SUPPORTING DATA-RICH INQUIRIES ON THE WORLD-WIDE-WEB

Eleni A. Kyza

ABSTRACT
Data-driven inquiries that resemble authentic scientific tasks are seen as one of the primary ways that could facilitate students' development of scientific reasoning skills and contribute to their understanding of the nature of science. However, the literature reports that students at the middle school level face substantial challenges when attempting to construct scientific explanations of complex data and that they need to be scaffolded to engage in a reflective examination of their data. Reflective inquiry has been defined in the literature in many ways, often as a set of practices that help the inquirer adopt a critical orientation on their process, such as monitoring and evaluating one's progress, and often with the explicit goal of producing evidence-based explanations. A review of the literature on existing web-based, scientific inquiry environments indicates that with a few exceptions, which will be discussed in the paper, most web-based investigations offer minimal support for reflecting on one's inquiry. The goal of this paper is two-fold: first, I present a review of four exemplary web-based inquiry science learning environments and strategies they adopt to scaffold data-rich inquiries on the web. Then, I describe the design elements of a web-based, data-rich inquiry environment that has the potential to support students in engaging in reflective inquiry online.

KEYWORDS
Science education, web-based learning, educational technology, inquiry-based learning, design of learning environments.

INTRODUCTION

One of the primary aims of education today is to develop self-regulating learners, who can monitor their ongoing understanding, can assess what they know in each learning situation and what they still need to know, and can employ cognitive strategies appropriately to help them attain their goal. Recent reform calls emphasize the role of inquiry in the teaching and learning of science as the way to enculturate students into the world of science. The model of inquiry put forth is one that resembles authentic scientific practices: like scientists, students work collaboratively and largely independently to solve complex, data-rich problems and construct evidence-based explanations of natural phenomena. Data-rich inquiries that resemble authentic scientific tasks are seen as one of the primary ways that could facilitate students' development of scientific reasoning skills and contribute to their understanding of the nature of science and the construction of evidence-based scientific explanations (AAAS, 1993; NRC, 1996). Several theorists and researchers alike have proposed that in order to successfully engage with data-rich problems students need to be reflective inquirers (Davis, 2003; Dewey, 1933; Quintana *et al.*, 2004; Reiser, 2004; White & Frederiksen, 1998). Reflective inquiry has been defined in the literature in many ways, often as a set of practices that help the inquirer adopt a critical orientation towards their process, such as monitoring and evaluating one's progress (Kyza & Edelson, 2003; Loh *et al.*, 1998), and often with the explicit goal of producing evidence-based explanations (Sandoval & Reiser, 2004). Reflection, the ability to monitor one's past and current progress and evaluate actions in a way that informs future planning is one of the qualities that can help learners self-regulate their behavior. Dewey (1933) even argued that reflective thinking is what distinguishes intelligent behaviour from impulsive actions. The argument is that often students are not being reflective in their inquiry, either because they ignore or minimize the importance of engaging in reflective practices or because they need additional support in order to be reflective. However, it is a reflective orientation to learning, and in particular to science learning, that can support students in making sense of scientific phenomena, developing evidence-based explanations and self-regulating one's learning. All too often, the instruction of science consists mostly of memorizing facts or practicing scientific process skills without any sense-making and any understanding of how the knowledge is meaningful for some purpose (Chinn & Malhotra, 2002; Kesidou & Roseman, 2002). Thus, an emphasis on higher-order skills is an attempt to overcome this reported departmentalization of knowledge towards a more integrated view of how to teach and learn about science.

The paper is organized as follows: it begins with a discussion of the promise of the World Wide Web in supporting inquiry-based learning, and continues with a discussion of existing research on the effectiveness of web-based environments to achieve this promise. The next section of the paper presents a review of inquiry and web-based learning environments. In each of the four learning environments presented, I first give a brief overview of the project's objectives and guiding principles, and then analyze the design of the environment along the following two dimensions: a) How is the Web being used in supporting data-rich inquiries? and, b) how is the Web being used in supporting reflective inquiry? I conclude with a discussion of a new web-based environment that builds on existing efforts for supporting students in engaging reflectively in inquiry-based science.

THE PROMISE OF THE WORLD WIDE WEB TECHNOLOGIES

The advent of the World Wide Web (Web/WWW) in 1990 has spurred a plethora of promises about how this new technology would revolutionize learning. Indeed, the Web has offered us immense opportunities for accessing and exchanging information, starting with plain text and currently supporting the downloading of streaming audio and video on-demand. The structure of the Web as a medium that transcends time-related, geopolitical, and often technical constraints while it supports multi-modal presentation of information and allows for interactivity makes it ideal for use in educational settings across borders. The Web is cross-platform, in the sense that with little modifications most web-based applications can run on most operating systems; it is portable, meaning that any computer capable of connecting to the internet can access it and can have access to files stored on remote servers; it is flexible, in the sense that, if designed as such, it can support multiple languages with little modifications; and finally, it facilitates communication by enabling the almost instant sharing of information. These features make the web a desirable medium for developing technology-enhanced learning environments as well as supporting the goals of science education, such as public sharing and critiquing of knowledge, and facilitating information exchange and collaboration in an increasingly global society. In this article, we review existing literature on how the Web has been used up to now to promote learning in science, focusing especially on the potential of this technology for promoting a reflective stance towards learning, by supporting students in analyzing and explaining scientific information.

INQUIRY ON THE WEB

Since the creation of the WWW in the early 1990's and a multitude of educational web sites later created with the intention to enhance learning, there is a still a scarcity of research-based reports of how the World Wide Web could support learning (Windschitl, 1998). From the limited number of research-based articles, it appears that in spite of the potential of the Web for enriched learning opportunities there are frequent mentions in the literature that the tool is being used in very limited ways (Owston, 1997; Windschitl, 1998). The recurrent theme in the literature is that pedagogically speaking the sites are far behind current accepted ideas of how people learn: e.g. interactivity is limited and when there is some interactivity it is usually based on predefined scripts; many educational websites resemble textbooks, few support inquiry pedagogy. The report by Mioduser et al. (2000) is one such mention. Mioduser et al. reviewed 436 educational web sites on the subjects of mathematics, science, and technology using a taxonomy which included issues of pedagogy (e.g. interactivity, locus of control, cognitive processes potentially elicited). Their findings indicate that most educational web sites in these three domains were text-based and did not take advantage of the advanced capabilities of the medium. For instance, less than 28% of the sites reviewed supported inquiry learning and less than 3% of the sites were found to support online collaborative work. In another analysis of science education sites (focusing on atomic structure in particular), Tuvi & Nachmias (2001) report that none of the 95 sites examined supported inquiry learning while only 8.4% supported some data analysis or problem solving. In their review of 465 science education websites, Mioduser et al. (2000) concluded that web-based learning environments were "one step forward for technology, two steps back for pedagogy", meaning that even though there have been remarkable technological advances enabling new representation and communication technologies such as data visualization and multi-modal sharing of ideas at a distance, the pedagogy employed to design the learning environment often does not adhere to even basic and widely accepted instructional principles, such as providing opportunities for constructivist engagement and providing feedback.

SAME OLD PROBLEM, NEW FACE?

In a way though, the problem identified by Mioduser et al. is not novel. The challenges to implement inquiry learning, regardless of the medium of delivery, have been documented quite strongly in the literature. For instance, the analysis conducted by Chinn and Malhotra (2002) showed that in spite of the inquiry rhetoric many textbooks and curricular materials are still designed in very traditional ways, which do not take into account recent findings about how people learn, and in particular constructivist ideas about learning, the importance of acquiring life-long learning skills, such as being able to self-regulate and reflect on one's learning. Simply put, just because the technology has advanced does not warrantee that its potential will be appropriately employed.

Early attempts at designing learning environments that use the internet for teaching and learning science labelled "network science" (Feldman & Coulter, 2000) also indicated that the designers and the inquiry projects faced several difficulties in being successful in changing classroom cultures and practices. The hindrances to the use of the web according to reform ideas are not only related to instructional and technical design. Moving away from the structure of the websites per se and towards students' use of the new technology, research shows that middle school students' early attempts to use the web resulted to many but surface-deep interactions, even in the case when the technology provided support for more complex behaviour (Wallace *et al.*, 2000). Wallace et al. also report that, in their study, even though sixth graders could use a web browser quite easily, they misinterpreted the task as presented to them by their instructor and used different criteria to assess when the task was completed. In summary, it appears that there is a scarcity of web sites whose design philosophy has embraced the new reform ideas (e.g. AAAS, 2001; NRC, 1996) and that, even in the case that an inquiry environment is available, the designers of inquiry learning environments on the web should do more to scaffold the users in engaging in meaningful and in-depth inquiries.

Reform based initiatives emphasize that learners need to assume more responsibility for their own learning than what has been traditionally expected from them. This also means that students need to be scaffolded in the Vygotskian way, meaning that they should be supported within their zone of proximal development (ZPD) in developing life-long learning skills that will eventually be self-sustained long after the scaffolding fades away. Reflective scaffolding, scaffolding that supports students' thoughtful and critical engagement with the learning of the content, is considered by several researchers as contributing to students' self-regulated inquiry learning.

A REVIEW OF SUCCESSFUL WEB-BASED INQUIRY ENVIRONMENTS

We next review four web-based inquiry environments in science. These environments were selected because they are frequently mentioned in the science education literature as exemplary projects with the goal of promoting inquiry science, changing teaching and learning practices and taking advantage of the unique affordances of the internet as a medium to facilitate inquiry. They share several common elements, such as all being funded in partly or completely by the U.S. National Science Foundation; having a design team which had an extensive background in developing innovative scientific curricula and which included several persons with different backgrounds (e.g. teachers, researchers, scientists); extensively researching and redesigning their tools iteratively, and putting pedagogy rather than the web's mere technical capabilities first. Table 1 lists the four inquiry environments.

Table 1. Web-based learning environments in science reviewed.

Project name	**Uniform Resource Locator**
The Learning through Scientific Collaborative Visualization project (COVIS)	http://www.covis.nwu.edu/
The Knowledge Integration Environment (KIE) and its successor Web-based integrated Science Environments (WISE)	http://wise.berkeley.edu
Kids as Global Scientists (KGS), and	http://www.onesky.umich.edu/kgs01.html
Global Learning and Observations to Benefit the Environment (GLOBE)	http://www.globe.gov

The goal of this selective review is to examine these exemplary projects and extract the ways that these environments attempt to support students first in engaging in data-rich inquiries on the web, and second in supporting them to engage in inquiry reflectively. Table 2 presents an overview of the four environments, along four dimensions: the goals of each project, whether the project includes material (such as curriculum) which is not included in the web-based environment and the web-based components, and their purpose.

Table 2. A summary of the web-based learning environments reviewed

Project name	**Project goals**	**Completely web-based?**	**Web-based components**	**Main purposes of web components**
CoVis	Scientific visualization using scientists' tools adapted for middle and high school students.	No	-Weather visualizer -Greenhouse Effect Visualizer -Collaboratory Notebook -Mentor database	1. Retrieving and representing weather data online. 2. Enabling communication between 50 schools across the USA.
KIE/WISE	-To promote knowledge integration about science using new technology -Scaffold students in critically evaluating web resources -Guide students in becoming autonomous, lifelong-learners.	No	-Evidence/ information pages -Inquiry Map -Assessments -Hints on demand -Notes/Journal	1. Emphasizing the role of evidence and providing a structure that helps students engage in evidence-based reasoning. 2.Providing adequate structure guiding the students' process while allowing them to self-regulate their learning.
KGS	-Using innovative technologies such as the internet for	No	-Weather View tool for visualizing real-time or archived	1.Hypercard front-end to enable a user-friendly method for

Project name	Project goals	Completely web-based?	Web-based components	Main purposes of web components
	promoting learning in science. The specific learning topic was atmospheric sciences.		weather data. -Message Board	collecting and visualizing data. 2. Message board used to facilitate communication between weather specialists and students, or between students themselves.
Globe	-To help students improve their understanding of and practice scientific inquiry -To increase existing scientific knowledge of the Earth	No	-Scientific protocols -Databank for uploading local data -Visualizer tool for representing the data retrieved from the project's databank	1. Sharing scientific information: protocols 2. Uploading and downloading data 3. Scientific visualizations of the data. 2. Communication between experts and students, and students across sites.

Following, I present a more detailed discussion of each of the inquiry environment. For each, I first offer a ***brief description***, describe the ***main features of the web based environment*** and how they are used to promote inquiry learning, and then discuss how the designers attempted to support ***student reflection***.

1. The Learning through Scientific Collaborative Visualization project (CoVis)

1.1 Brief description

The CoVis project was created by researchers at Northwestern University and funded by the US National Science Foundation (NSF). The designers of CoVis state that the project had three foci: a) it was project-based inquiry, b) it provided students with expert scientific visualization tools that enable them to engage in the same practices as those of the scientists in the field; c) it used internet and web-based technologies to support meaningful collaboration of students across the USA (Edelson *et al.*, 1996).

1.2 How the web-based learning environment supports inquiry-based science

The Weather Visualizer, which is one of the CoVis tools, automatically retrieves real-time weather data from the Web, which are then visualized for the user/learner. The transformation of the data from tabular to iconic makes use of visualization, a rather recent technique for data analysis, also reported by the designers, has revolutionized many scientific fields. The web-based nature of project CoVis afforded the retrieval and transformation of weather data: in specific, a front-end interface could download real-time data from world-wide, web-based data banks on demand. Without this feature, it would be extremely difficult for students to collect the breadth of data otherwise available to them through CoVis. Furthermore, if it were not for the "Weather Visualizer" tool, the visualization engine of CoVis students would have to spend an enormous amount of time to transform the data in way that they could start making sense of the data. Finally, the communication tools of CoVis (e.g. the Collaboratory Notebook tool) offered students the possibility to exchange data and engage in peer-critiquing or web-based discussions across geographic borders. One of the primary goals of project CoVis was to enable students to engage in authentic scientific practices, which meant using sophisticated scientific tools. To do this, the designers created tools that integrated techniques that scientists use on a daily basis and adapted those to the needs of the intended learners. Without this adaptation, which in this case enabled the students to automatically retrieve and visualize quantitative data, it would be very time-consuming for all students to transform the data for interpretation purposes

1.3 How CoVis supported web-based reflective inquiry

All of the CoVis tools were designed to support inquiry; the reflective inquiry support can be seen in the features of the Collaboratory Notebook (CN) in particular. Modelled after a scientists' notebook, with appropriate guidance by the teacher or one of the science mentors, who were an integral part of project CoVis, CN can serve as a place for students to record notes about hypotheses, plans, observations, interpretations, and further questions to pursue (Edelson, 1998). Students can also read and critique other groups' CN pages. Software supports for reflective inquiry can be seen in features such as the labelling of pages according the inquiry purpose they serve, such as "plan, evidence-for, evidence-against), and the ability to link the notebook pages to each other. The teacher or science mentor facilitation is also critical to encouraging the students to evaluate and reconsider their actions, as well as in planning follow-up actions. It is important to note the flexibility of the notebook feature, in that, notebook pages can be created and labelled as desired by either the teacher or the students. As such, the labels of the notebook pages can be modified according to the individual project or according to the ideas the student wants to convey. One of the basic tenets of the project was giving students the ability to converse with selected peers and experts around the United States, taking advantage of the inexpensive and quick electronic communication. The research behind CoVis has suggested that having an audience by interacting with peers and experts about one's work could create conditions for sustained reflection, as indicated in students' preoccupation with the quality of their work prior to communicating with other members of their community.

2. Knowledge Integration Environment (KIE) and Web-based Inquiry Science Environment (WISE)

2.1 Brief description

The primary goals behind KIE/WISE were to create scaffolded online learning environments. The design of the KIE/WISE environments was guided by the following four tenets, which seek to make science meaningful and support students in engaging in inquiry on the web: making science accessible, making thinking visible, helping students learn from each other, and promoting lifelong science learning (Linn, 2000). Currently, WISE includes a library of inquiry projects in several languages, with 25 of them being in the English language; each project is intended to support students in exploring scientific problems that have the potential to be meaningful to students (e.g. the deformed frogs mystery), critically evaluate internet-based data, and prepare for debates as to which explanation of the problem is more scientifically valid.

2.2 How the web-based learning environment supports inquiry-based science

One of the key goals of KIE/WISE is to guide students in critically evaluating information found on the web, as it relates to the scientific problem that they are investigating. To do so, KIE/WISE integrate a variety of tools (Bell & Davis, 2000), such as SenseMaker, which is a web-based tool that supports students in organizing evidence and constructing an argument, and Mildred, the cow guide. The latter is a cognitive software guide that can facilitates the annotation and explanation of evidence, and provides hints on demand that serve to probe student thinking. Support for inquiry is also derived from activities off the computer. For instance, Linn (2000) reports that the curriculum design assumes that students will spend time at the onset of the project to negotiate criteria for what is an adequate scientific explanation.

2.3 How KIE/WISE support web-based reflective inquiry

The design team of KIE and subsequently of WISE paid particular attention to scaffolding reflection on the web, carefully trying to provide structure and guidance while preserving student autonomy. Both learning environments have been extensively researched by several researchers around the world. The following key features in the web-based learning environment were intended to provide reflective support.

- A representation of the sequence of activities, in the form of a checklist, intended to provide reminders to students as to what has been completed and what still needs to be done**.**
- Advance organizers, such as evidence pages, that can be customized by the instructional designer.
- Online asynchronous communication tools, such as the Multimedia Forum Kiosk (Hoadley et al., 1995) that have been shown to allow time for reflection and response, and have been found to increase student participation (Hsi, 1997).
- Prompts for reflection. Davis (2003) has shown evidence that generic prompts facilitate reflection more than directed prompts.
- Guidance in the form of hints, presented on demand (like Mildred the Cow guide, or Amanda the Panda). This feature has been called a "cognitive guidance tool" (Davis & Miyake, 2004), since the purpose behind its design was to make expert thinking visible to students and guide them accordingly when they request help from the system.
- Notes/journal section where students can save notes of important information.
- Show/tell feature allowing students to selectively share web pages showing their work with peers.

3. Kids as Global Scientists project (KGS)

3.1 Brief description

The KGS project focuses on learning about the weather using real-time data from the Internet and was designed by a multi-disciplinary team, which included computer scientists, teachers, and researchers at a US research university (Songer, 1996). The KGS project can be seen as consisting of two phases: the Research phase, in which students engage in scaffolded activities with the goal of understanding the local manifestation of a phenomenon, and the Exchange phase, during which the students exchange information with peers in other geographic locations, with the goal of expanding their current knowledge beyond the local level.

3.2 How the KGS learning environment supports web-based inquiry

The KGS project includes a problem- based curriculum design effort, the Global Exchange curriculum, in which the use of new technologies in the form of internet-based tools has a prominent role: students inquire about weather patterns in their local area by analyzing visualizations of weather and climate data they can download from real-time professional weather services such as Intellicast using a hyper-card front end, which facilitates the access to the data. They can then compare patterns and interpretations of phenomena to those of other students in other parts of the United States. The students are then expected to discuss their findings and explanations with peers or atmospheric sciences experts using an online communication system. To support students in engaging in data-rich inquiries using the web-based interface, the designers of KGS found that they had to modify the scientific data available on the web and adapt them to the level of difficulty appropriate for middle-school students.

3.3 How KGS supports web-based reflective inquiry

The KGS project places emphasis on scaffolding reflection (Songer, 1996). In the first phase of the program, the Research phase, this support for reflection is mostly provided by activities off the computer, such as peer discussions and interactions between the students and mentors (teachers or expert scientists). During the second phase of the program, the Exchange phase, the students engaged in a process of questioning peers in other locations; this can be seen as a reflective process of furthering their understanding of what the knowledge accumulated during the exploration of the local phenomenon. The activities in this phase culminated with another reflective activity, that of producing a summary of the students' inquiry activities and the knowledge that resulted because of these.

4. Global Learning and Observations to Benefit the Environment (GLOBE)

4.1 Brief description

Project GLOBE is an international environmental science project which uses the web to enable students and scientists around the world to exchange scientific information about their local environments. Students use scientific measurement protocols designed by teams of scientists and educators to collect local data which are then uploaded to a database and added to similar data from other parts of the world. Students can also download collected data in the form of visualizations to use for analyses and comparisons to the data they had investigated in order to gain a deeper understanding of the phenomenon investigated. Students can also discuss their procedures, findings and interpretations with students around the world using an internet-based forum and can collaborate selectively via the web with other groups of students working with the same unit.

4.2 How the GLOBE learning environment supports web-based inquiry

GLOBE focuses on enabling students engage in the same kind of inquiry that practicing scientists use, offering the opportunity to collect data from remote places around the globe. Project GLOBE uses the web to contribute to the building of a global environmental databank, visualize data and to enable participants to communicate online. As it has been used by thousands of classrooms in many countries around the world this kind of give and take of data would be impossible without the use of the web.

4.3 How project GLOBE supports web-based reflective inquiry

GLOBE does not have any web-based features that can support student reflection. Rather, it assumes that such pedagogical interventions will be decided at the local level and it thus left upon the individual teacher to do so.

Common techniques among the four projects for supporting inquiry on the web

The four network science projects presented in this paper capitalized on two powerful sets of features of the web: a) the capability to exchange, retrieve and dynamically display information such as scientific data and primary sources of information, and b) the capability of communication between distant participants synchronously and asynchronously (e.g. via email, online chats, video-conferences). One could argue that these features are commonly used in educational web sites. However, in the case of the four projects showcased, and in contrast to several other educational sites, these two capabilities were only the starting point for the design of the learning environment. Each of the multidisciplinary design team attended to the following issues that guided the iterative design of the learning environment:

- Choice of driving questions which were relevant to students' lives (e.g. local weather patterns) and as such could be motivating and meaningful to them.
- Adaptation of expert tools to address the needs of the novice target population (predominantly) middle-school students). The designers modified the data (project GLOBE) or the presentation of the data (GLOBE, CoVis, KGS), so that they were at an appropriate level for the target population. For instance, Projects CoVis and KGS provided front-end interfaces that retrieved data from the internet and re-represented them as visualizations, which afford analyses that are considered more appropriate to answer the questions presented by each project.
- The features of the web technology were used to serve the science education goals and not the other way around. For example, engaging students in sharing and critiquing each other's work introduces the students into what is considered a common and highly valued practice among members of the scientific community at large.
- A variety of scaffolds were put in place to support students' inquiry. This scaffolding was of different types: social (students were required to collaborate on most occasions), teacher-initiated, or technology-based. It was the combination of interactions off and on the web that made these projects successful and not the mere presence of a web-based learning environment. This is an important point in that it needs to be carefully considered during the

design phase and should not be assumed that the technology will automatically be the catalyst for successful learning.

- The learning environment on the web was accompanied by curriculum materials (e.g. activities that needed to take place prior to the use of the web or concurrently) as well as guidebooks for the teachers.

It is important to emphasize the iterative nature of this design, since some of the challenges that emerged, such as the amount and kind of support that the teachers needed to enact the curriculum, were not obvious until the project was running in classrooms for the first time.

Supporting reflective inquiry on the web

Each of the design teams for the four projects reported at different points in the history of each project that reflective inquiry was important if students were to successfully engage in inquiry. However, it is known from the literature that students at the middle school level face substantial challenges in managing investigations (Carey et al., 1989; Schauble et al., 1995), do not always take the time to plan and reflect on their actions (Shute *et al.*, 1989), do not often distinguish between hypotheses and evidence-based explanations (Kuhn, 1989; Kuhn et al., 1988; Osborne & Freyberg, 1985), often interpret their data without considering theories (Ryder & Leach, 2000), or do not distinguish between the description of the evidence and the interpretation of the evidence (Allen *et al.*, 1983), and have difficulties in making sense of complex data (Radinsky, 2000). Furthermore, it has been reported that students may create explanations that are not supported by the data they had examined, or may fail to cite the evidence that supports their explanations (Sandoval, 2003) and that they may not attend to alternative explanations of the interpreted data, in spite of being able to do so when specifically requested by their teacher (Kyza, 2004). Such problems suggest that students need to be scaffolded to engage in a reflective examination of their data. These problems indicate that students need to be supported in engaging in *reflective inquiry* (Loh, 2003; Loh *et al.*, 1997; Radinsky, 2000; Tabak *et al.*, 1998).

The four web-based learning environments reviewed in this paper use a combination of software-based and off the computer features to support students' adopting a reflective stance towards their work with science. For environments such as CoViS and KGS reflection is supported through guiding students' asynchronous communication with other peers and mentors. Project GLOBE as it stands places emphasis on enabling inquiry using internet-based data, but includes no specific reflective scaffolding other than a communication portal accessed through the project's web site. However, the KIE/WISE team addressed the issue of reflection comprehensively, by attending to issues that are important to making sense of science inquiries but which have been traditionally shown to present serious difficulties. These are no more than explaining phenomena, providing evidence for and against a hypothesis, monitoring progress, etc.

STOCHASMOS: A design effort to support reflection in inquiry-based science on the WWW

The review of the literature and of existing web-based inquiry environments in science we have discussed thus far, indicates that, with a few exceptions, most web-based investigations offer minimal support for reflecting on one's inquiry. The four projects described begun soon after the introduction of the Web and served as test beds of how inquiry science could be made possible using the Internet technology. Lessons learned suggest that the design of web-based learning environments needs to attend to creating sites that afford meaningful interactivity and scaffolding the learning process such as structuring the task to avoid getting lost in the available information.

Informed by work such as the one described in this paper, our research team at the University of Cyprus is currently in the process of designing and investigating a web-based learning environment with embedded supports for reflective inquiry (for more information see http://www.stochasmos.org). The tool will offer an authoring system, which will allow curriculum designers to easily author inquiry environments for learning that incorporate reflective supports, in the forms of prompts, and areas for articulating data interpretations and explaining findings. This work builds on prior work with a non web-based software application, the Progress Portfolio (Loh et al., 1997) and the research conducted by the author (Kyza, 2004) and other researchers on scaffolding students' inquiries in science using computer-based tools (e.g. Loh, 2003, Sandoval, 2003, Davis, 2003). Findings from this work showed that reflective support in the form of prompts embedded in an interactive inquiry-support tool, such as the Progress Portfolio, has the potential to support students in engaging in reflective conversations about their data, which can, in turn, inform their self-regulated investigations in data-rich inquiries in science.

The aim of the scaffolding in STOCHASMOS will be to support students in making sense of the data and in constructing evidence-based, scientific explanations of the phenomenon under investigation. What is unique about this new environment, when compared with other web-based and problem-based environments reported in the literature is its interactive nature and inquiry scaffolding. Borrowing from the Progress Portfolio work, it will provide a work-space where students will be able to capture the data they believe can be used as evidence in special-purpose template pages and folders they will create on demand. The environment will automatically save selected data in the form of images and students will be able to organize and retrieve them throughout the investigation. Another novel element of the environment is that it will allow students to share and comment on other groups' scientific explanations online, which, with the appropriate curricular activity support, has the potential to engage students in the process of communicating and defending their explanations to others – skills associated with argumentative practices at the heart of scientific inquiry.

CONCLUSION

The Web is a promising medium for instruction, since it can provide instant access to instructional materials even to students in remote geographic areas, facilitate communication among peers and teachers, and afford the easy management and monitoring of the learning sites and of students' work. However, a review of existing learning environments shows that web-based instructional materials have not caught up to the theory of learning, which has long moved beyond the information transmission paradigm. At present, only few web-based environments offer opportunities for students to engage in inquiry-based science, while even fewer learning environments provide some embedded reflective guidance. Research reports suggest that students tend to use the web for engagements of lower-order type, even within projects that can foster higher-order reasoning (Oliver & Hannafin, 2000, Krajcik, et al. 1998). These findings suggest that we need to reconsider the design of environments that promote higher order thinking skills. In this paper, I argue that one of the ways to do so is to scaffold students in self-regulating their learning by providing support for online reflection.

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Eleni A. Kyza
13 Voulgare St., apt. 202
Strovolos, Nicosia
2014, CYPRUS
Email: ekyza@ucy.ac.cy