

Software in Context: Designing for Students, Teachers, and Classroom Enactment

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Abstract: While supportive features that address the needs of students and teachers are critical for the success of educational software, they are only the first step toward adoption and effective use of software in the classroom. As learning technologies gain increasing use in classrooms, designers must pay close attention to the pedagogical and logistical issues that teachers face during their enactment. This paper traces the design history of the WorldWatcher visualization software from a learner-centered to a classroom-centered framework, addressing the challenges that teachers faced during enactment and the affordances we have designed to facilitate teacher use.

Introduction

While supportive features that address the needs of students and teachers are critical for the success of educational software, they are only the first step toward adoption and effective use of software in the classroom. Sensitivity to the local context in which the software is used means looking beyond the explicit affordances of software tools to the subtle ways that these tools influence and become a part of classroom practices. In other words, a *context-sensitive* approach to educational software design must consider not only the general design features which facilitate understanding and use of the software, but also the roles, motivations, and expectations that students and teachers bring to classroom activities.

This is a story of the design evolution of an open-ended educational software tool and how our attention has shifted over the years as we have sought to support its use in classrooms. The story traces our design history in terms of the audiences we have targeted. Having begun with student-focused concerns, our attention has shifted to teachers and the challenges they face when implementing ambitious, technology-enhanced curricula. This emphasis takes as its main challenges (a) the need to understand the issues that teachers face in enacting technology-enhanced curricula and (b) the design of classroom resources (both within and around the software) that address the contextual issues that govern the enactment of such curricula.

Theoretical background

The increasing use of robust multimedia technologies in classrooms has brought about a heightened sensitivity on the part of software designers to the needs of learners. In particular, a learner-centered design perspective [Soloway, et al., 1994] calls attention to the tasks that students engage in, the tools they use to perform such tasks, and the context in which learning takes place. In considering these issues, designers incorporate cognitive supports into the software which help learners accomplish tasks that would otherwise be beyond their capabilities. Drawing on the traditions of constructivism and distributed intelligence, learner-centered design seeks to make explicit the processes involved in both knowledge construction and in the interactions that occur between individual learners and tools in their environment [Brown, Collins & Holum, 1991; Salomon, Perkins & Globerson, 1991]. Once these processes are made explicit, designers can attempt to support them through learner-centered scaffolds.

But while learner-centered design provides a valuable framework for dealing with many of the important issues of educational software design, focusing on the needs of learners is not sufficient for the success of

classroom technologies. If educational software is to facilitate a transition to new styles of activity and interaction in classrooms, as the current generation of reform-oriented educational software aspires, software designers must also acknowledge the roles that teachers play, the contexts in which they operate, and the design of curricular materials that support teacher understanding. In recent work, researchers have begun to explore what it means to conduct *classroom-centered design* [Smith & Reiser, 1998; Loh et al., 1998]. A classroom-centered design framework appreciates the prevalent culture of classrooms and resists the temptation to computerize all the supports that normally contribute to classroom learning. In particular, teachers play a pivotal role in the implementation of curricula which should not be ignored in the design of learning tools. Classrooms also have established work patterns, social roles, and cultures of communication. While these vary in different contexts, they nonetheless warrant close examination by software designers who seek to incorporate computerized tools within existing classroom environments.

There are a variety of ways to help teachers achieve the learning objectives they set for their students. Of particular interest is the role that curricular materials can play in teacher learning and instructional reform [c.f. Ball & Cohen, 1996]. Curricular materials, which can include activities, background content, forms of assessment, and teacher guides, if done properly, constitute a rich opportunity for designers to communicate with teachers. Unfortunately, designers of traditional curricular materials often fail to take into account the roles that teachers play in the implementation of curricular innovations and the teacher's need to learn in the process.

This problem is particularly acute in the design of reform-based educational software (which we classify as a type of "curricular material," albeit one that is relatively new to schools), where the need to support teacher learning is vital to the success of the innovation. Furthermore, where innovative software becomes a part of curricular change, we recognize the need to consider curricular issues of the sort outlined above alongside the more traditional issues of software design. To ensure their relevance, the curricular materials we have designed are the products of teacher-researcher collaborations and are thus heavily influenced by the concerns that teachers have during enactment. Our collaborative process has aimed not only to increase the fit of such materials to the subject matter and methodological interests of practicing teachers, but it has also sought to uncover and address some the major obstacles that teachers face during enactment.

In the following two sections, we will describe the design history of the WorldWatcher data visualization tool, paying particular attention to our progressive shift from student-focused to teacher-focused design issues, where both parties are conceived as learners. We do not claim that one approach is more important than the other, but rather we see the latter as having grown naturally out of the former as WorldWatcher came under increasing classroom use. As our discussion will reveal, teacher-focused concerns both include and go beyond the student-focused design issues.

Design for learners

In response to recent calls for science curricula that actively engage learners in inquiry activities, we have been engaged in research on software that supports open-ended science investigations by learners. The specific focus of this work has been on scientific visualization of geographic data, with the goal of creating visualization and analysis tools that are accessible to middle and high school students. Previously, giving students access to this type of data meant either giving them scientists' tools or presenting them with pre-rendered visualizations. Scientists' tools are generally unwieldy and lack the support that learners require, while pre-rendered images do not give learners the opportunity to experience the construction of visualizations or to work with the data in its numerical form. The goal of our software design effort has been to create a scientific visualization tool for geographic data that is accessible to a middle and high school audience but retains the power for analyzing data and customizing its display of the tools used by scientists.

When we began this effort, we recognized the significant challenge of taking a technology that was created for use by experts and converting it into a tool for learners [Gordin & Pea, 1995]. In adapting this technology for learners, we focused our attention on creating "supportive" interfaces for accessing, interpreting, and conducting analyses of data, and on collecting learner-appropriate data libraries [Edelson & Gordin, 1998 in press]. The product of this research is the WorldWatcher visualization software,¹ which enables learners to customize the display of geographically situated data, view multiple variables in parallel, generate animations, and perform a variety arithmetic and statistical operations on data [Fig. 1].

^[1] WorldWatcher for the Macintosh is available at <http://www.worldwatcher.nwu.edu>

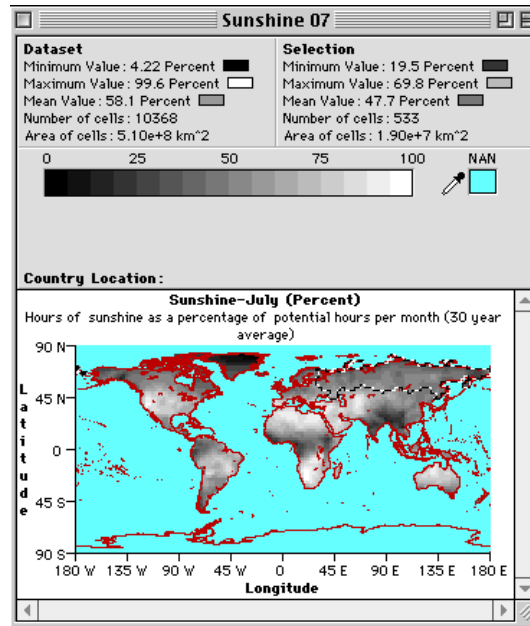


Figure 1: WorldWatcher visualization window.

Given the challenges of designing a complex data visualization tool appropriate for learners, most of our early research and design emanated from close work with students. However, as WorldWatcher began to see increasing classroom use, we encountered a new set of design challenges. While our initial experiences demonstrated that software and interface design problems can be outright impediments to the adoption and use of software in classrooms, even after design issues in the software were resolved teachers still faced numerous challenges in using WorldWatcher in their classrooms. Supporting learners was one thing. But teachers must also deal with an entirely different level of curricular issues. Thus, we turned our attention to supporting the teacher's role in enacting WorldWatcher-supported curricula.

Design for teachers

It is important to recognize that teachers are themselves potential learners; thus they can benefit from the learner-centered design scaffolds mentioned in the previous section. It is also clear, however, that thinking of teachers as users includes a much broader set of issues. Understanding how to use the tool is much different from knowing how to *teach* with the tool. As we began to work with teachers to implement WorldWatcher-supported activities in classrooms, we encountered several key challenges to successful enactment. In this section we will discuss the issues teachers encountered in teaching with WorldWatcher and how we sought to address these challenges.

Helping Teachers to Envision Classroom Use

While WorldWatcher was specifically designed with teachers and students in mind, it is nonetheless a complex tool. Its complexity occurs not only in the fact that it is a powerful computer-based technology, but also in that it provides access to new types of data previously unavailable in classrooms. Initially, teachers face both technical and conceptual challenges to operating the software. On one hand, introductory tutorials can lead users through the basic steps of using WorldWatcher, but knowing how to open data visualizations says nothing of how teachers learn to use such representations as tools for classroom learning. Getting teachers started, therefore, requires attention not only to technical obstacles, but also to the curricular issues that arise when they consider how the tool will impact their instruction. In other words, we need to help teachers envision how WorldWatcher might be put to effective use in the classroom.

Envisioning how WorldWatcher might be used in the classroom has several dimensions. Teachers must be able to integrate the tool into their regular planning and teaching processes. In order to do this, they must know more than just how to use the tool proficiently. They must also have an understanding of types of

instruction the tool calls for (its *curricular affordances*) what types of tasks it supports, how to organize and motivate student work around it, and what learning objectives it serves. Viewed from a slightly different angle, teachers who decide to use WorldWatcher must come to understand the tool within their existing domain knowledge, beliefs about teaching, and repertoire of instructional methods. In short, for teachers to feel comfortable using the tool with their students, they must first be able to envision just what the software is about. The question is, how can we support teachers as they learn how to teach with WorldWatcher? We feel that one good way for teachers to learn its value is through curricular examples.

Our first step in this direction was to provide sample activities which serve as both introductory tutorials for teachers and adaptable models for classroom use. Teachers have access to activities ranging from brief sample exercises which showcase software features to in-depth examples that illustrate subject matter, domain concepts, and possible pedagogical strategies. The activities we designed include step-by-step instructions for using WorldWatcher, explanations of the features used, and graphical images that guide users through the investigation [Fig. 2]. By engaging in these activities prior to classroom enactment, teachers get a sense of what classroom use of WorldWatcher entails, including pedagogical strategies, instructional methods, and content issues that might accompany classroom use of WorldWatcher. Furthermore, they can use these activities as inspiration for their own activity designs, or modify the existing examples according to the particular needs of their students. We recognize the difficulty in designing samples that will appeal to teachers in diverse contexts, and that successful enactment with WorldWatcher might take a variety of forms. The important point is that the sample activities provide a starting point from which teachers can begin to understand the types of learning the software can stimulate and as well as how it might be used effectively in the classroom. We do not propose to dictate the manner in which teachers use WorldWatcher; rather, we aim to help teachers develop competency with the tool such that they might be able to integrate it into their existing array of instructional practices.

Our current work with teachers has revealed the power that sample investigations, when tailored to a teacher's specific subject matter background, have in helping teachers to understand the communicative power of data visualizations. There is something dramatic about seeing a clear pattern emerge from complex data. The following statement from a history teacher illustrates how he came to understand the affordances of the tool over time:

The first time I opened up WorldWatcher on my own and saw the low life expectancy in Africa and then went to per capita GDP— there was something dramatic about seeing it for the first time. I'm not sure I had a sense going into this that this was the kind of thing I was getting into. That emerged throughout the experiences. There were lots of surprises.

This example hints at some ways in which sample activities can supply teachers with opportunities to explore the tool and get a feel for its curricular affordances— to take it for a spin, so to speak. They provide opportunities to interact with the software in a manner that will help them to understand what it can do for their classes. The extent to which such experiences are meaningful, furthermore, will be determined by how much they resonate with teachers' existing knowledge and experiences. The challenge of our current research, then, is to find ways to engage teachers in experiences that appeal to what they already know and encourage them to think in new ways about what they might be able to accomplish in their classrooms with the help of WorldWatcher.

Task Management in the Computer Classroom

Managing technology-supported classroom investigations is logistically difficult. Student-driven classroom work presents a variety of challenges for teachers, including task management, providing individual guidance to several students simultaneously, and coordinating students who work at different paces. These issues are compounded when computers are involved. Frequent technical mishaps and other byproducts of complex technologies often distract students and teachers from the curricular objectives. In addition, new media can have an impact on the way that classroom activities are conducted. Supporting student investigations in WorldWatcher, for example, involves a host of classroom management challenges for teachers, particularly where students are working simultaneously on different computers. Furthermore, traditional means of classroom management such as worksheets do not lend themselves to computer-supported investigations, where most of the activity happens on-screen.

Addressing the needs of teachers who use WorldWatcher, therefore, involves more than just helping them to learn about ways to teach with the tool. While sample activities provide teachers and students with a means by which to engage in activities with WorldWatcher, the teachers we worked with still faced challenges in actually implementing such activities with their students. In particular, the static paper-based sample activities

we provided initially were an inadequate medium for designing and supporting extended student activity with the software. A significant drawback to paper-based materials is that they are not dynamic—it is difficult to manage and cross reference the multiple documents and resources that may contribute to a given activity. Teachers reported that they had difficulty providing necessary support for students, having to provide conceptual guidance and technical support to many students at the same time. When students encountered difficulties, they often did not know where to find help in the software. Thus, our design challenge was to provide a medium in which activities could be dynamically linked to supporting materials and technical assistance. To support the problem of task management, we developed a document format for creating “notebook” files that can mix text, pictures, and video as well as links to specific visualizations and other notebook windows [Fig. 2]. The aim of the WorldWatcher notebook is to facilitate activities with the WorldWatcher tool by bringing together multiple resources within an integrated, linkable document format.

The value of notebooks for classroom management is that they allow teachers to author activity guides that can lead a student through an activity and provide links to all the resources that will be necessary to complete the activity, including relevant datasets, procedural instructions, textual prompts to consider key issues, and on-demand help documents. By providing links to relevant datasets, notebook windows eliminate the need for students to navigate through WorldWatcher’s extensive database. By integrating on-screen instructions with visual examples, notebook windows provide a means for students to engage in self-guided activities. In particular, teacher-authored instructions can call students’ attention to relevant information or patterns in the data. By providing students with on-demand help, furthermore, they need not rely on the teacher as the sole source of technical help. Thus, activity notebooks provide teachers with a variety of supports in classroom task management.

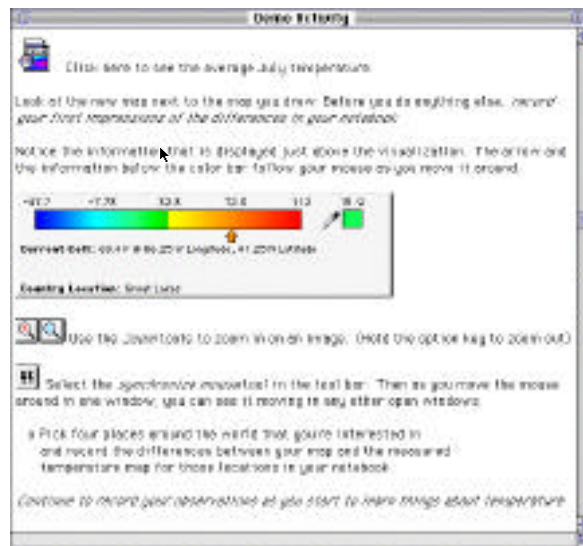


Figure 2: Sample activity in a WorldWatcher notebook window.

The sample activities that we have designed are distributed as notebook documents. Because they are electronic documents, teachers can edit or adapt them to their own needs. A drawback with traditional paper-based materials is that they are hard to edit, thus encouraging teachers to adopt them “as-is.” It is our intent that the activities we provide act more as inspiration for teachers than as canned activities, though teachers do have the option of using our activities verbatim. Also, since notebook windows are editable at any time, they can be used as multimedia worksheets where students type in their own responses to question prompts or insert pictures of—or links to— datasets they generate. In this way, notebook windows can provide teachers with assessable records of student work. Thus, the notebook window provides both a straightforward means to support student activity and a simple way for teachers to custom tailor activities to the needs of their students.

Overcoming Conceptual Challenges

A serious problem with many traditional curricular materials is that they fail to address teachers as learners [Ball & Cohen, 1996]. The use of technology-supported inquiry pedagogies in general and WorldWatcher in particular pose several challenges for teachers and opportunities for teacher learning. First, teaching with

WorldWatcher often means contending with a host of complex and unanticipated content issues arising from rich, real-world datasets. The extent to which teachers are able to deal with these issues can depend greatly on the depth of their subject matter knowledge and on their ability to represent such knowledge in teachable ways [Grossman, 1990; Shulman, 1986]. Thus, teachers with richer domain knowledge or extensive experience with data analysis are likely to have deeper “pedagogical content knowledge” which they can draw upon when guiding students through open-ended scientific inquiries. Teachers who lack rich understandings of the domain need support in addressing conceptual issues that surpass their content expertise.

Second, to facilitate inquiry-based learning supported by real-world datasets teachers must not only be familiar with the content at hand, but they must be effective managers of student-driven inquiry tasks. For many teachers, the investigation of complex datasets— particularly through the medium of visualization— represents a novel instructional approach. For example, real-life datasets are messy and often yield complex questions that are beyond the comprehension of students and teachers. Most teachers lack the expertise of domain specialists, and thus are often unprepared to deal with many of the unanticipated procedural obstacles that arise when using real-world data. If investigations of complex data are not properly supported, students and teachers can easily encounter road blocks that cause frustration and quickly derail classroom inquiries. Teachers therefore also need support in exploring instructional strategies and methods of classroom organization that support such tasks.

Third, teachers must also possess a “big picture” view of the investigation, understanding how the given task fits in with the overall curricular goals. The ability of teachers to understand and communicate short and long term learning goals, to manage both short term and ongoing tasks simultaneously, and to situate classroom activities within a larger instructional context facilitates both curriculum planning and student engagement. Therefore, teachers need support in integrating data-investigations within longer-term curricular frameworks, such as projects or other types of curricular units.

To facilitate an understanding of how to teach with WorldWatcher, we have augmented our sample student activities with educative supplements intended for teachers. These supplements, authored as notebook documents, are designed to support teachers’ content knowledge and pedagogical understanding, as well as provide supports for likely procedural and conceptual obstacles. The notebook facility has allowed us to design dynamic teacher guides, linked to the sample activities themselves, that provide task overviews, background information, explanations of the conceptual challenges in the given activity, and links to relevant help documentation. For example, a WorldWatcher teacher guide designed around sample set of activities exploring the greenhouse effect begins with a menu providing direct links to background readings on the subject (which are also in notebook document format), as well as an individually tailored teacher support document for each activity. Each support document provides a detailed explanation of the procedure, providing discussions of pertinent background content and highlighting conceptually difficult points and potential student pitfalls. Furthermore, these documents provide support for technically difficult areas of the activity through links to specific portions of WorldWatcher’s help documentation. Finally, these documents provide links to background information on particular datasets, references to outside sources of information, and links to other related activities.

Open Questions: Software and the context of teaching

Focusing on the logistical and conceptual challenges that teachers face in implementing WorldWatcher-supported curricula has called our attention to a host of issues that stem from the particular settings in which the software is used in a way that our earlier student-focused perspective did not. In designing for students, our goal was to create learner-centered scaffolds that made the exploration and analysis of complex geographic datasets possible for young learners. In designing for teachers, we aimed not only to support *use* of the tool, but also to support *teaching* with the tool. Thus, our work with teachers has been aimed at articulating and supporting the tacit and explicit challenges that arise during the enactment of WorldWatcher-supported curricula. Emphasizing the pivotal role that teachers play in enacting classroom technologies such as WorldWatcher— and finding ways to support this enactment— has raised our awareness of the importance of understanding not just the needs of individual users, but also the context of software use.

We have come to view curricular activities as one very important medium through which teachers, students, and classroom tools interact. Thus, we have focused our design efforts on creating curricular materials that facilitate this interaction and on supporting teachers’ ability to adapt and redesign such materials (e.g., the editable notebook interface). But there are still areas we have yet to explore. Accounting for the complexities that comprise the context of teaching is truly a daunting task. Given the significant variations that occur between contexts, it seems impossible to predict all the different ways that teachers might approach a tool like WorldWatcher. But the goal should not be to confront explicitly all the challenges teachers face. Rather, it should be to understand those challenges well enough such that we can engage teachers in an exploration of new

instructional practices and provide them with the opportunities and support to think such issues through for themselves. By focusing on the role that curricular materials can play in teacher learning, we should aim to provide a bridge between the novel affordances of WorldWatcher and the types of practices with which most teachers are already familiar.

Accomplishing this task requires an acute sensitivity to the context of enactment. Designers must draw upon a rich understanding of the different ways that teachers may choose to understand and envision the tool. They must understand how teachers in different settings think about the pedagogical affordances of the tool; they must have a sense of the different types of tasks teachers will find useful; they must understand the different learning objectives that teachers seek to achieve; they must be aware of the different methodologies and classroom management techniques that will facilitate its use in the classroom; and they must be aware of the diverse goals, objectives, and motivations that teachers and students have when investigating data. The answers to these issues lie in studies of the ways that teachers design and enact projects with WorldWatcher and the development of multiple enactment models around which designers can better consider the needs of teachers.

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