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Investigating the use of a digital library in an inquiry-based undergraduate geology course

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Abstract

Abstract: This paper reports the findings of a qualitative research study designed to investigate the opportunities and obstacles presented by a digital library for supporting teaching and learning in an inquiry-based undergraduate geology course. Data for this study included classroom observations and field-notes of classroom practices, questionnaires, and audiotapes and transcripts of interviews conducted with student and instructor participants. The findings suggest that although both the instructor and students recognized a number of opportunities presented by the digital library to support teaching and learning (e.g., provides access to various types of data), they encountered a number of obstacles (e.g., difficulty with the search mechanism) that discouraged them from taking advantage of the resources available. Recommendations are presented for (a) developers of digital libraries, and (b) instructors wishing to integrate use of a digital library for supporting their teaching and student learning in an inquiry-based course.

Abstract : Le présent article rend compte des conclusions d'une étude de recherche qualitative élaborée afin d'examiner les occasions et les obstacles que présente une bibliothèque numérique appuyant l'enseignement et l'apprentissage dans le cadre d'un cours de géologie de premier cycle axé sur la recherche. Les données pour cette étude comprenaient les observations effectuées en salle de classe et les notes d'excursion des pratiques en salle de classe, les questionnaires, les bandes audio ainsi que les transcriptions des entrevues menées auprès des étudiants et de l'instructeur participant. Les conclusions laissent entendre que bien que l'instructeur et les étudiants reconnaissent un certain nombre d'occasions que présente la bibliothèque numérique en appui à l'enseignement et à l'apprentissage (p. ex. accès à divers types de données), ils ont dû surmonter un certain nombre d'obstacles (p. ex. difficulté avec les mécanismes de recherche) qui les ont découragés de profiter des ressources disponibles. Des recommandations sont présentées pour les a) développeurs de bibliothèques numériques et b) les instructeurs qui veulent intégrer l'utilisation d'une bibliothèque numérique afin d'appuyer leur enseignement et l'apprentissage de leurs étudiants dans le cadre d'un cours axé sur la recherche.

Investigating the Use of a Digital Library in an Inquiry-based Undergraduate Geology Course

Digital libraries, collections of digitized resources in a variety of formats (e.g., audio, video, text), can serve as primary repositories of data to support teaching and learning in science classrooms. Initial research on digital libraries has focused on issues such as library infrastructure, effective ways to manipulate mass-information on the Net, and effective search and retrieval mechanisms. To date there has been very little research focused on evaluating the usability or assessing the learning outcomes associated with use of digital libraries in classroom instruction (Borgman et al., 2000). Given the significant investment of funding and research that has been invested to create usable digital libraries, it is imperative that educational researchers examine the ways that digital libraries can, and are, being used in classroom settings. Accordingly, this paper reports the results of a qualitative investigation conducted to delineate the opportunities and challenges experienced by a geology professor and her students in utilizing a specific digital library (DLESE) to support teaching and learning in an inquiry-based undergraduate geology course.

Digital Libraries and Science Education

Experts on learning have concluded that superficial coverage of scientific concepts and an over-emphasis on the teaching of isolated facts occurs far too much in science education at all levels (Bransford, Brown, & Cocking, 2000). This problem is especially evident in introductory science courses in colleges and universities where instructors typically focus on covering content from textbooks, exposing students to a plethora of facts and highly-structured problems, but rarely, if at all, engaging students in the process of scientific inquiry (National Research Council, 1996b). Yore, Florence, Pearson and Weaver (2002) have described this as the 'science as a noun' perspective which "stress[es] encyclopedic volumes of knowledge and lists of procedures and processes about science" (p. 5). Recently however, within the science education community there has been a move towards adopting a 'science as a verb' perspective which "emphasiz[es] the human endeavors, successes, failures, and emotional dispositions associated with doing science as inquiry" (Yore, et al., 2002, p. 5).

Inquiry-based learning is the science education community's choice of action to integrate the 'science as a verb' approach for science instruction ranging from primary school grades through graduate education. Inquiry describes the "diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (National Research Council, 1996a, p. 23). Inquiry also refers to the activities of students "in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p. 23). Thus inquiry describes both a process that scientists use to investigate phenomena in the natural world, as well as an instructional methodology that can help students achieve understanding of scientific concepts through active participation in activities typical of working scientists.

Despite their best intentions, science instructors who seek to implement inquiry-based learning may falter when they attempt to assemble the resources needed to engage their students in authentic scientific inquiry; this is where digital libraries come into play. Just as computer technology has become integral in most forms of scientific practice, computer technologies have come to be viewed by the science education community as offering unparalleled opportunities for supporting inquiry-based learning (Edelson, Gordin, & Pea, 1999). A digital library is one such technology that can provide new opportunities to engage students in inquiry-based science (Edelson & Gordin, 1996).

Although it is easy to view digital libraries as merely another source of information, Wallace, Krajcik and Soloway (1996) describe several features of digital libraries that support student learning and differentiates them from traditional libraries. Firstly, content in digital libraries is current, providing students with access to up-to-date, even real time, information to help them address the questions they may be exploring. Digital libraries may also contain information and data from the same sources typically used by scientists, such as images or visualization data. Unlike a traditional library, resources in a digital library may be represented in a wide variety of formats, and because information is available in a digital form, it allows for manipulation and integration by students. Finally, digital libraries can provide students with the opportunity to create and publish their work in digital form, sharing their work with a wider audience.

DLESE, the Digital Library for Earth Systems Education (http://www.dlese.org), is a National Science Foundation (USA) funded library specifically developed to serve as a repository for resources and data related to earth science. Incorporated into an inquiry-based earth science course, DLESE is a technological resource that instructors can use to provide students with access to the types of tools (e.g., visualization technologies) and resources (e.g., real-time meteorological data) useful for engaging in inquiry-based learning activities. Digital libraries, such as DLESE, can support inquiry-based learning by providing access to resources that (a) enable students to investigate authentic scientific questions using real data, (b) help students develop a view of science as inquiry, and (c) provide a common ground linking students with a community of practicing scientists (Edelson & Gordin, 1996).

Integrating a Digital Library into an Inquiry-based Geology Course

The specific purpose of this study was to characterize the opportunities and obstacles presented by a specific digital library (DLESE) for: (a) an instructor attempting to create an inquiry-based learning environment, and (b) students learning in an inquiry-based learning environment. The ultimate goal of this research is to generate design guidelines for incorporating digital libraries into science instruction in higher education, thus a detailed investigation of how a digital library was (or was not) used is an appropriate first step. The specific research questions were:

1. What are the professor's perceptions of the opportunities and obstacles presented by DLESE for supporting the teaching of an inquiry-based geology course?
2. How does the professor use DLESE to support student learning in an inquiry-based geology

course?
3. What opportunities or obstacles do students perceive DLESE has for supporting their learning in an inquiry-based geology course?
4. How do students use DLESE to support their learning in an inquiry-based geology course?

Two important factors were considered en route to defining and answering the research questions in this study. First, the features and functionality of DLESE as a tool were considered with respect to its potential to influence the ways in which both the professor and students were able to make use of the library. Second, the ways in which DLESE was integrated into the course, i.e., the nature of the learning tasks, were considered with respect to their potential to influence both student use and student perceptions of DLESE.

Characterizing DLESE as a tool

DLESE is an organized repository for resources and data specifically related to earth science. Its features include the ability to search for resources according to: grade level; resource type (e.g., visualization data, animations, video, etc.); collections (DLESE resources that are organized by themes or other evaluative criteria, e.g., the DLESE Reviewed Collection); and standards (including the National Science Education Standards and the National Geography Standards). Once a resource of interest is found, a summary of the resource's properties are displayed including: a brief description of the resource; resource type; subject areas addressed; and grade level(s) for which the resource is appropriate. Users are also able to see others' reviews of the resource, teaching tips for using the resource, and other resources related to the topic of interest.

DLESE currently houses over 12,000 resources, which are organized into 27 thematic collections related to a range of topics dealing with earth science. At the time this research was conducted, the DLESE library contained approximately 9,000 resources. With respect to the types and number of resources available to both the professor and students, approximately 6,500 of the total resources available in DLESE were categorized as containing information relevant to the geological sciences.

Characterizing the learning tasks

The inquiry-based activities used in the course were structured according to the guidelines for creating inquiry-based learning environments suggested in the *National Science Education Standards* (NSES) (National Research Council, 1996a). The inquiry-tasks used in this course were more 'guided' than 'open' inquiry tasks, in that the students were provided with an inquiry question to pursue and provided with a multitude of data from which to formulate their explanations. Unlike traditional 'cookbook' laboratory activities in which all the important decisions such as which data should be collected, or how data should be analyzed (Clough, 2002), these inquiry tasks were designed to encourage students to actively engage in cognitive activities that are integral to meaningful inquiry (e.g. developing alternative explanations, interpreting data, selecting among alternative hypotheses) (Clough, 2002). Where appropriate and possible, the use of DLESE was explicitly incorporated into the inquiry task, while in other cases, students were encouraged, but not required, to use DLESE. Apedoe, Walker and Reeves (2006), provide a

more detailed description of the course and the learning tasks used.

Method

Context and Setting

This research was conducted in an upper-level undergraduate geology course that consisted of two hours of lecture and three hours of lab per week, at a large research university in the south-eastern USA. The course, which was a required course for all geology majors, focused on principles of paleobiology, including biostratigraphy, paleoecology, taphonomy, and macroevolutionary dynamics.

Participant Selection

All students were invited to participate in the study, but participation was voluntary. This course had a typical enrolment of 10–15 students, which provided an ideal classroom environment in which to engage students in inquiry-based activities (Oliver-Hoyo, Allen, & Anderson, 2004). A total of eight students were enrolled in the course, of which seven students agreed to participate in the research. See Table 1 for a detailed characterization of the student participants.

Table 1. *Characterization of Students Enrolled in Geology Course*

Research Questions	Method	Type of data	Analysis Method	Frequency of data collected
What are the instructor's perceptions of the opportunities and obstacles presented by DLESE for supporting the teaching of an inquiry-based geology course?	Interview	Audiotapes & transcripts	Thematic & constant comparative analysis	3
How does the instructor use DLESE to support student learning in an inquiry-based geology course?	Interview Direct Observation Archival Data	Audiotapes & transcripts Field notes Lab Assignments	Thematic & constant comparative analysis of interviews, observations and archival data	3 32 8
What opportunities or obstacles do students perceive DLESE has for supporting their learning in an inquiry-based geology course?	Interview Questionnaire	Audiotapes & transcripts Completed questionnaires	Thematic & constant comparative analysis of interviews, observations, and open-ended survey questions	3 3
How do students use DLESE to support their learning in an inquiry-based geology course?	Direct Observation Interview Questionnaire	Field notes Audiotapes & transcripts Completed questionnaires	Thematic & constant comparative analysis of interviews, observations, and open-ended survey questions	32 3 3

Student participation involved completion of three questionnaires and three interviews throughout the semester. In addition, student participants allowed the researcher to access copies of their completed assignments and exams, and agreed to be observed as they completed inquiry-assignments during lab periods. Participation by the professor involved completion of three interviews throughout the semester. In addition, the professor provided the researcher with access to copies of all her instructional materials. All information gathered from participants by the researcher was kept confidential. The professor did not receive a final report of the results of the study until the following semester.

Research Approach and Data Sources

This interpretive study utilized a layered case-study approach, in which both a study of one macro-level case and case studies of several individuals (Patton, 2002) were conducted to document the implementation of DLESE into the geology course. The primary unit of analysis (Patton, 2002) for the data reported in this paper was the undergraduate geology course. The case studies of individual students' learning experiences in this course are reported elsewhere (see Apedoe, 2006).

Data collection procedures consistent with an interpretivist investigation employing qualitative methods such as direct observation, document analysis, and interviews were used to help address the research questions. See Table 2 for a detailed description of the research questions and their associated sources of data. Further elaboration of these measures follows.

Table 2. *Summary of Data Sources*

Participant	Age / Gender	Academic Standing	Major / Minor	Geology Background (credit hours)	Comfort with Inquiry?	Comfort with computers / WWW?
Jackson	20 year old/ Male	3rd year	Geology / Forestry	7	Comfortable	Not very comfortable
Jake	22 yr old/ Male	5th year	Geology	7	Comfortable	Very comfortable
Karen	20 yr old/ Female	3rd year	Geology	12	Comfortable	Very comfortable
Melanie	21 yr old Female	4th year	Anthropology / Geology	11	Somewhat Comfortable	Comfortable
Kyle	58 yr old/ Male	3rd year	Geology/ Russian	6	Not very Comfortable	Comfortable
Robin	20 yr old/ Female	3rd year	Geology/ Japanese	7	Somewhat Comfortable	Very comfortable

Semi-structured interviews in which student participants were asked to respond to a series of open-ended questions regarding their use and experiences with DLESE were conducted. Students were interviewed at the beginning, middle, and end of the semester. Interviews were also conducted with the professor (once at the beginning, middle and end of semester) to gather information about her individual experiences facilitating student learning in the geology course. (See Appendix A for a sample of questions asked during the interviews.)

Questionnaires were given to student participants to gauge their reaction to the inquiry-based learning activities, their experiences in the course, and their experiences using DLESE. Questionnaires included both open-ended and close-ended questions and were administered prior to the interviews. See Appendix B for a sample of topics addressed on the questionnaires.

Participant observation was used throughout the semester. During every class session, the researcher observed student participants working to complete their inquiry assignments. The researcher recorded field notes, which were expanded and analyzed following the class session in which they were collected.

Archival data such as instructor-developed assignments, lecture-notes, or worksheets were also collected to help characterize the professor's use of DLESE to support learning in the geology course.

Analysis

Interview transcripts were analyzed on multiple passes by the researcher (Miles & Huberman, 1994). In one pass, a thematic analysis procedure was used to analyze the interview transcripts. Thematic analysis is an inductive analysis procedure in which categories are derived from the data, that is, the specific nature of the themes and categories are not predetermined (Ezzy, 2002). Thus, the interview transcripts were explored, units of meaning were identified, codes were developed and categories and sub-categories were created (Ezzy, 2002). This process was followed until a 'master list' of codes was developed, which reflected the recurring themes and patterns in interviewees' responses (Merriam, 1998).

On a second pass, the constant comparative method of analysis (Merriam, 1998) was employed to examine interview transcripts in light of the four major research questions. This process involved examining interview transcripts, comparing codes identified on the master code list, and then organizing the coded data according to each research question that it addressed.

On a third pass, the constant comparative method of analysis was used again, however this time interview transcripts were coded with respect to the interview questions. Individuals' responses to interview questions were compared across interviews to identify any themes or categories that may have been missed during the initial two coding passes. Then the coded responses were compared across interviews to identify any new themes or categories that were specific to the interview question being addressed. The three coding passes allowed the researcher to conduct detailed, cross-coded searches for themes and categories.

A similar analysis procedure was used for coding of the open-ended questions from the questionnaires, as well the field-notes from classroom observations. On the first pass of the data, a thematic analysis procedure was used to identify any categories or themes that emerged from participants' responses and behaviours. On the second pass, comparative analysis was used to code the questionnaire data and field-notes against the research questions. Questionnaire data was coded on a third pass based on the questions to which the participants responded. In combination with the interview and questionnaire data, the field notes from direct classroom observations were used as a source to validate and crosscheck findings (Patton, 2002).

Findings

Findings are presented according to the four major research questions of interest in this study. Participants have all been given pseudonyms.

Research Question 1: What are the professor's perceptions of the opportunities and obstacles presented by DLESE for supporting the teaching of an inquiry-based geology laboratory?

The greatest opportunity that Dr. Sanders believed DLESE presented for supporting teaching and learning in an inquiry-based geology course was that DLESE could serve as a portal for access to scientific information, which can often be difficult to find when using a general search engine:

> *It's all peer-reviewed, it's all scientific, there's no creation science on it. That's fantastic! Because like I said, if I type in the Grand Canyon geology the first six hits let say, well I don't know right now but I remember- the first six hits are creation science, its not good science—and I can go to the DLESE site, with you know, checking the different boxes, type in the Grand Canyon and I'm going to get science. And that's the huge plus right there. And I think that's really important for the public to know about, because some people don't know the difference between creation science and science.*

Although Dr. Sanders perceived DLESE to be a valuable service, she encountered a number of obstacles to using DLESE to support her teaching. The two major themes that emerged from Dr. Sanders' responses were: (a) the lack of useful or relevant resources available, and (b) the functionality of the search engine.

With respect to the lack of useful resources, Dr Sanders reported that she was unable to find specific information that would be of use, or support, her teaching. As a consequence her use of DLESE was minimal:

> *Well I have to tell you that I tend not to use DLESE because there are a lot of things on there that I can't use and the level of information I can't really use.*

Regarding the functionality of the search engine, the inability to instantaneously find the information she was looking for was a significant barrier to Dr. Sanders' use of DLESE. Ease of use, and the amount of time required to find a resource, was of primary importance to Dr. Sanders thus, she was more inclined to use general web search engines such as Google™ when looking for material to support her teaching:

> *If I was putting together a K–12 project, or looking for information just in general it's [DLESE] good, but I have to do a lot of searching. I can't get anything instantaneously. I have to click a lot of buttons, and things like that—at least for what I've used. I use Google all the time. I just type in, I get Google up, I type in the word I want, I put a comma, I put definition and BAM it's right there! The top one, I can use. I can't do that in DLESE. DLESE takes more thought, more preparation, its not instantaneous gratification.*

Finally, Dr. Sanders perceived the categorization of resources by different grade levels within DLESE as both an opportunity and an obstacle:

> *The other plus is that, information is in different levels. I mean I found it as a barrier because I'd have to sift through stuff, but for most people, you could find what K–12 information is, or just K information, you could find university information. I like that a lot. I think that's great. So I could go in and find out 'oh that's kindergartener level, oh, okay' and I could learn very quickly what kindergartener level is and write something at that level.*

Thus, although Dr. Sanders perceived DLESE to be a potentially valuable resource and service, the lack of relevant material and characteristics of the search features posed significant obstacles to her use of DLESE for supporting her teaching.

Research Question 2: How does the professor use DLESE to support student learning in an inquiry-based geology course?

Despite the challenges Dr. Sanders encountered while trying to use DLEE, she was still a strong advocate for its use by her students. Dr. Sanders encouraged her students to use DLESE in the following ways: (a) referencing DLESE as a resource on six of the eight inquiry assignments, (b) frequently mentioning DLESE in class, and (c) providing students with Internet access—with the homepage set to the DLESE web site. Dr. Sanders belief in the potential value of DLESE, led her to develop a *DLESE Project* to replace the second midterm exam. With this project, students were required to search DLESE to find a topic that was not well represented in the library, and develop the content for what could be turned into a web-based resource to add to DLESE. The *DLESE Project* assignment was informed by the learning principle that the creation of an external knowledge representation (in this case, a resource for DLESE) leads to enhanced learning (Harel & Papert, 1991).

Research Question 3: What opportunities or obstacles do students perceive DLESE has for supporting their learning in an inquiry-based geology course?

Students reported that DLESE presented a number of opportunities for supporting their learning. Two themes that emerged from student responses included: (a) different types of data available in DLESE, and (b) assurance of the scientific nature of resources available. For example, Jackson believed that, although most information could be found in his textbook, DLESE could provide access to other types of information:

> *I mean most of the stuff you know it will be in our book pretty much other than some maps and charts and things like that will be on the website that might not be in our textbook.*

DLESE was also viewed as a source of images and graphics that could be useful for presentations and reports. For Melanie, although the information she found was below her educational level, DLESE provided her with access to useful graphics:

> *I really only found like little kid stuff like volcanoes exploding, but it had good graphics I used in my presentation.*

In addition, students recognized the potential value of using DLESE to find resources because it provides added assurance regarding the credibility and scientific accuracy of resources found within the library. For example, Robin stated that she believed the advantage of DLESE for some individuals would include not needing the skills to critically evaluate a web-resource:

But I mean I could understand why it's a good idea to have that because some people don't really know how to tell a bad webpage from a good webpage.

Another student, Karen, gave the following example of how she had encouraged others to use DLESE because of the added assurance DLESE provides for finding scientifically accurate resources:

> *Yes! I tell everybody about DLESE. I was in my Surficial Processes class just now … like a couple hours ago and we had like a lab every week and umm he was like oh yeah look in these books if you know you want to look at this stuff, or look online—Google it —and I was like no—don't Google it because they could be wrong- use DLESE! And this guy behind me was like who's in the [geology] class was like 'Oh yeah thanks!'*

There were two main themes that emerged from students' responses regarding the *obstacles* presented by DLESE for supporting their learning. Much like the obstacles perceived by Dr. Sanders, students perceived both (a) the features and functionality of the DLESE search engine, and (b) the lack of relevant and appropriate resources in the library, to be challenges.

With respect to the search engine, both Jake and Robin reported that the user-interface was counterintuitive making it difficult to locate resources of interest. For Jake, a poor user-interface results in an unsuccessful digital library:

> *Yeah, the whole thing about DLESE is it wants to be a source for peer reviewed, very scientific information about the earth sciences—it fails in that because people can't get that information out of the site … what I really know needs to be done to that site is it needs to be kind of tweaked a little bit as far as its design for it to be useful.*

A second theme that emerged from both observation data and students' responses during interviews was the lack of relevant and appropriate resources available on DLESE. Students either had difficulty finding resources that dealt with topics covered in the course, or finding resources that dealt with the topic at a level appropriate for a university student. The problem of finding relevant resources may lie in the search terms associated with the DLESE resources. For example, when students entered specific scientific search terms such as 'biogenicity criteria' or 'komatiites' or 'graptolites,' they got very few or no results. When this occurred, students were quick to either (a) give up searching, or (b) switch to another search engine such as Google™ to continue searching for the needed information.

One such example of a student who quickly switched to searching on Google™ after not finding what was needed on DLESE, is illustrated in the following observation:

- **Start:**
- 12:57pm
- Robin: are you all done with this? (To Karen - referring to the pc)
- Karen: yes
- Robin does search for 'biogenicity criteria'
- [no results]
- Robin then searches for 'fossil life criteria'
- [no results]
- Robin then searches for 'life criteria'
- [Gets 2 results]
- 12:59pm
- Robin clicks on 'Nova PBS site'
- 1:00pm
- Robin [closes DLESE and goes to Google]
- **END**

Although some students were more successful at finding resources pertinent to their topic, the educational level of the material was not always appropriate. This issue led some students, like Jake, to express feelings of frustration with the library:

> *The way they have them sorted into different age groups or like levels I guess, I find that like totally inadequate. Because like you'll get like, the file we were like looking at was Life on Mars, and its like for every age range from like grad students to kindergarten kids, so we're sitting here trying to figure out this article and we have to really like search this article to find the parts that are pertinent to like people on our level.*

For other students, like Karen, the usefulness of DLESE declined as the semester progressed:

> *I think I tried using it and I think once I got past a certain point in the class, like I don't know if it was too advanced or it just wasn't covered on DLESE.*

> *For some things it's [DLESE] really good but for a majority of it, it's, there's a lot of stuff that's not on there. It's so hard to find exactly what you're looking for, and so many websites have, it has a little bit of yours and a lot of other stuff you know, that you are not looking for. And really there's not*

a lot of stuff on there, like I thought, there's a little bit, but.

Thus, although students were able to recognize some of the opportunities DLESE could provide to support their learning (e.g., access to different types of data, and the credibility of resources), these opportunities were not perceived as being great enough to overcome the perceived limitations of DLESE (e.g., functionality of the search engine, and lack of relevant or appropriate content).

Research Question 4: How do students use DLESE to support their learning in an inquiry-based geology course?

The students enrolled in this geology course found the obstacles to using DLESE to be too great to warrant any significant investment of time or energy into utilizing DLESE to support their learning. A number of rationales for not using DLESE were discussed by the students, including: (a) personal issues regarding computer use, (b) credibility issues with web resources, (c) negative experiences with DLESE, and (d) time and effort required to use web resources.

For example, Jackson was a self-professed anti-computer person (*"I'm not a real big computer person —I try to use computers as little as possible to tell you the truth"*) and thus cited this as one of his primary reasons for not making extensive use of DLESE. Another student, Drake, indicated that he was very comfortable and experienced with computers and WWW use, however, he expressed a strong critical stance towards information and resources found on the Internet:

> *I'm very queasy on using the Internet or an online library or anything like that just because I mean my roommate showed me websites that say we never landed on the moon and stuff you know. I can't whole heartedly believe everything that is on the Internet you know, so I can use it as a good start and say I've got this question and then you type it in on the Internet and you get a couple of hits, and you're like alright I think its that, and then you like go to a book, and you find out for real.*

Other students were more receptive to using web-based resources, such as those that could be found in DLESE. However, the negative first experiences that some students had with DLESE were a deterrent to their returning to the website. For example, Robin's first experiences with DLESE confronted her with a search mechanism that she found confusing. Consequently, she returned to using her regular search engines for finding geological information on the Web. Jake expressed similar sentiments regarding his experiences with DLESE and the impact those experiences had on his subsequent use of the digital library.

Finally, the use of web-based resources to support learning for some students was viewed as a much too laborious process to be worth their time. For example Jake stated:

> *You're discouraged from going on the Internet because you get on there and you are surfing to find something that's pertinent and if it's pertinent 'is it scholarly at all?', and if it is, even if it is scholarly, 'is it credible?' I mean, if you're going to be referencing it. So it's like you're adding, just by making your source the Internet source, you're adding work.*

In the final analysis, the majority of students sought alternative sources of information (e.g., teaching assistant, textbook, peers) and did not use DLESE to support their learning except when explicitly directed to do so as part of the inquiry-based assignment.

Implications of the Study

The main goal of this study was to ascertain the opportunities and challenges experienced by a geology professor and her students in using a digital library (DLESE) to support both teaching and learning in an inquiry-based undergraduate geology course. Both the professor and students in this case study experienced significant challenges using DLESE, leading them to utilize traditional search engines, such as Google™ to support their activities. These results have implications for both developers of digital libraries and instructors who are interested in using digital libraries to support their teaching and student learning.

Lessons for Digital Library Developers

A well-designed user-interface is a must. As Arms (2000) states, "When a system is hard to use, the users may fail to find important results, may misinterpret what they do find, or may give up in disgust. A digital library is only as good as its interface" (p. 160). Although, not all students experienced difficulty with the search features of DLESE, for those that did, their experience was negative enough to deter them from using DLESE again. This speaks to the importance of users' first experiences with a resource—for digital library developers it is of the utmost importance to ensure that the user-interface will not alienate potential users. The tools for finding, managing and using digital resources must be powerful and easy to use so that students can take full advantage of the digital resources (Marchionini & Maurer, 1995). Although the developers of DLESE have done extensive usability testing, based on the results of this case study there may be usability issues that still need to be resolved.

Second, the content coverage of the library is of utmost importance. While DLESE has promoted itself as a repository of web-based resources related to earth system science for all grade levels, clearly there are a number of topics and concepts related to geology that are not represented in the library. For a digital library to be beneficial to students, collections that are content rich and contain age-appropriate materials are needed (Wallace, Krajcik, & Soloway, 1996). It is acknowledged that the DLESE library is still growing and that resources are being added daily, but a formidable challenge that both the professor and students in this study faced was not being able to find relevant resources for their use. As the digital library continues to grow, developers inevitably need to strike a balance between the quality of resources and the scope of resources that should be included in the library. The content topics of this course, encompassing paleobiology, biostratigraphy, paleoecology, taphonomy, and macroevolutionary dynamics, were perhaps too esoteric for the resources accessioned into DLESE at the time of this study.

One potential solution would be to focus the growth of the collection on a narrower range of education levels, or on a narrower range of topics. With respect to undergraduate earth science courses, one potentially effective strategy could be to align DLESE resources with specific pedagogical strategies, such as inquiry-based learning. Another approach might be to align DLESE resources with best-selling textbooks, but such a direction might simply reinforce traditional pedagogy rather than inquiry-based learning. These decisions should be made based on input from current regular users of DLESE. In addition, these decisions should be explicitly stated and expressed on the DLESE web site, so that potential future users are clear about the focus and scope of the library, thereby reducing the level of frustration experienced by first time users.

Another potential solution would be for digital library developers to actively reach out to members of their intended audience, seeking input regarding resources and topics they would like to see covered in the library. DLESE was originally developed in response to a perceived need to improve earth science education at all levels, in both formal and informal contexts, and thus the students and professor in this case study are part of DLESE's primary target audience. Actively seeking to include resources on topics commonly covered in undergraduate geology courses would encourage and foster use of DLESE by both students and professors in the university geology community. Special collections for specific types and levels of undergraduate courses could be developed.

Finally, library developers need to carefully review the cataloguing procedures of library resources. Digital librarians face challenges in determining the range and distinctiveness of the metadata used with resources within a library (Marchionini, 1998). It may be the case that resources in DLESE are being labelled with search terms (metadata) that are not sufficiently specific, thus contributing to the number of 'no result' searches users encounter. As one student in this study, Jake, clearly stated, a digital library is ineffective in its mission to provide users to access with valuable resources if users cannot get that information out of the library because of weaknesses in the search mechanisms.

Lessons for Instructors

For instructors who are interested in using a digital library to support learning in an inquiry-based undergraduate classroom, the rationale for deciding to incorporate a digital library into classroom use

should be considered carefully. Results from this case study suggest that students hold a range of views and expectations related to issues such as computer use, acceptable sources of information (e.g., web-based vs. textbook or instructor), and perhaps even more importantly, perceptions of the time and effort that should be invested into finding additional information. Students' perceptions and expectations about these and other issues can significantly affect their willingness to adopt and use technology such as a digital library to support their learning. Therefore, instructors should be wary of making the assumption that all students are now skilled Internet users, much less members of the so-called Millennials or Net Generation (Howe & Strauss, 2000) who reportedly enjoy spending large amounts of time using Web-based resources. Most importantly, there is little evidence that today's college students have the critical web-evaluation skills necessary to effectively use web-based resources (Walton & Archer, 2004).

Secondly, the importance of choosing a digital library that contains resources that deal with topics that are covered throughout the course cannot be overstated. Although it seems like common sense, the assumption made at the outset of this study by both the instructor and the researcher was that there would be a number of useful resources for the topics covered in this advanced geology course in DLESE. Unfortunately this was not the case, as the few specific resources that did deal with relevant topics were not appropriate for undergraduate students. The instructor in this course concluded that DLESE appeared to be primarily populated with resources appropriate for K–12 education. If this perception is correct, then efforts to promote DLESE usage by postsecondary instructors may be misguided. If this perception is incorrect, then mechanisms to help undergraduate instructors more easily find and align DLESE resources with their plans for inquiry-based learning activities must be provided.

Finally, instructors wishing to incorporate use of a particular digital library into their course may need to design the learning tasks in such a way that it requires use of the digital library for completion. In this particular geology class, although DLESE was suggested as a resource to be used for completion of almost all Laboratory Exercises, it was only required for the completion of Laboratory Exercise 2. It was hoped that the mandatory use of DLESE early in the course would provide students with additional exposure to DLESE, and encourage future use, however this did not occur. Students expressed a preference for getting additional information in ways that were either most familiar to them or that they perceived to require the least amount of time and effort. Thus, most students relied on their textbook, the instructor or teaching assistant, or if necessary, web-based resources and search engines with which they were already comfortable such as Google™.

The bottom line is that most students are accustomed to using their textbook or asking another individual when faced with needing additional information or clarification of concepts or ideas. It is difficult for both instructors and students to move from an information giving and receiving mode to one that is primarily inquiry-based, and this change will not occur simply with access to a digital library and its resources (Wallace et al., 1996). Therefore, if an instructor wishes to promote a 'science as a verb' perspective, lessening students' dependence on highly structured textbooks and encouraging exploration of concepts and ideas using real-world web-based resources, then one suggestion may be to make the textbook optional in the course. This way, students may purchase the text if they feel it will provide useful information, but in addition, this strategy will promote the view that a textbook is just one of many possible sources of information rather than the sole source of information for learning in the course.

Conclusion

This research examined the belief that digital libraries can provide new opportunities to engage students in inquiry-based learning. Both students and the instructor in this study encountered significant challenges, and thus the vision of a technologically supported inquiry-based learning environment was left unrealized. However, the challenges faced by both the professor and students in utilizing the digital library to support their teaching and learning has brought to the fore a number of issues that can be useful for both developers of digital libraries and instructors of inquiry-based

courses.

Future research directions could include qualitative studies such as this one, which would provide a wealth of knowledge and insight into the perceptions, uses, and needs of instructors and students attempting to make use of a digital library to support their teaching and learning. This research could be based within this particular course, after refining the design of the inquiry activities to more fully incorporate use of DLESE resources, or it could be situated within a more general (perhaps introductory level) geology course. In addition, studies that utilize different digital libraries and alternative course designs would allow researchers to begin to identify the various factors and conditions that may enable the successful integration of digital libraries into inquiry-based classroom environments. These studies are necessary if we are to begin to take advantage of the numerous affordances of digital libraries as well as the compelling pedagogical strategy of inquiry-based learning.

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Appendix A
Sample Interview Questions

Student Interview

1. Talk me through the process of how you completed lab [x]
2. What did you do in class
3. What did you do at home
4. What resources did you use
5. What did you learn from this lab
6. Tell me about your experiences using DLESE
7. How frequently do you use DLESE
8. How useful is DLESE for your learning in this class?
9. How useful is it for your other classes?
10. Based on your experiences with DLESE thus far what changes if any would you recommend?

Instructor Interview

1. Tell me about the DLESE project you are planning to do and what was the impetus for it?
2. Tell me about some of your experiences with DLESE
3. Positives
4. Negatives
5. What recommendations do you have for ways that DLESE can be improved that would better suit your needs as an instructor? Your students' needs?
6. How much of a difference has DLESE made to your instruction? The way you teach?

7. What impact, if any, do you think having DLESE or the Internet available to students during lab time had on students learning?
8. Will/would you continue to provide students with Internet access during lab time?
9. Will you continue to promote DLESE as a resource to future students?
10. Do you think you will make greater use of DLESE in the future in your instruction?

Appendix B
Questionnaire Topics

Demographics

- Name
- Age
- Gender
- Academic Standing
- Major/Minor

Educational Background

- Prior Geology courses taken
- Current Courses enrolled
- Other science background
- Experience with Inquiry
- Comfort with collaborative learning

Technology Background

- Comfort with computers
- Comfort with WWW
- Skill with: Word processing software; email; WWW;
- Familarity with DLESE

DLESE Specific

- Time spent using DESE
- Usefulness of DLESE for supporting learning
- Difficulties using DLESE

Course Specific

- Activities enjoyed most
- Activities in need of improvement
- Challenging aspects of course
- Factors that impacted learning

Other

- Level of motivation for learning in this course
- Anticipated time to spend outside of class for this course

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