ownership of the problem or question. Without ownership of the problem, learners might be less motivated to solve it (Jonassen, 1999; Savery & Duffy, 1995). One way to promote ownership of the problem is to allow learners to generate their own problem or question. As Savery and Duffy (1995) indicate, allowing

learners to generate their own problem is a key to engaging learners in problem-based learning. Therefore, when developing a topic, instructional designers need to construct an authentic situation and allow learners to immerse themselves and if possible, to determine their own question or problem.

Issue 4: Engaging learners in various learning activities
During the inquiry process, learners experience many learning activities: planning, exploration, discussion, construction, presentation, evaluation, and reflection. To engage learners in various activities, several issues should be considered, such as spontaneous inquiry planning, carrying out investigation, making sure knowledge construction is meaningful, and ensuring effective reflection. Here are the brief descriptions of each issue.

Spontaneous inquiry planning
Instead of following a predetermined inquiry process, learners should be allowed to plan their own learning and to determine their own learning strategies (*PLAN* phase shown in Figure 1). The designers aim to help learners to plan their learning so that they can explore the problem. In IBL, learners deal with project management issues (eg, time management, data collection methods, available resources, etc). Learners might be asked such questions as 'What methods would you use to solve the problem?', 'How will you collect data?', 'What is your timeline?', 'What resources are available?', 'How will you access them?' The design process does not occur without actively interacting with other elements of the learning environments. In order to plan their investigation, learners need to use resources and tools provided by the system and to discuss some issues with their peers. By the same token, instructional designers may need to provide a template or rubrics for project management or research methods that guide learners to conduct their investigation.

Carrying out an investigation
When learners begin to explore an unknown phenomenon in accordance with their planning (*EXPLORE* phase shown in Figure 1), instructional designers should prepare a series of problem-solving activities related to the main question for learners to carry out an active investigation. During this phase, learners actively immerse themselves in the surrounding online learning environment and sometimes go outside it to search and collect data. In online situations, learners need to be guided in a more systematic way.

There are several issues regarding designing learners' exploration on the web that need to be addressed. First of all, how are the tasks, processes, or activities presented? The concern is how to maintain openness while providing guidance to control learners at the same time. To engage learners in doing systematic exploration, it is important to provide integrated, ill-structured, and authentic tasks or processes and to avoid using step-by-step or directive tasks and processes. Exploring a solution to the problem should not be done in an arbitrary way, but should be a more systematic process. In online situations, instructional designers should not ask learners to explore without providing

them with specific processes or activities. Learners need to be given processes or activities to follow, and as a result of finishing activities, they may develop a solution to the problem. When activities and processes are too directive and step-by-step, however, there might not be much room for inquiry. In this case, the activities do not allow learners to seek alternative solutions and do not help them to develop multiple perspectives. Also, step-by-step activities do not help learners to handle real world problems that are untidy. Even though some specifics to the activities might be needed online, it is important to find a way to give them an opportunity to do the same process but without someone telling them the specific steps. One possible solution to this issue is to create a collaborative working place in which learners can explore, provide feedback to each other, and have discussion and reflection.

Second, how can we guide learners to develop a new perspective and to come up with new solutions? It is important to clearly communicate that learners are expected to provide multiple solutions and cope with complexities. Learners often look for only one correct answer and when they come up with one solution, they do not tend to pursue an alternative. If they are not asked to find another solution, their inquiry will not continue. Therefore, it is important to clearly communicate that they are expected to provide several possible solutions. On the designer's part, providing a mechanism to ensure multiple solutions is important. The mechanism works in a way that the outcome is something different from a specific answer that the designer was looking for and there are also some ways that learners can create their own answers. Another way is to prepare diverse, conflicting activities. For example, one activity might ask a positive aspect of a phenomenon and others might ask a negative side of the same phenomenon.

Third, how to organise and sequence tasks and activities? Organising and sequencing activities are important in order for learners to carry out an effective inquiry on the web. One strategy of sequencing activities is to use an easy-to-difficult, specific-to-general sequence. In the LTTS project (see http://ltts.org), the first set of activities starts with assessing their own current practices. The activities should be easy to follow and be motivating for learners. The second set of activities asks learners to look for other examples and let them compare the examples with their practices. These activities ask learners to reflect on their practices. These activities lead learners to the next activities. The third set of activities asks learners to seek ways to improve their current practices and expand their perspective. This cycle is a kind of spiral process: assess a current practice; look for other examples or solutions; and revisit the current practice and improve it.

The last one is about the level of complexity of problems or tasks. It is important to avoid too many complex questions and to make tasks or processes manageable. If the task is too complex, the learner may be easily overwhelmed. It has been found that too many diverse activities do not help learners focus on essential learning tasks. Also, if the activities are too complex, learners may easily lose interest in learning the module.

Making sure knowledge construction is meaningful
It is important to connect inquiry to creating or constructing something meaningful. Inquiry performances conceptualise this kind of activities that display and advance the learners' inquiry skills during the whole process of inquiry. Inquiry performances are thought-provoking activities to make hidden cognitive operations overt. One of the key ideas of inquiry is that it is not just to answer a question in some purely academic sense, but also usually to turn that answer back into action. To make knowledge construction effective, the design should allow learners to demonstrate what they have learned from the online exploration. For example, learners might create a presentation using Powerpoint presentation software to integrate what they have learned during their inquiry.

Ensuring effective reflection
Reflection is the last part of the inquiry cycle and also provides a starting point for the next inquiry cycle (*REFLECT* phase is shown in Figure 1). Learners not only assess and reflect on their learning, but also prepare or brainstorm a new problem or question that comes out of the learning cycle. They may be required to finish up a K-W-L (ie, what you Know—what you Want to know—what you have Learned) sheet and answer the questions that they have formulated at the beginning. In order to facilitate reflection, instructional designers need to prepare rubrics and evaluation templates. Adding a note for reflection might be a good way to promote reflection.

Issue 5: Guiding the inquiry process with various scaffolds
In order to design an inquiry on the web, scaffolding, a temporary support provided by a system or an instructor to help students accomplish a complex task, should be carefully prepared and promptly provided. The online scaffolding provides learners with more opportunities for inquiry by helping them move ahead over potential sticking points and by managing some of the attention-draining details of complex problems. Based on Tharp and Gallimore (1988) and Tharp (1993), Dennen and Bonk (1999) indicate various forms of scaffolding enabled online as follows: social acknowledgement; questioning; direct instruction; modelling/examples; feedback/praise; cognitive task structuring; cognitive elaborations/explanations; a push to explore; fostering reflection/self awareness; encouraging articulation/dialogue prompting; general advice/scaffolding/suggestions; and private email or discussion.

To be able to help learners complete an online inquiry learning module, appropriate scaffolding should be provided. When learners are wrestling with an inquiry learning module, they do a lot of things, for example, formulate a tentative solution, search for a database, save and organise information, discuss issues with others, and determine solutions. In online situations, they need a place or 'learning environment' in which to work. They can take a note using an electronic note, visualise connections of complex ideas by using a visualisation tool or concept mapping tool, save information using a database system, and discuss issues using asynchronous or synchronous systems.

The major challenge is how to support the learners in a way to improve inquiry during their learning process. In order to provide effective scaffolding, some considerations

should be made beforehand. One is what kinds of scaffolds are to be prepared, and another is when to provide them.

Types of scaffold

There are two types of scaffold for designing an inquiry on the web. One type of scaffold basically displays information, for example, online lectures, examples, job-aids, and resources. These are static scaffolds that only disseminate information: neither stimulate any action nor ask for any interaction or feedback from learners. The other type of scaffold requires learners' input or provides some interactivity. These include technology tools, templates, rubrics, checklist, EPSSs, human facilitators, and community of support. These dynamic, interactive scaffolds ask for some actions on the learners' part. For example, templates for the WebQuest (see http://edweb.sdsu.edu/webquest) ask learners to fill in the boxes and help them to create a WebQuest page. In a lecture (a kind of static scaffold), however, learners only listen to audio files or see video vignettes (even though there might be some kinds of cognitive activity). It is important to provide various scaffolds (both static and dynamic) since OILEs are not simply a place to learn contents, but are organizational 'launch pads' or 'springboards' to initiate an inquiry. They often require sophisticated technology tools. For example, learners may use their electronic notebook throughout their learning to take notes and to organise their thoughts.

Scaffolds in the inquiry process

In addition to the proper combination of scaffolds, instructional designers need to consider when to provide what kind of scaffolding. Table 1 below shows the inquiry stages and suggested scaffolds.

Issue 6: Maximising learning by coordinating resources, tools, and community of inquiry

During the inquiry process, learners are wrestling with the unknown to make sense of the world and usually solve the problem in a lonely manner. The process is self-

Table 1: Inquiry stages and scaffolds

Stage	*Description*	*Scaffolds*
Ask	Learners brainstorm possible topics, module scope, problems, and various ways to solve them.	Visualisation tools (eg, *Inspiration*), human facilitator, examples, community of support.
Plan	Learners plan the process leading to problem solution.	Project management tool.
Explore	Learners explore resources that are available for solving the problem and collect data for problem solutions.	Resources, note-taking tools, community of support.
Construct	Learners synthesise resources and provide solutions.	Templates, EPSSs, checklists.
Reflect	Learners discuss the lesson and implications for further refinement.	Rubrics, checklists.

regulated, so learners can be easily distracted, confused, and frustrated. Besides providing scaffolds for learners, there should be a more systematic way to support inquiry. Learners will have successful inquiry experiences if instructional designers carefully coordinate resources, tools, and community of inquiry.

Preparing resources

Online resources help learners explore without leaving the online environments. Since the resources are critical to inquiry learning, providing quality resources is important to successful inquiry. This is somewhat different from face-to-face inquiry learning. In the face-to-face inquiry-based learning environment, learners are often encouraged to find resources by themselves and are not be given a list of resources. But on the web, learners usually start their inquiry using the existing, digitised resources. And as they become more engaged in the inquiry, they are encouraged to add newly found resources during the inquiry.

In order to become independent inquirers, learners need to be encouraged to become competent in the use of one or more search engines. In addition to providing resources, it might be important to encourage learners to use a search engine by themselves in order to find additional resources.

Learners may be encouraged to review and criticise existing resources. For example, in a local professional development project called *TICKET* (see http://www.indiana.edu/~tickit), learners are encouraged to review and criticise existing resources. Evaluating resources is a critical inquiry skill. As time goes on, learners may grow as independent reviewers. In the programme, learners used a web forum to review the resources and to share their opinions with other learners. Another way is to add a 'review' menu under each resource. Reviewers or learners might go to the review page (by clicking the 'review' icon), write their own opinions about the particular resource, or see others' reviews.

Using technology tools

Some technology tools are useful in facilitating inquiry. With the careful use of technology tools, online learners can go through difficult, sometimes tedious inquiry process. For the best result, it is important to select appropriate tools at the appropriate time. The issue is what kinds of tools exist and how to use them at which point of the inquiry process.

As for the typology of online tools, Windschitl (2000) introduces three types of technology tools to use online: visualisation tools, simulations and microworlds, and modelling tools. He asserts that visually-enhanced data analysis tools not only allow learners to enter collected data in tables, but also provide illuminating ways to transform this information into a variety of iconic representations. Simulations and microworlds are manipulated computer-based models of complex phenomena such as economic cycles, food web dynamics, or astronomical motion. Lastly, modelling tools permit learners to create and test their own models as a means to understanding

complex systems. Some of these tools scaffold novice modellers by representing parts of a system with concrete images and connections between elements of the model with qualitative descriptors.

These are cognitive tools which support learners' performance of complex and authentic tasks in online learning environments. The cognitive tools are intellectual devices for visualising, organising, automating, and supplanting learners' cognitive activities. Jonassen (1999) introduces another typology of technology tools in terms of cognitive help: (1) problem/task representation tools, (2) knowledge modelling tools, (3) performance support tools, and (4) information gathering tools. These tools are critical to construct a nurturing environment for inquiry. They can ease learners' cognitive burdens, facilitate their inquiry, help learners focus on the inquiry process without spending time on technical matters, and provide a firm basis (eg, building a database) for further inquiry.

Some examples of technology tools in OILEs are video, templates, and rubrics. These technologies seem to be effective in supporting the learner's inquiry. Using video to present a problem as well as to model the inquiry process might be effective. Providing video vignettes on the web is worthwhile in terms of visualising and modelling the inquiry process. Also, providing some kind of templates may help learners focus on the content or inquiry activity. A template is a kind of performance support tool. It provides an easy way to create a lesson unit or learning module without sophisticated technical skills. It is important to encourage learners to use rubrics or checklists to reflect on their learning. Lastly, rubrics and checklists can be effectively used to ensure the quality of a product that learners have developed as a result of finishing an inquiry module. The rubrics need to provide detailed criteria for the main components of the product.

Developing a community of inquiry

According to the social-constructivist view of learning, learning is a knowledge-construction process and the process should be modelled and supported in a community. That is, knowledge is constructed in relation to a community of learners (Wenger, 1998). 'Learning community', 'community of learners', 'community of practice', or 'community of inquiry' are terms that indicate the importance of community support in a knowledge building process. Through participating in a community, learners learn with collaboration and interaction with other members. It ensures members' professional growth and transformation in a process of social interactions (Palloff & Pratt, 1999).

When defining a community of practice (CoP), Barab, Scheckler and Makinster (2004) indicate four characteristics: (1) shared knowledge, values, and beliefs; (2) overlapping histories among members; (3) mutual interdependence; and (4) mechanisms for reproduction. A community of inquiry has similar characteristics except that it emphasises the sharing of inquiry practices and results among members. It is an ongoing social network of individuals who work together to inquire about unknown phenomena and to share their findings with each other based on mutual understanding.

Learners' contributions to the community through sharing and collaboration distinguishes a community of inquiry approach from others such as practice fields approach (Barab & Duffy, 2000). Even though a practice fields approach is utilised in collaborative problem solving and clearly different from traditional school learning, it still engages learners in 'school tasks' abstracted from the community and does not allow learners' contributions to the community. OILEs should allow learners to work in a community, to share their findings with others, and to contribute to their community. It should provide an online space in which learners have all kinds of people representing the inquiry that they are engaged in.

Although an interest in online communities seems to exist (Barab *et al*, 2004), building a community online is still very challenging and requires enormous energy from the designer to reach its full potential. The *TICKIT* project has some implications for building an online community. In the *TICKIT* learning environment (see http://www.indiana.edu/~tickit), learners can look at all projects by other learners, log onto the discussion forum, share their opinions, and check reviews by others on resources and free tools.

Building a community of inquiry online requires the design and manipulation of various technologies in ways that facilitate the inquiry process and collaborative inquiry among members of the community. These technologies range from email or listserv to high-end multimedia tools. Discussion forum, messengers, and team pages (collaborative work space to allow people to share documents and ideas) may ensure learners form teams and learn inquiry modules together.

More importantly, some social techniques can foster collaboration and communication among members of a community of inquiry. The 'online critical friend' method is one good example of the social techniques. A critical friend is a person who will listen and provide insights into one's efforts. He or she should make suggestions when this helps another to move forward. The pair can switch roles and provide support for each other.

Conclusion

This study has discussed major issues in designing an inquiry on the web. The discussion shows difficulties and challenges that instructional designers might tackle when they try to design a successful inquiry experience on the web. Since online environments have advantages and disadvantages in terms of facilitating an inquiry and using IBL, it is important to acknowledge the issues regarding the use of IBL on the web. With proper design strategies, instructional designers can provide positive learning experiences for the online learners. These issues are: (1) seeking a balance between a system-generated guide and human facilitator, (2) visual representation of the inquiry process, (3) motivating learners with the right question, (4) engaging learners in various learning activities, (5) guiding the inquiry process with various scaffolds, (6) maximising learning by coordinating resources, tools, and community of inquiry.

These issues are just a few identified by examining three representative cases, and there might still exist many unexplored issues and challenges. Instructional designers should be open to new issues emerging from their design process and implementation. In order to provide learners with genuine experiences of IBL, instructional designers should solve the issues in creative ways and provide proper design strategies. The design principles suggested in this study may help designers handle the difficulties they might face in near future.

References

Barab, S. & Duffy, T. (2000). From practice fields to communities of practice. In D. Janassen & S. Land (Eds), *Theoretical foundations of learning environments*. Mahwah, NJ: Lawrence Erlbaum Associates.

Barab, S., Scheckler, R. & Makinster, J. (2004). Designing system dualities: building online community. In S. Barab, R. Kling, J. Gray, R. Pea, J. Seely Brown, & C. N. Heath (Eds), *Designing virtual communities in the service of learning*. Cambridge: Cambridge University Press.

Barron, A. & Ivers, K. (1995). *The Internet and instruction: activities and ideas*. (ERIC Document Reproduction Service No. ED392447).

Benson, A. & Bruce, C. (1998). *Using the web to promote inquiry and collaboration: A snapshot of the Inquiry Page's development*. http://www.students.uiuc.edu/~apbenson/collaborative_inquiry.html.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Gudzial, M. & Palincsar, A. (1991). Motivating project-based learning: sustaining the doing, supporting the learning. *Educational Psychologist, 26*, 3&4, 369–398.

Bonk, C. J. & Dennen, V. (1999). Teaching on the web: with a little help from my pedagogical friends. *Journal of Computing in Higher Education, 11*, 1, 3–28.

Bonk, C. J. & Reynolds, T. (1997). Learner-centered web instruction for higher-order thinking, teamwork, and apprenticeship. In B. H. Khan (Ed.), *Web-based instruction* (pp. 167–178). Educational Technology Publications.

Bonk, C. J. & Smith, G. S. (1998). Alternative instructional strategies for creative and critical thought in the accounting curriculum. *Journal of Accounting Education, 16*, 2, 261–293.

Brown, A. L. & Campione, J. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), *Classroom lessons: integrating cognitive theory and classroom practice*. Cambridge: MIT/Bradford.

Bullen, M. (1998). Participation and critical thinking in online university distance education. *Journal of Distance Education, 13*, 2, 1–32.

Chi, M. (1996). Constructing self-explanations and scaffolded explanations in tutoring. *Applied Cognitive Psychology, 10*, 33–49.

Chong, S. M. (1998). Models of asynchronous computer conferencing for collaborative learning in large college classes. In C. J. Bonk & K. S. King (Eds), *Electronic collaborators: learner-centered technologies for literacy, apprenticeship, and discourse* (pp. 157–182). Mahwah, NJ: Lawrence Erlbaum Associates.

Cognition and Technology Group at Vanderbilt (CTGV) (1997). *The Jasper Project: Lessons in curriculum, instruction, assessment, and professional development*. Mahwah, NJ: Lawrence Erlbaum Associates.

Collins, A., Brown, J. & Holum A. (1991). Cognitive apprenticeship: making thinking visible. *American Educator 15*, 6–11, 38–39.

Dennen, V. & Bonk, C. J. (1999). *Cases, conferencing, and communities of practice: a qualitative study of online mentoring for preservice teachers*. Paper presented at the Annual convention at the American Educational Research Association. April, 1999, Montreal, Canada.

Driscoll, M. (1998). *Web-based training: using technology to design adult learning experiences*. San Francisco, CA: Jossey-Bass Pfeiffer.

Edelson, D., Gordin, D. & Pea, R. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *The Journal of the Learning Science*, *8*, 3&4, 391–450.

Hannafin, M. J., Land, S. & Oliver, K. (1999). Open learning environments: foundations, methods, and models. In C. Reigeluth (Ed.), *Instructional-design theories and models* (Vol. II). Mahwah, NJ: Erlbaum.

Hara, N. & Kling, R. (1999). *A case study of students' frustrations with a web-based distance education*. Working paper for the Center for Social Informatics. http://www.slis.indiana.edu/CSI/wp99-01.html.

Jonassen, D. H. (1999). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional design theories and models: a new paradigm of instructional theory* (2nd ed.) (pp. 215–240). Mahwah, NJ: Lawrence Erlbaum Associates.

Kearsley, G. (2000). *Online education: learning and teaching in cyberspace*. Belmont, CA: Wadsworth.

Lim, B. (2001). *Guidelines for designing inquiry-based learning on the web: online professional development of educators*, unpublished doctoral dissertation, Indiana University at Bloomington.

Lim, B., Plucker, J. & Bichelmeyer, B. (2003). Attitudinal effects of learning by web design with graduate students. *College Teaching*, *51*, 1, 13–19.

Linn, M. C. & Hsi, S. (2000). *Computers, teachers, peers: science learning partners*. Mahwah, NJ: Lawrence Erlbaum Associates.

Looi, C. (1998). Interactive learning environments for promoting inquiry learning. *Journal of Education Technology Systems*, *27*, 1, 3–22.

Martinello, M. & Cook, G. (2000). *Interdisciplinary inquiry in teaching and learning* (2nd ed.). Pearson Education, NJ: Upper Saddle River.

Marx, R., Blumenfeld, P. & Krajcik, J. (1998). New technologies for teacher professional development. *Teaching and Teacher Education*, *14*, 1, 33–52.

McLellan, H. (1998). The Internet as a virtual learning community. *Journal of Computing in Higher Education*, *92*, 2, 92–112.

Palloff, R. M. & Pratt, K. (1999). *Building learning communities in cyberspace: effective strategies for the online classroom*. San Francisco: Jossey-Bass Publishers.

Pierce, W. (2000). Online strategies for teaching thinking. *Syllabus: New Dimensions in Education Technology*, *14*, 2, 21, 24.

Savery, J. & Duffy, T. (1995). Problem based learning: an instructional model and its constructivist framework. *Educational Technology*, *35*, 5, 31–38.

Schwartz, D., Lin, X., Brophy, S. & Bransford, J. (1999). Toward the development of flexibly adaptive instructional designs. In Charles Reigeluth (Ed.), *Instructional-design theories and models: new paradigm of instructional theory* (2nd ed.) (pp. 183–214). Mahwah, NJ: Lawrence Erlbaum Associates.

Slotta, J. (2002). Designing the web-based inquiry science environment (WISE). *Educational Technology*, *42*, 6, 15 Cambridge 20.

Tharp, R. & Gallimore, R. (1988). *Rousing minds to life: teaching, learning, and schooling in social context*. Cambridge: Cambridge University Press.

Tharp, R. (1993). Institutional and social context of educational practice and reform. In E. Forman, N. Minick & C. Stone (Eds), *Context for learning: socio-cultural dynamics in children's development* (pp. 269 Cambridge 282). New York: Oxford University Press.

Wenger, E. (1998). *Communities of practice: learning, meaning, and identity*. Cambridge: Cambridge University Press.

White, B. Y. & Frederickson, J. (1998). Inquiry, modeling, and metacognition: making science accessible to students. *Cognition and Instruction*, *16*, 3–118.

Windschitl, M. (2000). Supporting the development of science inquiry skills with special classes of software. *Educational Technology Research and Development*, *48*, 2, 81–95.