The Educative and Scalable Functions of Authoring Tools to Support Inquiry-based Science Learning

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Abstract: Specialized authoring tools enable non-programmers to develop computer-based learning environments that reflect a particular task model. Large-scale implementation of novel but pedagogically sound environments is made possible if the resulting environments reflect the intended essential pedagogical features. We explore the balance between constraints and generativity through five teams' experiences with a specialized authoring tool, STOCHASMOS. We hope to spark a critical discussion of the role of specialized authoring tools in scalability. We also suggest that future research examine the educative function of these tools.

Symposium Goals and Overall Focus

There is general consensus over the need to orchestrate learning in the disciplines around rich experiences where students engage in first-hand activities relevant to future application contexts (Edelson, 2001). Yet, such learning environments, often supported through technology, typically require innovative materials that draw on a wealth of intellectual and tangible resources. Thus, transferability and scalability are inseparable from pedagogical considerations and goals. We aim to advance our understanding of issues of scale-up by examining the role of specialized authoring tools (Bell, 1998) in this process.

Specialized authoring tools pose one type of strategy for scaling-up science education reform efforts, by making it easier to produce a wide-range of inquiry-based learning environments that capture the essential features of environments that were developed, studied and found productive within a research context. However, this potential can only be realized if the use of such authoring tools results in the development of new environments that reflect such essential features. This is especially true when these features relate to discipline-specific needs, such as combining molecular diagrams and equations in chemistry, or explicitly supporting the integration of evidence in scientific argumentation. Yet, it is just as important that these tools provide enough flexibility to allow for the creation of new problems, so that a range of curricular topics, learning goals, and learning contexts can be served by these new learning environments, rather than serve the narrow production of isomorphic problems. Thus, there is a tension between the two criteria for effective scale-up: rigidity in the authoring tool that preserves essential features and malleability in the authoring tool that allows for generativity and variation.

We will present case studies from five teacher-researcher teams each working with the same authoring tool, STOCHASMOS (in Greek: reflection), to design different problem scenarios aimed at engaging students in evidence-based reasoning around socio-scientific issues. These teams, each from a different partner country, are part of a broader project called Digital Support for Inquiry, Collaboration, and Reflection on Socio-Scientific Debates (CoReflect, http://www.coreflect.org) funded by the European Commission's Seventh Research Framework Programme (FP7). Each case study explores key affordances and constraints surrounding their use of STOCHASMOS, how this exposes the tension between rigidity and malleability, and what implications there might be for the roles that specialized authoring tools may play in scalability. Mainly we have found that such tools can serve as boundary objects (Star & Griesemer, 1989) and as educative materials (Davis & Krajcik, 2005) that convey pedagogical and technological knowledge. We aim to engage the audience in a critical discussion of these roles and their implications, as we describe in the symposium structure section. Our broader goals are to initiate a conversation in the community on the ways in which authoring tools can foster collaboration and professional development beyond their utility in technical efficiency.

Rationale and Background

The past few decades have been marked with the creation of computer-based learning environments that are intended to help young science learners contend with rich problems. As a field, we have accrued considerable knowledge about the types of representations and modes of interaction that can be incorporated in these learning environments to productively support collaborative scientific inquiry (e.g., Edelson, 2001; Kali, 2006). However, developing such learning environments is very resource intensive. This is especially true, because they often include unique representations, simulations, and interface structures that scaffold novice reasoning. Recent research has examined not only how to develop particular learning environments geared toward overcoming particular learning challenges or toward meeting particular learning goals, but also how to reduce the time and cost involved in developing such learning environments. These initiatives aim to capitalize on existing knowledge and encourage its reuse (Roschelle, Kaput, Stroup, & Kahn, 1998).

Efforts in this direction include, but are not limited to, research on open source (e.g., Scharff, 2002), learning objects (e.g., Graaff, Laat, & Scheltinga, 2004), and authoring tools (e.g., Murray, 1999). Of these three, authoring tools impose the least demands on end-users in terms of requisite programming knowledge, which makes them quite apt for providing non-programmers access to the development of computer-based learning environments. The realm of authoring tools includes a wide spectrum. At one end of the spectrum are general-purpose tools (e.g., Adobe Authorware or Moodle) that only alleviate the need to program, but that do not provide any guidance about the structure of appearance of profitable learning environments for particular disciplines of study. Another genre of authoring tool, midway through the spectrum, are authoring tools that reflect a particular pedagogical approach and/or group of target tasks, so that they provide pedagogical guidance. Thus, end-users can only create a particular class of environments, but this class of environments is open to multiple problem definitions and allows for some flexibility in the design of the flow of interaction. Finally, at the other end of the spectrum are authoring tools that present a fixed structure so that the nature of the activity is preset and development consists only of inserting new content.

In this symposium, we focus on authoring tools of the mid-range genre, which we refer to as specialized authoring tools. As we have noted, the efficacy of specialized authoring tools hinges on the tension between rigidity that preserves essential features and malleability that allows for generativity and variation. We examine how different teams used the same specialized authoring tool to develop different problem-based scenarios in an effort to gauge the extent to which it was possible to develop problems that differ from a prototype in more than just surface features, while not posing too great a departure from a prototype so as to lose its essential pedagogical features.

STOCHASMOS and its Use in the CoReflect Project

The STOCHASMOS Specialized Authoring Tool

The CoReflect project uses a specialized authoring tool called STOCHASMOS (Kyza & Constantinou, 2007) to develop a set of computer-based learning environments that support learners in investigating socio-scientific problems. STOCHASMOS lets teachers or designers build a multi-modal web-based environment that can support learners in coordinating theory and evidence (e.g. analyze data as they relate to hypotheses), in constructing evidence-based explanations and arguments, and in planning, monitoring and evaluating these actions.

Overview of Underlying Pedagogy

STOCHASMOS was designed to develop learning environments that support reflective inquiry. We define reflective inquiry as a set of practices that help the inquirer adopt a critical orientation, such as planning, monitoring and evaluating one's inquiry-related actions (Loh et al., 1998). Based on prior research (Kyza & Edelson, 2005), a key part of supporting this process lies in supporting students in developing and sustaining common ground, and in making sense of data rich environments. STOCHASMOS was designed to help designers implement learning environments that include specific supports for these processes. The tool provides structured workspaces that reflect some of the epistemic games (Collins & Ferguson, 1993) associated with scientific inquiry. These workspaces can be shared between users and are integrated with communication devices such as forums and chats. This is one of the ways that STOCHASMOS makes thinking visible and shared, thus supporting the construction of common ground. The approach to supporting sense-making includes a combination of context-dependent prompts that can compensate for limited background knowledge, and context-independent prompts that can encourage adoption of general data interpretation and management practices.

Underlying Pedagogy as Realized in the STOCHASMOS Authoring Tool

The functions and design features of STOCHASMOS are accessed through tabs (see Figure 1): Project, Templates, Inquiry Environment, Add Group, Review, Group Pairing, Partnership, and Forum. Designers access different functions and design features as the names of the tabs imply. The "Inquiry Environment" tab allows designers to add content to the basic environment the students will use. The "Templates" tab enables the design of template pages that are later accessible to students through the WorkSpace area. These templates can help structure student work around important ideas, such as connecting data to hypotheses. The WorkSpace also provides guidance in the form of prompts and articulation boxes, which are also customizable at the level of access of the individual teacher. The "Add Group", "Group Pairing", and "Partnership" tabs enable teachers to setup collaboration patterns and rules. The "Review" tab allows teachers synchronous and asynchronous access to their students' ongoing inquiry work on STOCHASMOS. Other authoring features, such as a generic graph tool, the customizable glossary, and the history log are accessible from a side menu. Teachers also have the ability to control the timing, presentation, and deactivation of pages in the inquiry environment and the WorkSpace templates, and are thus able to control what their class will have access to, according to their progress.

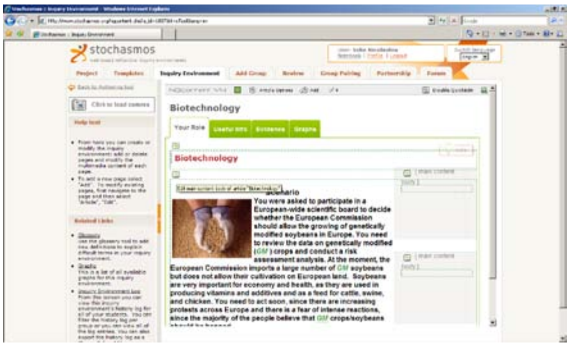

Figure 1. The STOCHASMOS Authoring Tool.

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. The activation of other features can support the design of a more flexible and customized environment, within the STOCHASMOS framework, 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 by default. 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.

The CoReflect Project Structure and Teacher-Researcher Working Groups

The overall goal of the CoReflect project is to advance scientific literacy among youth in Europe by cultivating evidence-based reasoning skills around socio-scientific issues. There are seven partners from different institutions who focus on the development, enactment and study of learning environments that support these overall goals. These partners represent six different European and associate state countries. An eighth partner focuses primarily on dissemination goals of the project. The seven partners who are involved in the design and development aspects lead teacher-researcher teams that are referred to as Local Working Groups (LWG). Each LWG is charged with developing and enacting a problem scenario concerning a socio-scientific issue using the STOCHASMOS platform.

As part of this development process each LWG, based on its local culture, local school structure, national learning goals, group expertise and interests chose a target domain, issue and grade level for its problem scenario. The project conducted a number of meetings that included workshops that introduced the authoring tool, provided instructions on its use, and included some hands-on practice. In these meetings, partners reached some common ground concerning their approaches to science education, inquiry, collaboration, motivation and additional pertinent themes, but, each partner was free to explore their own fine-grained stance and interpretations of these issues. The resultant learning environments span a range of disciplines, such as physics, chemistry and life sciences, as well as a range of ages from elementary through middle to high school levels, and cover different socio-scientific issues such as genetically modified crops, and exploration of extra-terrestrial life.

How the Collective Presentations Fit Together

In line with the different topics, learning goals, and group composition of the different participating design groups, each LWG underwent different design and team collaboration processes. Each LWG interpreted STOCHASMOS in subtly different ways, and orchestrated work around the tool in different ways. This variability makes comparison possible, while the partners' affiliation with the CoReflect project and its broad aims lends a sense of coherence to this comparison that may not have been possible if we were to examine completely unrelated projects. Of particular importance is the shared aspect of teacher-researcher teams, which are not necessarily the norm in every learning-environment design team, but which turned out to be a key point for identifying contributions of specialized authoring tools that extend beyond their technological streamlining utility. Thus, this unique study context provides an opportunity to explore nuances of use and to consider their analytical implications.

Major Issues Addressed by the Collective Work

Any computer-based learning environment design effort entails a process of translating pedagogical ideals and practices into content structures, process flows, and representations in the software. This in turn leads to an explication of often tacit pedagogical approaches, and when diverse teams are involved, such as teacher-researcher collaborations this can be a setting in which these approaches are an object of negotiation. Each LWG contributing to this symposium considered instances where the inbuilt features of STOCHASMOS have facilitated the bringing forth of important pedagogical issues when the LWG was discussing design decisions. Similarly, they considered instances where conceptualized design directions may have been constrained by the authoring tool, as well as the processes that were involved in resolving these dilemmas and their associated solutions. These instances were distilled to a set of analytical points that carried generalizable significance concerning the broader role of specialized authoring tools. This has led us to consider four main issues:

- The importance of exposure of the design teams to past implementations to the efficacious use of specialized learning environments
- The contribution of specialized authoring tools for prompting and guiding pedagogically-focused design discussions.
- Costs and benefits of the inclusion or exclusion of process-flow support in a specialized authoring tool.
- Costs and benefits of the complementary design of offline activities to augment the computer-based learning environment.

Symposium Structure

The symposium will be conducted as a structured poster session. We will open with a 10-minute introduction to the session and to STOCHASMOS. In the next 40 minutes, the audience will be invited to visit the different poster sites around the room. Each poster will present the dilemma or insight encountered by that group pointing to implications about the educative and scalable functions of STOCHASMOS, the authoring tool. Following this, we will reconvene for a 10-minute commentary from a discussant. The remaining 30 minutes will be devoted to a structured discussion with the audience that will draw on the commentary and on a set of analytical questions. We will present a set of overarching questions that arise from the case examples in the various posters, such as:

- Are there pedagogical aspects (such as task flow) that are best left under-determined in specialized authoring tools? Would this maximize tailoring to local contexts?
- Do specialized authoring tools require an accompaniment of prior implementation case-examples in order to produce learning environments that are consistent with the intended vision?
- Should future research examine how authoring tools can suggest the nature of "off-line" activities and supports that can complement and maximize the potential of the computer-based learning environments?

These questions as well as questions gleaned real-time from the discussant's commentary will initiate and guide the closing discussion with the audience.

The session will be chaired by Iris Tabak. Our discussant will be Elizabeth A. Davis.

Potential Significance of the Contributions

This session can help reconceptualize the ways in which specialized authoring tools are conceived of in the learning sciences as conveyors of knowledge with functions beyond those of technical efficiency. In particular, it illustrates various functions that such tools perform in facilitating collaborative design processes in mixed-expertise groups. This reconceptualization can inform the use of specialized authoring tool as well as their future design. In addition, it can initiate a line of research that examines the educative (Davis & Krajcik, 2005) role that specialized authoring tools can play, and how this might affect scalability in terms of broad development and adoption of computer-based learning environments.

Brief descriptions of each of the poster presentations included in the symposium appear in the concluding section below.

A Specialized Authoring Tool in Use: Cases and Lessons Learned

The following set of individual posters present examples of design tensions, dilemmas, insights and serendipitous design plans associated with our use of STOCHASMOS. We aim to synthesize and extrapolate from these cases in order to inform the design of specialized authoring tools, and to better understand the communicative and educative functions of these tools.

Knowledge of prior implementations leverages authoring tool efficacy: The case of the Cyprus University of Technology team (CUT)

The case of Cyprus University of Technology, like most of the cases included in this session, combines issues related to a participatory design process with issues related to the use of a specialized authoring tool. The co-evolution of these processes gave rise to the educative role that such authoring tools might play. Members of the Cyprus University of Technology team were previously involved in the development of the prototype learning environment upon which STOCHASMOS is based. Thus, some of the members of this team entered the new design tasks of the CoReflect project with a rich understanding of the features, structures, and tools encapsulated in STOCHASMOS and the roles that they play in particular problem scenarios. However, this knowledge was not shared by all participants.

This discrepancy surfaced early in the design process when it became evident that considering scientific data with the purpose of creating a base of evidence to service the first-hand investigations of learners in an inquiry-oriented computer-based learning environment differed from the perspective of answering a scientific question or creating typical activities for science lesson. Thus, it became evident to the group leader that the LWG needed to reach some common ground before the design efforts could continue productively. Based on the group leader's general experience in developing computer-based learning environments, and her intimate experience with STOCHASMOS, she introduced written, top-down design guidelines tailored to the affordances of STOCHASMOS. The guidelines were augmented by several presentations of the tool's capabilities and the evolving team design. Gradually, the team came to frame the design alternatives in terms of the best way to take advantage of the tool's functions. This seems to have resulted in strong coherence between the teams' envisioned conceptions of inquiry and pedagogical supports and their implementation using STOCHASMOS. This is exhibited in part by their use of templates to support collaboration, critique and reflection.

The participatory design process was evident in the two-way interaction between teachers and researchers, which in the end took advantage of the expertise and diversity of the LWG members. For instance, the design of the accompanying activity sequence was highly influenced by the epistemology of the enacting teacher: the teacher sought to integrate hands-on experiments with the work conducted on STOCHASMOS to enable students' deep comprehension of pre-requisite biological concepts she felt could not be delivered through STOCHASMOS alone. At the same time this collaborative process and the enactment of the designed environment with students allowed the participating teacher to grasp the ideas behind the integration of learning technologies in her teaching and helped her confront newly-realized anxieties over the loss of control of students' actions.

Team: Kyza, E. A., Nicolaidou, I., Terzian, F., Hadjichambis, A., Kafouris, D.

Using STOCHASMOS to scaffold students in discussing key issues while retaining ownership of their learning processes: The case of the Kristianstad team (HKr)

The Kristianstad team had a strong investment in supporting collaborative processes in scientific inquiry using a kind of Fostering Communities of Learners (FCL) approach. Their domain of focus was astrobiology, a content area that entices questions in students in relation to their worldview (Cobern, 1996). The emphasis on fostering a community of learners, and the recognition that worldviews may be quite variable and salient in this context, prompted this team to elicit explicit discussion of presuppositions of science at the onset of the learners' experiences. This suggested particular curricular sequences. STOCHASMOS does not provide direct or explicit support for process-flow. In the case of HKr this proved to be an asset, as they were able to easily maintain their pre-existing commitment to FCL.

Nonetheless, working with the authoring tool enabled them from the start to have an initial image of what the learning environment would look like in practice and what features it might have. Consequently, they decided to employ particular software features to augment and enhance their conceptions of collaborative and inquiry-flow processes. These included three main features: (1) Organizing students in functional triads taking a pre-test of worldviews into consideration, but keeping group functionality foremost (2) Having the teacher use the notes tool to comment on group work between work sessions. A form of teacher-student interaction which the participating teacher had noted was welcomed but novel to her. (3) Using the chat tool and sharing of workplace pages to try to sustain continuous group work and collaboration.

Team: Redfors, A., Rosberg, M., Hansson, L., Lundh, I.

Specialized authoring tool as boundary object: The case of the Ben Gurion team (BGU)

The Ben Gurion University (BGU) team consists of some individuals who have prior experience in developing computer-based learning environments and some who do not. Developing educational software requires one to think of pedagogical moves and instructional supports in terms of software features and interface objects. In creating software "from scratch," this requires one to imagine and envision what these features and consequent user interactions might look like once a prototype is created Such visualization may be difficult or impossible without prior experience. Specialized authoring tools display the main features and software interactions (devoid of content) of the intended learning environment, and provide a concrete object around which pedagogical discussions can occur. This alleviates some of the need to engage in visualization and mental translation of pedagogical moves to software interactions. Some of the team's design discussions used the language of the STOCHASMOS tools and interface features to discuss the problem structure, student activities and supports (e.g., the "role tab", or "the template"). Thus, the translation from pedagogy to interface preceded and guided the design considerations and discussion.

This figured most prominently in considering how to deal with anticipated student difficulties. The team's interpretation of STOCHASMOS and its features was that assistance could be supported mainly through the features of the "template" and the "hints." Often the team would envision ambitious analysis on the part of the student, followed by a wave of strong concern over students' ability to contend with these tasks in light of their current background knowledge and skills This, in turn, was followed by consideration of what forms of scaffolding and guidance could bridge these gaps. Our considerations were framed in terms of "hints" and "templates." When the team did not frame their suggestions in terms of a hint or a template, one of the team members, usually the main hands-on developer of the learning environment, would respond with a question of how the suggestion could be implemented as a hint or template. So, the features of STOCHASMOS acted as a translational device translating pedagogy into interaction with computational media. In this way, STOCHASMOS, facilitated the design process, and served as a boundary object bridging between team members who had prior experience in software development and those who did not. One of the broader implications or questions for the field lies in determining the relative costs and benefits between facilitating the translation process from pedagogy to software interaction and constraining the space of software-realized scaffolding to the authoring tools' existing features.

Team: Tabak, I., Asher, I., Nasser, S., Gnaim, L., Fried, M., Katz, I., Weinstock, M.

Design foreclosure and the proliferation of offline activities

The case of the Leibniz Universität Hannover team (LUH)

In the case of Leibniz Universität Hannover (LUH), issues pertaining to the use of the specialized authoring tool were conflated with issues concerning the participatory design approach adopted in the CoReflect project. The participatory design approach asks to merge different kinds of experiences offered by teachers and researchers. Stringently adhering to the tenets of this approach calls for negotiating and reconciling the different viewpoints. The researchers seemed to provide presuppositions based mainly on published educational research and theory, whereas teachers seemed to draw on classroom experiences and their emergent intuitive theories, as well as their conceptions of best practices that also seemed to be anchored in their prior experiences. The design requirements of using STOCHASMOS made these tacit distinctions surface, because a direct importation of prior best practices into the learning environment was not possible. This instigated an explicit discussion of what activities are desirable and why.

The STOCHASMOS learning environment seemed to project to the participating teachers an image of instruction as based on texts and data sheets inside a computer. This was in contrast to the teachers' strong commitment to hands-on experimentation (wet labs, i.e. laboratory experimentation using chemicals, or biological matter, etc.). This commitment stems from both disciplinary and instructional considerations. Chemistry is an experimental science and there is a longstanding tradition to focus chemical education on hands-on experiments rather than "chalkboard chemistry." From an instructional perspective, the teachers believed that the hands-on experiments provided insights that could not be derived from declarative data sources, and that they would need to engage in experimentation in order to deal well with core concepts. In addition, they believed that the students would explicitly ask for these hands-on activities. Simulations, videos and pictures seemed to be regarded as competing with wet-labs on classroom time, and as offering an instructionally inferior alternative. Therefore, the participatory design team's decision was to provide students with both learning opportunities: hands-on experiments, as well as pictures and descriptions of these experiments inside the STOCHASMOS-based learning environment.

Findings from a pilot study revealed mixed results. Students made little use of the hands-on opportunities, reporting that the STOCHASMOS pages were sufficient for understanding the basal concepts. However, the analysis of the students' learning products revealed a lack of integration of these concepts. The team is currently working on this issue, discussing additional within-STOCHASMOS and out-of-STOCHASMOS activities to foster the integration of scientific concepts mediated by the experiments to be tested in Spring 2010.

Team: Schanze, S., Saballus, U., Neumann, A., Manske, M., Sieve, B., Söhlke, M., Janßen, O.

The case of the University of Thessaly team (UTH)

The University of Thessaly team was dedicated to fostering conceptual change and a scientific approach to the ways in which students explain physical phenomena, focusing on the topic of evaporation and condensation of water. These goals coincided with strong prior commitments to activities that are not explicitly supported in STOCHASMOS. They also had expectations about how students might engage in inquiry. As a result, there were instances where they had a hard time mapping their envisioned curriculum to the authoring tool implementation. For example, they were concerned that STOCHASMOS afforded more degrees of freedom and autonomy than their students were equipped to handle. Consequently, they devised a framework for teacher moves in which the teacher manages the flow of the investigation based on awareness of students' misconceptions, and on the quality of student argumentation. Generally, in CoReflect we adopt a distributed scaffolding stance that posits that support cannot be achieved through a single means, and that offline activities and supports are an essential part of the overall learning environment. Thus, designing offline activities does not in and of itself subvert the essence of intended designs underlying STOCHASMOS. However, one question to contend with is whether there is a point at which a proliferation of offline activities obviates rather than augments the technological supports.

Team: Kollias, V., Matos, A., Davaris, A., Karnavas, A., Daropoulos, A., Zaganas, K., Christodoulopoulos, V., Tsaknia, Th.

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