

# THE RATIONALE, DESIGN, AND IMPLEMENTATION OF A WEB-BASED INQUIRY LEARNING ENVIRONMENT

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## ABSTRACT

It is reported that, without appropriate support, students might face several difficulties when engaging in high-level reasoning in science. This paper discusses the design of a software-based tool to support students' inquiry. This scaffolding is provided through the use of STOCHASMOS, a web-based platform designed to support teachers' authoring of inquiry-based learning environments and students' reflective inquiry practices. In this paper, we present the theoretical background supporting the development of STOCHASMOS, present the platform and discuss findings from a classroom study. The results have wider implications for the design of web-based learning environments and for the role of self- and group-reflections in facilitating inquiry processes with scientific data.

## KEYWORDS

Reflection, inquiry, scaffolding, science education, web-based platforms, WWW

## INTRODUCTION

Inquiry is seen by theorists, reformers and educators as one of the primary ways for students to learn science (AAAS, 1993; Dewey, 1910; NRC, 2002). According to the United States National Science Education Standards (NRC, 1996)

“Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations.” [NRC, National Academy of Sciences, National Science Education Standards, 1996 Chapter 2, p.23]

However, there is no one single definition as to how to engage in inquiry, as the approach can vary across disciplines but also depending on the research questions asked. The NRC definition reflects the complexity and foregrounds the challenges teachers face when deciding to adopt inquiry-based learning and teaching. Above all, though, the most enduring message sent by organizations such as the NRC is that all students, whether they ultimately choose to become scientists or not, need to become scientifically literate by doing science, not by simply learning about science. One of the instructional challenges in orchestrating learning by inquiry is finding resources that can sustain students' interest in answering scientific questions that are personally motivating, while at the same time helping students develop scientific reasoning skills. One of the learning challenges in approaching learning via inquiry is supporting students in making sense of information and gradually becoming self-regulated learners.

In this paper, we describe the development and empirical examination of STOCHASMOS (Kyza & Constantinou, 2007), a web-based teaching and learning platform, designed to empower teachers in

building or customizing learning environments that cater to their students' interests, while embedding scaffolding their students might need to engage in complex reasoning about the world around them. We believe that environments like STOCHASMOS can support the development of current and authentic learning environments, can give teachers the ability to customize them to meet their students' needs, and can support learners as they make sense of web-based, data-rich environments.

We next describe our approach in designing STOCHASMOS: we first explain the theoretical framework on which the platform was based and, then, present and explain the different parts of the learning and teaching platform. Finally, we report on classroom implementation studies of STOCHASMOS and discuss existing empirical findings.

## CONCEPTUAL FRAMEWORK

Students need help in order to manage the complexity of data-driven inquiries. The need for reflective inquiry scaffolding, especially when students are engaged in complex investigations, has been extensively discussed in previous research (Davis, 1998; White & Frederiksen, 1998). Scaffolding can take on different forms; in this paper, we focus on software-based scaffolding designed to support students' self-regulated engagement in reflective inquiry practices. Without appropriate scaffolding, it is reported that it might be difficult for many students to engage in high-level reasoning when dealing with data-rich environments.

### Reflective Inquiry

Reflection is an important component of high-level thinking (Dewey, 1910). Reflective practices, such as ongoing monitoring and evaluating one's process and products, are especially important in inquiry-based science, where students are asked to take an inquisitive role towards learning and assume responsibility of regulating their problem-solving activities. Students are reported to face several challenges when engaging in open-ended, data-rich, inquiry investigations that relate to such issues as managing large data sets, keeping descriptions and interpretations of the data distinct, interpreting data as they relate to hypotheses, and construct evidence-based explanations (Kuhn, 1989; Kyza, 2004; Sandoval, 2003; Schauble *et al.*, 1991). In order to solve these problems students need to coordinate their cognitive and metacognitive strategies (Reiser, 2002) and engage in reflective inquiry. Traditionally, reflection is something reserved for the end of the learning sequence (Loh, 2003); this operationalization of reflection is problematic in that a reflective stance to learning is necessary throughout the learning process in constructivist, student-led environments, such as the ones created by introducing inquiry-based approaches to learning and teaching. In this paper, we discuss a software-based scaffolding mechanism for changing classroom practices and making reflection an essential part of engaging in inquiry.

### Scaffolding

Scaffolding (Wood *et al.*, 1976) is based upon the work of L. Vygotsky, and can be defined as the support that one receives from a more knowledgeable adult or peer to help them move within their zone of proximal development and engage in activities that would have been challenging, if not impossible, without this support. Ultimately, scaffolding should fade as the learner becomes able to perform the same or a similar activity on their own. In this paper, we discuss the role of software-scaffolding, as one of the interacting agents in supporting students' reflective inquiry learning. We also view the classroom as a complex system where scaffolding provided by the technology, by the teacher and peers needs to work in synergy. This scaffolding is faded in the sense that students may depend on it more at the beginning of the investigation to help them organize their ideas and may gradually internalize it.

### Web-based learning environments for supporting inquiry-based science

There are but a few software tools available to directly support student reflection in science, even though the literature suggests that students at the middle school level face several challenges when asked to engage in higher-order reasoning, such as the skills involved in solving complex and data-rich problems (Carey *et al.*, 1989; Edelson *et al.*, 1999; Kuhn *et al.*, 1988; Sandoval, 2003). Even though

there are several attempts to design web pages for inquiry-based learning it appears that few online learning environments embed scaffolding to support student learning (Soloway et al., 2000). Examples of environments whose development has been guided by an explicit intent to include pedagogical scaffolds based on findings of empirical research on student cognition in science, include ARTEMIS (Wallace et al., 1998), a digital library to support student searching and learning on the internet, IDEAKEEPER (Zhang & Quintana, 2005) an environment to further support making sense of data online, and KIE/WISE (Linn, 2003) an environment that supports teachers in authoring their own web-based inquiry while providing scaffolds to support student learning. At the core of these environments is the use of scaffolding strategies in order to engage the learner and sustain the interactivity between the system, the content, and the user. There are several research reports on these environments suggesting that the scaffolding used can support students in engaging in online inquiry: for instance, software-based prompting can help students make sense of online data (Davis, 2003). Our work builds on existing work such as the one mentioned above. Furthermore, the work described in this paper seeks to capitalize on lessons learned from the empirical research of web-based and standalone software tools.

Examples of reflective inquiry scaffolding include the prompts and notepad feature of the WISE environment seek to support students in being reflective. One other example of supporting reflective inquiry is the Progress Portfolio (Loh et al., 1997), a stand-alone, inquiry-support software tool that provides a separate space where students can organize data, and are prompted to explain their reasoning while making connections to the data they can use as evidence in support of their ideas. Prior qualitative work has suggested that the use of inquiry-support tools such as the Progress Portfolio has the capability of scaffolding students' sense-making in science (Kyza, 2004). However, such support is absent from many online environments, and this is the kind of support that the STOCHASMOS learning environment is seeking to provide.

## STOCHASMOS: A WEB-BASED PLATFORM FOR LEARNING AND TEACHING

In order to support students' reflective inquiry practices, we have designed a web-based platform, STOCHASMOS, which is comprised of two environments: the teacher authoring environment, in which teachers can build or customize multi-modal, web-based inquiry environments, and the learning environment for the students, where students can collect and organize data, explain their thinking, interpret and construct explanations of the data. For each inquiry environment teachers can design template pages, accessible through the Work Space area. These templates can help structure student work around important ideas, such as connecting data to hypotheses. The Work Space also provides guidance in the form of prompts and articulation boxes, which are also customizable at the level of access of the individual teacher. Figure 1 shows an example of the students' inquiry environment while Figure 2 is a screenshot of the STOCHASMOS Work Space area, customized for the inquiry investigation "The Larnaca Salt Lake Flamingos".

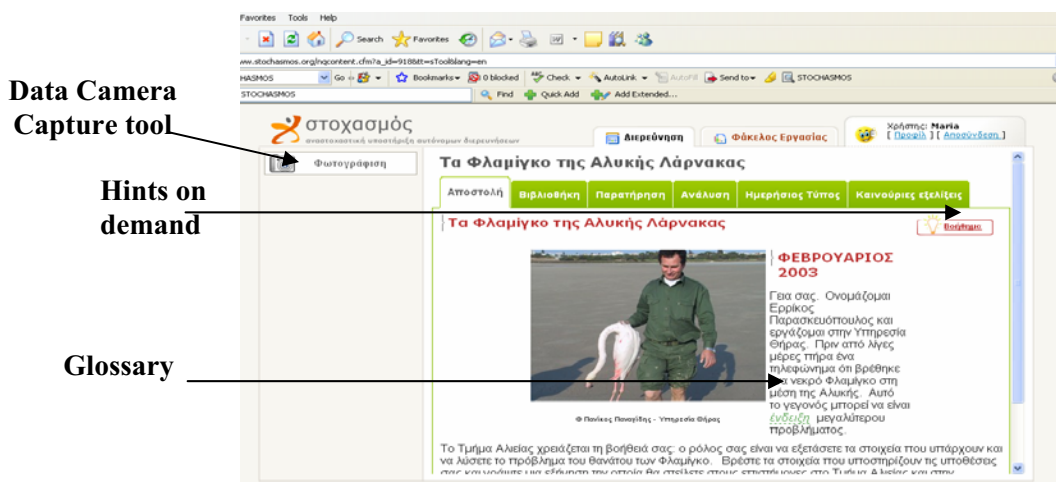


Figure 1. The Flamingo investigation an inquiry environment



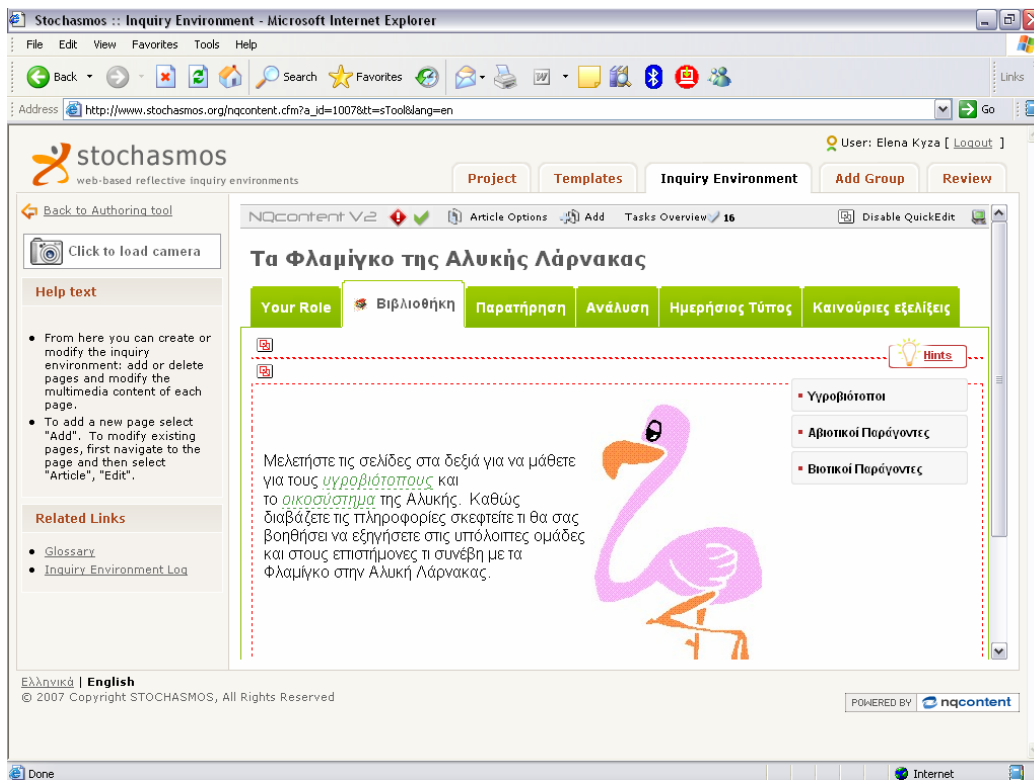


Figure 3. The authoring environment of STOCHASMOS

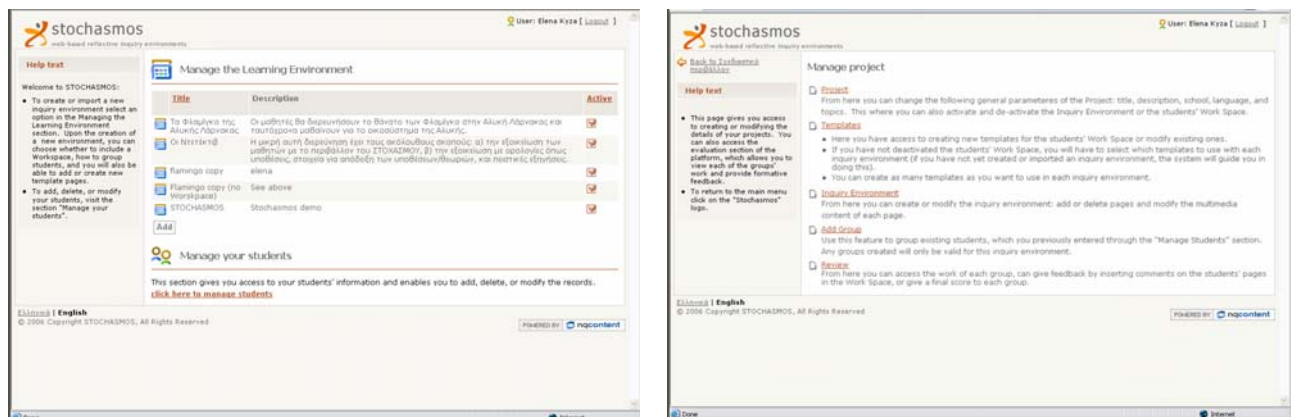


Figure 4. The project management environment of STOCHASMOS

Teachers who choose to create or import an existing inquiry environment have the ability to import WorkSpace templates or create their own templates to accompany the students' investigation. Other platform options can support flexibility and customization of the environment to address teaching and learning needs. For example, the teacher has the ability to use the inquiry environment or the WorkSpace environment of the STOCHASMOS platform separately, or use both of them, which is the default option. This possibility allows flexibility in the case that a teacher wants to use the WorkSpace area with other web pages that already exist in cyberspace, or even a desktop based software application. In this case, the image capture tool remains available to enable the user to transfer screen shots of their work from any other application on their computer (e.g. from a database or spreadsheet program). Another customizable feature is the glossary: teachers can add glossary definitions according to the age group and cognitive needs of their students; these definitions are not global and will only appear in the specific inquiry project. The project management features of STOCHASMOS allow teachers asynchronous access to their students' work. This means that a teacher can review a group's

work and add comments to their WorkSpace pages, thus providing feedback the students can view and use at the beginning of their next investigation session. Furthermore, the history log of the tool can give teachers information on which inquiry environment pages the students have visited and the time between accessing each of the web-pages stored in the STOCHASMOS system.

## CLASSROOM ENACTMENTS

The STOCHASMOS web-based learning platform, including the authoring and project management tool, is currently fully functional and available in the Greek and English languages. The platform has been used by learners of varied ages (6<sup>th</sup> and 11<sup>th</sup> grade students, graduate students at the university level, as well as by in-service elementary and high-school teachers). These implementations provided useful feedback for revising the STOCHASMOS platform. A first inquiry investigation “The Larnaca Salt Lake Flamingos” was used in the research examination of the software-based reflective support provided by the platform. Following the principles of design-based research (Barab, 2006; Barab & Squire, 2004), the investigation was first enacted in three sixth grade classes; the results of this enactment guided the revision of the learning unit and of the platform, and led to an enactment in two other sixth grade classes at a local elementary school. A total of 128 students participated in these two enactments. In all enactments students worked in pairs, as we perceive collaboration as a strategy to engage students in articulating and externalizing their ideas, and promote reflective inquiry.

In one of our studies, we compared 53 sixth-grade students’ collaborative inquiry processes and final explanations of the Flamingo investigation problem. During this enactment, the students were asked to use the online data, organized in the STOCHASMOS inquiry investigation environment, in order to explain why many Flamingo birds died at the Larnaca salt lake during the winter of 2003. The students worked in pairs. One of our research topics was the effect that differential scaffolding may have had on the inquiry of pairs of varying academic achievement. To examine this, we grouped students in three grouping conditions: homogenous pairs of high and low academic achievement, and pairs of mixed academic achievement. The students’ achievement level and the equivalency of the two classes was determined using the results of the Raven’s test, an ad-hoc, non-verbal intelligence measure, and students’ responses to a pre-test examining students’ conceptual understanding of the Larnaca salt lake ecosystem and their inquiry skills.

The pairs in each class were asked to use a different support system to conduct their investigation: the pairs in one class (n=13, one group was actually a triad) used the STOCHASMOS workspace and the pairs in the other class (n=13) used Microsoft PowerPoint to help them organize their data in order to create an evidence-based explanation. Both classes were taught by the same teacher. A variety of research data were collected during the enactment. To test the students’ individual conceptual understanding of the Larnaca Salt Lake ecosystem we asked them to construct pre- and post-instruction concept maps of the system. The comparison of the pre- and post-instruction concept maps indicated a statistically significant difference after the intervention for the WorkSpace class,  $t(26)=-3.891$ ,  $p<.001$ , and for the PowerPoint class,  $t(25)=-2.5$ ,  $p<.005$ .

In another analysis, we examined the relationship between the pairs’ final explanations, the scaffolding used (WorkSpace, PowerPoint), and their grouping condition (high, low, mixed achievement). In comparing the pairs’ explanations with and without the use of web-based reflective scaffolding, we found that the web-based scaffolding, provided through the STOCHASMOS WorkSpace, was more beneficial to the lower achievement pairs. Specifically, the results showed no statistically significant differences in different-achievement pairs’ explanations of the Flamingo problem in the class using the reflective supports of the WorkSpace environment. In contrast, there were statistically significant differences between the explanations of different achievement pairs who were not using the WorkSpace but were, instead, using PowerPoint to support their inquiry. These results support findings presented in the literature (Zimmerman, 1986) that lower achieving students need to be supported in self-regulating their learning. In another ongoing analysis, using six pairs’ videotaped interactions during

the Flamingo investigation, we are examining the relationship between students' metacognitive engagement and the scaffolding used.

The Larnaca Salt Lake Flamingo investigation was also used by twenty-four 11<sup>th</sup> grade students in the context of their Environmental Education class. At the moment, several other inquiry environments are being developed using STOCHASMOS, such as Meles-Meles (Michael *et al.*, 2007), an investigation of a socio-scientific problem relating to the spread of the TB disease, "Choosing the best bottled water", an investigation of the quality of drinking water (Ioannou & Constantinou, 2007), and "New residents in the Athalassa ecosystem: An investigation into the introduction of new species" (Demetriou *et al.*, 2007).

## CONCLUSION

Our experience from three enactments in 6<sup>th</sup> and 10<sup>th</sup> grade classes in Cyprus suggests that the introduction of a software-based inquiry-support tool such as STOCHASMOS can alter the students' mode of work and can introduce reflection as an integral part of the learning process. For instance, when using the STOCHASMOS environment students continuously move between examining the inquiry environment data, identifying and capturing data that could be used as evidence, and documenting and explaining these data in their workspace pages. Prior work in the United States (Kyza, 2004) has shown that this new mode of work can support students' reflective conversations about their data. Our current work continues this line of work and examines the role of such scaffolding in 6<sup>th</sup> grade students' inquiry practices in Cyprus. The results of additional ongoing analyses of the research data can contribute to our understanding of the conditions during which software-based scaffolding can best support students' inquiry learning.

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For more information on the project please visit <http://www.stochasmos.org>

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