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Understanding Adoption of Software Tools: Comparative Case Studies of Teacher Beliefs About and Use of Inquiry-Support Software

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Abstract: This set of comparative case studies takes some first steps at understanding how to support teachers' efforts to adopt and use an inquiry-support software environment called the Progress Portfolio. We explore two key issues: teachers' beliefs about the functionality of the tool, and ways in which teachers customize it to support inquiry-based learning. Using interview data and software artifacts, the study explored some of the striking similarities and differences in beliefs and tool customization across three teachers engaged in the same instructional unit. Findings provide evidence for an initial category scheme of tool functions perceived by teachers to meet both teacher needs and student needs in scientific investigations. Additionally, teachers' customized Portfolio templates revealed a continuum of general-purpose to task-specific designs to scaffold student inquiry within or across science units. Implications for future research are discussed in light of these results, including a need to expand on the existing belief category scheme and customization examples, and a need to do longitudinal research that will shed more light on changing beliefs and use as a result of experience.

Keywords: Teacher beliefs and practices, science education

Introduction

Reform efforts in science education have emphasized a need for students to engage in collaborative, inquiry-based projects, which pose a number of challenges for learners as they formulate questions, gather, analyze, and interpret data, draw conclusions, and communicate results in complex investigations (Linn, Songer, & Eylon, 1996; NRC, 1996). Researchers and curriculum developers have responded with designs for software tools to support various aspects of authentic scientific inquiry. One such development effort produced an inquiry-support software environment called the Progress Portfolio (Loh et al., 1997), designed to make the process and products of an investigation into explicit objects for reflection. Classroom case studies with the Progress Portfolio have explored the affordances and constraints of the tool's various design features to support inquiry (Loh et al., in press; Loh et al., 1999). However, as we try to understand how to support teachers' efforts at adopting this tool, we must also look at two key issues: teachers' beliefs about the functionality of the Progress Portfolio, and the ways in which they customize it for classroom use. This set of comparative case studies has taken a first step by exploring some of the similarities and differences in beliefs and tool customization across teachers engaged in the same instructional unit.

Review of Past Research

Many researchers have noted the connection between teachers' practice and their beliefs. Teachers attempting innovation in their classroom, such as using technology to support inquiry, face a long and difficult path (Borko & Putnam, 1996). When we encounter something new, we see it through the lens of our existing knowledge and beliefs (Borko & Putnam, 1996; Yerrick, Parke, & Nugent, 1997). It follows then that for there to be meaningful change in teaching practice there must also be change in teachers' beliefs (Borko & Putnam, 1996). Krajcik, Blumenfeld, Marx and Soloway (1994) argue "[T]eachers' beliefs, knowledge, and experience need to be taken into consideration, because these factors influence what teachers understand, what they adopt, and how they implement changes" (p. 484). As Thompson (1984) notes, the behaviors of instructional practice are driven by beliefs, both conscious and unconscious. In her case study she found "the observed consistency between teachers' professed conceptions of mathematics and the manner in which they typically presented the content strongly suggests that the teachers' views, beliefs, and preferences about mathematics do influence their instructional practice" (1984, p. 125).

As teachers are exposed to new ideas and try to put those ideas into practice in the classroom, their belief systems do change, but the new beliefs may not entirely supplant previous beliefs. Indeed, teachers may not recognize the fundamental differences between reform visions and traditional views, and assimilate the new beliefs into their current belief system without recognizing the inherent contradictions (Yerrick, Parke, & Nugent, 1997). Calderhead (1996) notes: "Teachers' beliefs, however, may well be quite generalized, abstract value commitments, and it has been found that teachers can sometimes hold quite conflicting beliefs that create dilemmas for them in thinking about practice or result in contrasting beliefs being used to justify contradictory actions . . ." (p. 721).

Specific to computer-supported inquiry practice, Maor and Taylor (1995) found "it is not the computer itself that facilitates inquiry learning; the teacher's epistemology is a key mediating influence on students' use of the computer as a tool of scientific inquiry" (p. 839). With this in mind, the study reported here takes some first steps at exploring different teachers' beliefs about the Progress Portfolio and the ways in which they mediate students' interaction with the tool through software customization.

Method

Research Context

The study's data was collected during a four week pilot enactment of a curriculum called "Create-A-World" (Edelson, 1998), in which students examined factors affecting global temperature variation. The unit is divided into three phases: a) eliciting students' prior understandings and generating initial predictions about the factors that affect global temperature, using computer-generated temperature data; b) investigating and explaining factors that may or may not affect global temperature differences, based on data from computer-based and hands-on investigations; and c) applying the principles of temperature variation developed in phase b investigations to the design of one's own world with maps to display land and water boundaries, temperature, elevation, ground cover, and other variables.

In their investigations, students used the WorldWatcher software (Brown & Edelson, 1998), a scientific visualization environment, to generate and compare data visualizations for global temperature and other variables. The software provides data sets for a large number of variables, including Earth's surface temperature, vegetation (ground cover), land elevation, and incoming solar energy, to name a few. Upon selecting a particular data set, the software displays for students a color map visualization of the data. A large number of tools are provided for exploring and comparing data within and across data sets. In Create-A-World, students compare temperature with other variables to discover possible relationships. WorldWatcher also provides tools for users to generate their own map visualizations; students used these in Create-a-World to create maps to represent variables in their own world designs.

Students used the Progress Portfolio software over the course of the unit to capture, organize, analyze, and annotate their data and observations, and to document their thinking and world designs along the way. With the Progress Portfolio, individual students or groups create a project file comprised of pages. Each page can hold any combination of pictures, text, audio clips, post-it-like sticker notes, or graphic organizers such as tables. The software includes a data camera tool that easily allows the user to take a picture of an image from any other application running simultaneously on the computer (such as WorldWatcher), and to paste that image on a Portfolio page. As students engaged in unit investigations with WorldWatcher they captured pictures of the WorldWatcher visualizations to store and annotate on Portfolio pages and to use as evidence for supporting their evolving understanding of the principles that influence global temperature variation. They also stored in their Portfolio files their maps and explanations for their own world designs. Finally, the Progress Portfolio also includes an authoring tool for teachers that allows them to custom design page templates to serve different functions in a unit (e.g. a data observations page or a student-generated questions page). These page templates, referred to as "page types," also allow the teacher to include prompts with directions or with questions to scaffold student reflections. For this study, we asked each teacher to custom design the Progress Portfolio page types on which students would collect and sort textual and graphical data to represent their work and thinking in the Create-A-World unit.

Participants

Three middle-school science teachers, from urban schools in Chicago, participated in the study. It was the first time they taught the Create-A-World unit. Jill and her students had experience using the Progress Portfolio in five previous science projects that year. Bill and Meryl had no previous experience with the Progress Portfolio, and

received software training prior to the unit. All three were considered strong science teachers by their peers and by others in our research group with whom they had worked in the past.

Data and Analyses

Data was collected through videotaped teacher interviews, planning and debriefing meetings with all three teachers, classroom field notes, and Progress Portfolio files that included the teachers' page type designs. Interviews before the unit included questions about teachers' goals for the investigation, plans for Portfolio software use, and their view of the Portfolio's strengths, weaknesses, and potential uses. Interviews after the unit included questions about issues or obstacles they had to face, learning goals they felt they had accomplished, resources they found useful, and their view of the Portfolio's strengths, weaknesses, and uses.

For this study a bottom-up analysis was applied to post-interview responses and software artifacts to look for striking similarities and differences in teachers' beliefs about Progress Portfolio use and function, and in their support of inquiry through the customization of Portfolio page types. Videotape transcripts from the post-unit teacher interviews were reviewed to identify categories for teacher statements about Portfolio use and function. Similarly, the teachers' Portfolio page type designs were reviewed to identify dimensions that might point to similar or different approaches.

Results

In this section, we start by reporting on the results of an analysis that compared teacher beliefs about the use and function of the Progress Portfolio as a tool to support science inquiry. We then look at a comparison of teacher customization of the Progress Portfolio across the same instructional unit.

Teacher Beliefs about the Progress Portfolio

A review of the interview responses by our three teachers about the Progress Portfolio software revealed a range of categories for talking about its function and usefulness in the classroom. Table 1 provides a summary of the categories reflected in teachers' statements about the tool's use and function. All three teachers viewed the Progress Portfolio as a tool that could support both teacher and student needs. There were some common conceptions; however, there were also some differences across teachers in the ways that they conceptualized the tool.

Examples of teacher statements will help to better illustrate some of the use and function categories in relation to perceived needs. In terms of the Progress Portfolio's support of teacher needs, all three teachers mentioned assessment functions. Jill talked about the difficulty of understanding students' vague notes: "What are the kids looking at that they're getting that information from? When you're able to tie those two things together, the actual artifact and the notes, you're able to see a little bit closer really how they're thinking." Bill spoke about using the Progress Portfolio artifacts to look at student work and pinpoint errors in their reasoning. Meryl thought about the Progress Portfolio as a way to keep all of the students' reflections in one place, where she could check periodically throughout the year without fear of students losing their work. Two of three teachers mentioned another category for Portfolio use: supporting teachers' role as facilitator. By this they meant that Progress Portfolio artifacts, that showed student work and thinking, helped them to interact with and question students to prompt deeper reflection about what they were doing. One teacher, Jill, suggested two other categories. She emphasized her need to establish habits of inquiry that would develop throughout the school year. She believed that she could inscribe these habits through her design of particular Portfolio page types that students would see and use over and over again. Jill also thought that the Portfolio pages provided structure and some directions that would free up time she typically spent on task directions and management.

Table 1. Summary of categories for teacher beliefs about Progress Portfolio use and function

Support for teacher needs:	**Bill**	**Meryl**	**Jill**
Assessment of student progress and thinking	√	√	√
Teacher role as facilitator		√	√
Establish inquiry norms or habits			√
Free teacher from task management activities			√
Support for student needs:			
Organize and analyze data or information	√	√	√

Document and review progress in one's thinking	√		
Communicate or present thinking and work to others	√	√	
Collaborate on work with team members	√		
Support creativity		√	

As far as supporting student needs, all three teachers mentioned the Progress Portfolio's ability to help students to make sense of, to organize, and to analyze rich data or information sources. Jill said, "It's a way of organizing information that the kids are trying to gather." Meryl concurred that students "need a place to organize all that information and all those illustrations." She also thought that the Progress Portfolio helped students to make concrete connections between pieces of information. Bill mentioned the problem that students have "zeroing in on the important information," and that the Progress Portfolio data camera encouraged students to pick just the specific information that is important to their investigation. Other categories for support of student needs, which were mentioned by one or two teachers, included documenting one's thinking, presenting one's work to others, collaborating on project work, and facilitating student creativity.

While these findings provide some initial insights, these interviews do not always paint a complete picture of the teachers' beliefs about Progress Portfolio use and function. Teachers may have held beliefs that they did not mention in their response to our open-ended interview questions. For example, we know from our classroom observations that Jill's students used the Progress Portfolio to present their work to other students; however, she did not mention this in the interview.

Teacher Customization of the Progress Portfolio

We were also interested in any striking similarities or differences in teachers' customization of the Progress Portfolio, in particular their design of Portfolio pages to guide and support students' inquiry activities in the Create-A-World unit. An analysis of page artifacts revealed a continuum for the degree of specificity assigned to the function of page types or particular elements on a page. This provided added insight about the perceived role of the Progress Portfolio to support valued inquiry practices. We used two terms to refer to the degree of specificity. Page types or elements on a page that were designed for one task only were called "task-specific." By contrast, the term "general-purpose" was used to refer to page types or elements on a page that were designed to be used for more than one task within phases of a unit, across unit phases, or even across units.

All three teachers created general-purpose text prompts on pages to emphasize particular inquiry skills. In this way, they all assigned a general-purpose function to particular page elements (text prompts) that were repeated on more than one page type. The inquiry skills that were emphasized in this way included observing and explaining data, and explaining or predicting relationships in data. Jill emphasized the practice of documenting observations of visual data, and explaining possible patterns or relationships that were observed in order to generate temperature "rules." Similarly, Meryl emphasized the practice of documenting and explaining "variables" that students thought affected surface temperature. She also prompted students to document new questions that arose at different points in the unit. Bill prompted students to explain the meaning of a given piece of visual data, and to explain relationships or differences observed when comparing more than one piece of data.

Table 2. Continuum in degree of page type specificity between three teachers

	Bill	**Meryl**	**Jill**
Total number of page types	5	6	3
Number of task-specific page types	5	4	0
Number of general-purpose page types	0	2	3

There was much greater variation between teachers in the specificity of the function of particular page types themselves. Table 2 provides a quantitative summary. At one end of the continuum, Bill designed only task-specific page types to be used just once by students for a given task in the unit. As an example, one of Bill's page types asked students to observe and explain a graph showing water versus soil heat absorption and release, and then to explain the relationship of that graph to the climate in their city of Chicago. Meryl created both task-specific and general-purpose page types. At the other end of the continuum, Jill created only three page types, all of which were

general-purpose. A comparison of Meryl's and Jill's page types provided further qualitative differences in their general-purpose designs. One of Meryl's general-purpose page types instructed students to answer questions related to data that the students had captured to investigate the relationship of temperature to some other variable. Questions on the page included: 1) "What variable are you exploring on this map?" 2) "What questions do you have now about surface temperature?" and 3) "What are the patterns or relationships that exist between this variable and surface temperature?" Students could repeatedly use this page each time they investigated a different variable; however, it is unlikely that they could use that page, without some modifications, for a different scientific investigation in another science unit. By contrast, Jill designed page types that could be used in other science units. Her "comparison page" had no written instructions, but students had been told to paste pictures of data for variables they were comparing, and to annotate and point to possible patterns or relationships in the data. Secondly, a "rule page" provided a space for data, and instructions to explain and defend a rule that was supported by that data.

Discussion

This case study has offered us an opportunity to expand our understanding of the range of beliefs about Progress Portfolio use. We have evidence that while there are some similarities across teachers, there is also diversity in their beliefs about the functionality of the Progress Portfolio to support inquiry. And, while the designers had previously focused primarily on ways in which the tool met student needs, the teachers in this study brought to the forefront conceptions about the Progress Portfolio's support of teachers' needs, including assessment.

We also gained some insight about ways in which Progress Portfolio page design may be influenced by the degree to which the affordances and constraints associated with a general-purpose or task-specific approach are aligned with a teacher's goals for student learning. Jill's general-purpose pages provide fewer specific directions for students, thus putting more responsibility on students to make decisions about how to document their work and thinking in a particular activity. With this approach, the teacher may need to do more modeling for how to use the pages initially. However, we know from our discussions with Jill that over the year, she wanted students to take on more responsibility for initiating and practicing particular inquiry habits, and she thought that more generic Portfolio pages could move students in that direction. Bill's task-specific approach to page design afforded him opportunities to give his students more directed instructions in an efficient manner, which he thought they needed. We know from classroom observations that he employed a lot of directed instruction in general and he often used worksheets with very specific instructions for the steps to follow in an activity.

We suspect however, that a teacher's approach to page design could change with experience and/or through interactions with other teachers. We can speculate about the role of experience by looking at Jill (the more experienced user) and her use of the Progress Portfolio over the course of an entire school year. Some of her early attempts at page design, before the Create-A-World unit, included both task-specific and general-purpose pages for a particular unit, much like we saw for Meryl's page designs. However, it was not until the Create-A-World unit at the end of the school year that Jill began to design pages with the explicit intention of supporting inquiry habits that she wanted to establish and develop over multiple science units. In fact, we know that subsequent to this study, as she started off her second year of using the Progress Portfolio, she explicitly designed general-purpose page types that she intended for use across units during the year. Along with experience, we observed that a teacher's approach to page design could also evolve as he or she interacts with other teachers about ways of using the tool. For example, at a post-unit meeting of all three teachers, Bill commented that he liked Jill's more general page designs and would probably try that approach in the future.

We are currently engaged in research that will help us to further broaden our understanding of teachers' beliefs and customization of the Progress Portfolio. We continue to work with new teachers in a variety of classroom contexts and curriculum units to elaborate our use and function classification scheme (illustrated in Table 1), and to collect a larger sample of Portfolio page type examples. To better understand the possible changes brought about by experience, we are conducting longitudinal investigations of the Progress Portfolio's use by particular teachers over one or more years. Because student beliefs will also influence the way a tool is used in the classroom, we are collecting similar data about students and their use of the Progress Portfolio, both in short and long-term investigations. While this comparative case study did not set out to make explicit links between teacher beliefs and practice, we recognize that this is another important aspect that should be explored more fully in the future. Finally, future research should be expanded to consider other variables related to teachers' use of the software tool, including a) teacher beliefs about inquiry-based learning, teaching, and assessment, b) teachers' own content knowledge, and c) measures of student learning.

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The Progress Portfolio is available at http://www.progressportfolio.nwu.edu.

WorldWatcher is available at http://www.worldwatcher.nwu.edu/.