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# Exploring the Influence of Web-Based Portfolio Development on Learning to Teach Elementary Science

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This qualitative case study examined web-based portfolio development in the service of supporting reflective thinking and learning within the innovative context of Professional Development Schools. Specifically, this study investigated the nature of the evidence-based philosophies developed by prospective teachers as the central part of the web-based portfolio task and the ways in which the technology contributed to it. The findings of this study illuminated the participants' understandings about learning and teaching science emphasizing a student-centered approach, connecting physical engagement of children with conceptual aspects of learning, becoming attentive to what teachers can do to support children's learning and focusing on teaching science as inquiry. The way the task was organized and the fact that the web-based format provided the possibility to keep multiple versions of their philosophies gave prospective teachers the advantage to view how their philosophies were changing over time, which supported a continuous engagement in metacognition, self-reflection, and self-evaluation. Built on these findings we suggest that future research be directed in the area of teachers' knowledge and beliefs about science teaching and learning and the kinds of experiences that influence their development. The ways in which technology tools can contribute to supporting prospective teachers in developing personal theories consistent with current recommendations of reform focusing on supporting learning through inquiry should also be explored.

In recent years, the notion of a "portfolio" has become easily recognizable as a part of the everyday language. Olson (1991) reported that a portfolio was originally defined as a portable case for carrying loose papers or prints—*port* meaning to carry and *folio* pertaining to pages or sheets of paper. Today *folio* refers to a large collection of materials, such as documents, pictures, papers, work samples, audio, or videotapes.

Portfolios have been used in teacher education in different formats, in a variety of ways, and for different purposes. The diversity of the functions and uses of portfolios have consequently produced multiple definitions depending on the purpose that the portfolio serves. Initially portfolios were associated with a scrapbook that included artifacts that had been saved and which could eventually be shown to a prospective employer (Aschermann, 1999). Portfolios also were described as a purposeful, integrated collection of work (Paulson, Paulson, & Meyer, 1991), and as an extended resume (Wolf, 1994). Dana and Tippins (1998) referred specifically to the science portfolio as "a researched presentation of the accomplishments of a teacher of science documented with teacher and student work and substantiated by reflective writing" (p. 723).

Portfolios can be used to demonstrate effort, progress, and achievement (Barrett, 1998) and to illustrate good teaching (Aschermann, 1999). According to Wolf (1991) portfolios can give teachers a purpose and framework for preserving and sharing their work and stimulate them to reflect on their own work and on the act of teaching. Other purposes of portfolio development involve the enhancement and development of teaching skills (Collins, 1990), the encouragement of reflection upon one's teaching (Richert, 1990), and professional growth through collegiality (Shulman, 1988). As Lyons (1998a) suggested, "the portfolio may be considered from three perspectives: as a credential, as a set of assumptions about teaching and learning, and as making possible a powerful, personal reflective learning experience" (p. 4).

This study focused on the development of web-based portfolios in science teacher education. Two issues are important in this study: (a) the emphasis on supporting prospective elementary teachers' reflection and (b) the construction of their knowledge of learning and teaching science. The literature review that follows illustrates the different approaches to portfolio development in teacher preparation programs.

## LITERATURE REVIEW

Several studies have been conducted to investigate the use of portfolios in teacher education programs. For example, in their study, Dana and Tippins (1998) proposed a model of portfolios for science teaching as a form of self-reflection and evidence of the prospective teachers' thoughts and understandings of what it means to teach science to children. For their study, prospective teachers were asked to identify a problematic aspect of science-specific pedagogy, and then collect and select evidence demonstrating what they knew and were able to do about it. In addition, prospective teachers had to organize the evidence for presentation in the teaching portfolio and to engage in conversations with their peers about their thinking, growth, and development. The science teaching portfolios were required to have an opening statement expressing the portfolios purpose, a variety of evidence with tags or captions, and a reflective synthesizing statement (Dana & Tippins, 1998). The findings of this study supported the argument that science teaching portfolios support reflective self-inquiry about science pedagogy. More specifically, as the findings of this study revealed, participants engaged in reflective activities while developing their opening statements. In addition, most of them used lesson plans and student work as evidence while a few of them produced artifacts especially for their portfolios (e.g., bibliography, HyperCard stack, videoclips and pictures). In their synthesizing statements, many of the participants reported that in the beginning it was difficult to develop their own questions or how to go about learning about their questions, but they were comfortable in doing so at the end. As the researchers concluded:

> Engaging prospective teachers in the preparation of portfolios as a form of self-reflective inquiry in collaboration with peers, university instructors, and classroom teachers fits well with the goal of making explicit the knowledge, skills, and dispositions that teachers of science have about teaching, learning, and content. (p. 730)

Despite their potential to facilitate thoughtful reflection, traditional paper-based portfolios often fail to capture the dynamic and complex process of teaching and learning (Aschermann, 1999). Depending on the ways in which they are used, traditional paper-based portfolios may be nothing more than a container of papers. Paper-based portfolio development enhances the danger of paying too much attention to the final product rather than the process. Other drawbacks of the traditional paper portfolios have to do with the substantial photocopying costs (Dollase, 1996) and storage problems (Aschermann, 1999). A solution to these problems appears to be in the use of hypermedia technology. Jonassen, Myers and McKillop (1996) defined hypermedia as a way of representing and organizing information using electronically connected networks of nodes, which are the basic units of storage in hypermedia. One hypermedia tool is the electronic portfolio, which has recently gained popularity among teacher educators.

A growing number of studies are reporting the uses of electronic portfolios, also known as e-portfolios, in teacher education (Aschermann, 1999; Barrett, 1998; Glasson & McKenzie, 1999; McKinney, 1998). For example, Glasson and McKenzie (1999) examined the development of multi-media portfolios for enhancing learning and assessment in a science methods class. Their study focused on the portfolio development of a group of four prospective teachers who planned three days of investigative science activities with middle school students. According to the researchers, the activities engaged students in collecting and identifying macro-invertebrates to assess stream quality. Follow up activities involved the students working in groups to negotiate pertinent aspects of development along the stream, such as where to locate homes and industry (Glasson & McKenzie, 1999). The prospective teachers collected information and documented, both their own and their students' learning, in portfolios using a multimedia-authoring tool. They also included in their portfolios videotaped interactions with students, scanned samples of student work, digitized photographs, curriculum plans, and written assessments of their learning. Two prospective teachers participated in videotaped interviews where they discussed their perceptions of the process of developing a portfolio. Both of them mentioned that the portfolio was useful for understanding and assessing the progress of the children while serving as an assessment tool for themselves to be used by their teachers. As Glasson and McKenzie (1999) concluded, "Through this process of designing their own portfolio, the ability of these prospective teachers to assess their own learning and students' learning was greatly enhanced" (p. 342).

A type of hypermedia portfolios is the web-based portfolio. When e-portfolios are specifically created for and placed on the web, they are referred to as web-based portfolios (Watkins, 1996). The Web, as both a technology and an interface, enables prospective teachers to have ultimate control in assembling and re-organizing, as well as integrating narrative captions among the evidence to emphasize the interrelated nature of learning (Watkins, 1996). Similar to other forms of hypermedia, web-based portfolios have the potential to support reflection and revaluation because they provide a means of storing multiple iterations over time and a mechanism for ease of editing and revisions. Substantial revisions involve reflection on course content encompassing processes like reordering and reevaluating, resulting in new insights (Yates, Newsome, & Creighton, 1999).

The literature suggests that the web-based format has additional benefits to offer beyond those of other types of e-portfolios. In specific, the web-based format provides instant access to a variety of audiences. As Pierson and Kumari (2000) illustrated, the web environment permits prospective teachers the flexibility to maintain their portfolios in a web-space that can be remotely accessed from anywhere at any time, by the prospective teacher, faculty, peers, and potential employers. Research in the area of web-based portfolio development is limited. However, the few findings that exist are consistent and suggest that web-based portfolio development is a constructivist process that facilitates meaningful reflection (Avraamidou, 2001; Milman, 1999; Morris & Buckland, 2000; Watkins, 1996; Zembal-Saul, 2001).

A study by Milman (1999), for example, suggested that engaging prospective teachers in web-based portfolio development results in engaging them in reflective activities while connecting course work and field experience. In this study, Milman (1999) documented the use of the World Wide Web (WWW or Web) to create electronic teaching portfolios in a pilot prospective teacher education course as a tool for reflection. The objectives of the course were for prospective teachers to create electronic teaching portfolios, to reflect upon their coursework and teaching experiences, and to become more proficient with the technology. Interviews with the participants, analysis of their journals, and observations in their classes revealed that the process was constructivist, demanding and multifaceted. The prospective teachers reported that the process of creating electronic teaching portfolios was very positive, resulting in reflection about themselves as teachers. Through the process of analytic induction of the participants' journals, interviews, and observations, the following assertion was made, "Creating electronic teaching portfolios is a constructivist process that promotes an examination of prospective teachers' beliefs, philosophies, objectives, and purposes for teaching" (Milman, 1999, p. 3).

According to Pearson (1989), the challenge in teacher education is to enable prospective teachers to take what they have learned about teaching and to use it on their own in the teaching situations in which they find themselves. In an attempt to meet this challenge, and considering the fact that the two innovations, portfolio development and hypermedia authoring combined in support of learning are largely unexplored, this study aimed to investigate the use of web-based portfolios in a reform oriented elementary science methods course as a vehicle for supporting reflection and learning to teach.

## PURPOSE AND GUIDING QUESTIONS

Given the need to incorporate opportunities for critical reflection into teacher preparation and the potential of hypermedia authoring to support this level of reflection, this study examined web-based portfolio development in the service of supporting reflective thinking and learning within the context of a reform-oriented science methods course. In this course, portfolios were used to assist prospective teachers in developing meaningful understandings about learning to teach science. Using the web-based format to develop portfolios was intended to provide prospective teachers with opportunities to connect their personal theories of teaching and learning with their field experiences. In addition, the web-based format facilitated the development of dynamic and complex interconnections among claims made by prospective teachers and multimedia evidence used to support those claims.

The web-based portfolios included two main components: (a) a collection of evidence that consisted of course assignments; and (b) a personal, evidence-based philosophy about science teaching and learning. The purpose of the web-based philosophies was to: (a) support the development of personal theories about teaching and learning science explicitly and publicly; (b) promote reflection on personal theories in light of new experiences and learning; and (c) facilitate the development of connections among theory and practice.

At a general level this research aimed to answer the question: What is the nature of prospective elementary teachers' science teaching philosophies for supporting children's science learning and how do they change over time. Specifically, the questions that guided this research were:

1. What is the nature of prospective elementary teachers' philosophies about science teaching and learning?
    - What kinds of claims do prospective elementary teachers pose?
    - What are the nature and sources of evidence prospective elementary teachers use to support their claims?
    - In what ways do prospective elementary teachers justify their evi dence in light of the claims they were used to support?
2. In what ways does the web-based portfolio task support thoughtful reflection associated with learning to teach science?
3. In what ways does the technology contribute to the portfolio task?

## METHODS

### Design

This study used a qualitative case study design to examine the development of prospective elementary teachers' understandings of teaching science as supported by and illustrated through the development of web-based portfolios, within the context of a reform-oriented elementary science methods course. Specifically, this study manifests the characteristics of a multi-participant case study (Merriam, 1998). For the purpose of this study, two individuals were investigated within the larger case of prospective elementary teachers' understandings of teaching science with the support of web-based portfolios. These two individuals were chosen because it was believed by the authors that their representativeness would lead to main assertions about prospective teachers' understandings of teaching science. Both of the participants were traditional prospective elementary teachers (i.e., 22 years old, females with no science-specific background). To maintain the confidentiality of the participants, the pseudonyms Sarah and Jane were used in all aspects of this study.

### Context

As described by the instructor of the course (Zembal-Saul, 2001) the participants in this study were members of a cohort of prospective elementary teachers engaged in a year-long internship program. The internship took place during the final year of a four-year teacher education program. The prospective teachers spent the entire year in one of four professional development schools (PDSs) that were part of a local school-university partnership (Zembal-Saul, 2001). Mentor teachers in these schools were actively engaged in their own professional development (e.g., taking coursework, engaging in classroom-based research, participating in methods course planning). The web-based portfolio project was completed as part of the elementary science methods course. The course was co-designed by the university-based methods instructor and a team of five mentor teachers, a PDS principal, and a curriculum support teacher. The web-based task was structured as an evidence-based argument about teaching and learning science that was developed over time. Prospective teachers generated a series of assertions or claims, supported those claims with multiple pieces of evidence/artifacts (e.g., course projects, classroom observations), and justified evidence in light of the claims they made. Over the course of the semester, claims were added, modified, or rejected on the basis of new evidence (Zembal-Saul, 2001).

Specifically, in the first version of their science teaching philosophies, prospective teachers were required to include at least three claims and use at least one piece of evidence to support each claim. In addition, all evidence needed to be justified. That is, an explanation should have been included of why the specific piece of evidence supported the corresponding claim. The prospective teachers were asked to develop a second version of their philosophy halfway through the semester, and a third version at the end of the semester. In the second version of their philosophies, prospective teachers had to include at least four claims about how children learn science and what teachers can do to support children's science learning. As with the first version of the science teaching philosophy, all evidence should have been justified. In the third version of their philosophies, each new claim needed to be supported by at least two pieces of evidence. Each existing or modified claim should have been supported by at least three pieces of evidence. Again, all pieces of evidence had to be justified in light of the claims they were used to support. An example of the main page of the web-based portfolio is presented in Figure 1.

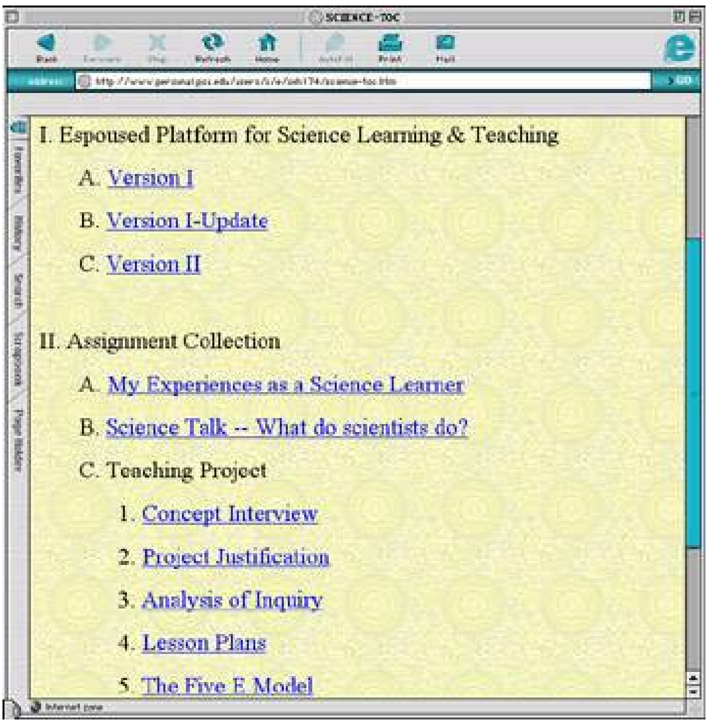


**Figure 1.** Sample of the main page of a web-based portfolio

## Data Sources

Multiple sources of data were used in this study. The main source of data was the web-based portfolios that the participants developed during the Fall 2000 semester. More specifically, three versions of the web-based science teaching philosophies that each of the participants developed as part of their web-based portfolios were examined. Another source of data was the reflection statements developed by each of the participants. In their reflection statements, participants were asked to discuss what changes were made in the different versions of their philosophies and explain why. Specifically, participants were asked to reflect on how they saw their science teaching philosophies changing over time and to comment on the revisions they were making in each iteration.

## Data Analysis

Three analytic techniques were used to analyze the web-based portfolios: (a) pattern-matching, (b) explanation-building, and (c) time-series analysis (Yin, 1984). Pattern matching refers to the patterns identified, through multiple readings of the web-based portfolios, in relation to the nature of claims developed, evidence used to support claims and justifications. The purpose of the explanation-building was to analyze the data by building an explanation about each case (Yin, 1984), referring to why the science teaching philosophies developed the way they did in the different versions. The time-series analysis refers to the analysis of changes over time and identification of trends in developing a web-based science teaching philosophy throughout the semester. Identification of trends refers to the changes noticed in the science teaching philosophies, moving from the first version to the second and from the second version to the third.

Furthermore, a content analysis of the participants' reflective statements was done to illuminate their understandings of how their views of teaching and learning were changing over time. To investigate how technology contributed to the task, the way participants made use of the multimedia possibilities of the web-based format and the way they used hyperlinking, were investigated. Specifically, the kinds of artifacts the participants used as evidence in the three versions of their philosophies and how they chose to link further information and artifacts within the text were examined. After the within-participant analysis was done, a cross-participant analysis followed to identify similarities and differences across the two participants.

## FINDINGS AND INTERPRETATIONS

Data from the three versions of the participants' science teaching philosophies and from their two reflection papers were analyzed to explore the nature of their philosophies, the ways that the web-based portfolio task supported thoughtful reflection and the ways technology contributed to this task. The findings are described based on the assertions that were made around three core areas: (a) the nature of the prospective elementary teachers' claims, evidence and justifications; (b) prospective elementary teachers' understandings about teaching and learning science; and (c) the role of the task and the affordances of technology.

### Nature of Participants' Claims, Evidence, and Justifications

The claims that Sarah and Jane developed throughout the three versions of their philosophies are presented in Table 1 and Table 2. Overall, the claims that both of the participants developed, transformed from being generic in initial versions of their philosophies to being precise and science specific in the final versions. A discussion about the nature of the evidence and justifications the participants developed, and how they transformed from the first to the later versions of their philosophies follows.

**Table 1**

Jane's Claims Across the Three Versions of her Philosophy

| Versions | Claims |
|---|---|
| V1 | Children learn science by asking questions.<br>Children learn science by relating it to the world outside through hands-on activities.<br>Children learn science by being challenged to reflect deeply on science observations. |
| V2 | Children learn science by asking questions.<br>Children learn science by experiencing it through hands-on and minds-on activities.<br>Children learn science by being able to reflect deeply on science observations.<br>Teachers support science learning best when they ask questions to probe students' thinking as opposed to asking questions to elicit a certain answer. |
| V3 | Same as Version 2. |

**Table 2**
Sarah's Claims Across the Three Versions of her Philosophy

| Versions | Claims |
|---|---|
| V1 | Children learn science through hands-on activities.<br>Children learn science through inquiry-based investigations.<br>Children learn science through activities that engage and challenge all learners.<br>Teachers can support children's learning by modeling joy in science.<br>Teachers can support children's learning by creating a safe and collaborative learning environment. |
| V2 | Children learn science through hands-on and minds-on activities.<br>Children learn science through inquiry-based investigations.<br>Children learn through talking about science.<br>Teachers can support children's learning by mediating their science experiences. |
| V3 | Children learn science through hands-on and minds-on activities.<br>Children learn science through inquiry-based investigations.<br>Children learn best through talking about science.<br>Children learn science through collaboration.<br>Teachers can support children's learning by mediating their science experiences. |

***Making connections between university coursework and field experiences.*** As it became evident through the participants' web-based philosophies, the greatest influence on their learning was the model lessons they experienced in the science methods course. Specifically, the most commonly used sources of evidence were the model lessons of the elementary science methods course. In addition, moving from the first to the third versions of their philosophies, participants incorporated more evidence drawn out of their teaching experiences while they continued using evidence drawn from their science methods experiences. Table 3 illustrates how Sarah and Jane used evidence to support their claims in the three versions of their philosophies.

**Table 3**
Sources of Evidence Across the Three Versions of Participants' Philosophies

| Participant | Methods Course | | | Readings | | | Teaching Experience | | |
|---|---|---|---|---|---|---|---|---|---|
| | V1 | V2 | V3 | V1 | V2 | V3 | V1 | V2 | V3 |
| Sarah | 2 | 3 | 3 | 0 | 2 | 2 | 0 | 1 | 6 |
| Jane | 3 | 5 | 5 | 0 | 1 | 2 | 0 | 1 | 5 |

In general, the participants relied heavily on their experiences as learners in the methods course throughout the different versions of their philosophies. As shown in Table 1, both Sarah and Jane used several pieces of evidence that reflected central concepts from the model lessons they experienced in their science methods course to support their claims.

Furthermore, both Sarah and Jane included an increasing number of examples of their teaching experiences over time. Specifically, as soon as they began teaching, they incorporated these experiences as evidence. As presented in Table 3, in the second version of her philosophy, Sarah used one piece of evidence capturing her teaching experiences. In the final version of her philosophy she used six of them. A similar trend was identified in relation to how Jane made use of evidence drawn out of her teaching experiences. In the second version of her philosophy, Jane used one piece of evidence and in the final version she used five pieces of evidence drawn out of her personal teaching experiences. Additionally, Sarah used many pieces of evidence that captured her observations of her mentor and other teachers teaching. Specifically, in the final version of her philosophy, Sarah referred to six pieces of evidence from her observations in the field.

The fact that both of the participants integrated evidence drawn out from both their experiences from the science methods course and the field, suggests that they were making connections between university coursework and field experiences. The impact of the mentor teachers' teaching activities on the participants' personal philosophies became apparent through the evidence that Sarah used in her philosophy that was drawn out of observations of her mentor and other mentor teachers' practices. This finding is significant because research suggests that prospective teachers often lack powerful models in school contexts that reflect what they are learning in their coursework. For a variety of reasons, including strong socialization pressures, prospective teachers often conform with school context and culture (Darling-Hammond, 1994). This suggests the need for a better cooperation between school and university and particularly the pairing with mentor teachers.

Mentoring is crucial to the prospective teachers' development as professionals and it greatly affects their enculturation into the teaching profession (Putnam & Borko, 2000).

***Transformation from being descriptive to being explanatory.*** A trend that emerged through the participants' justification statements is that they shifted from being descriptive and brief to being explanatory, reflective, and elaborative. However, some differences in the way Sarah and Jane developed their justification statements throughout the three versions of their philosophies were observed.

Specifically, in the first version of her philosophy, Sarah did not really justify the ways in which different pieces of evidence supported her claims, but instead she just further described the specific pieces of evidence used to support the claims. For example, in order to justify *Air Activities* for the claim stating that children learn science through hands-on and minds-on activities, she described the model lesson:

> This is an example of a hands-on/minds-on activity. Before experimenting, the class generated a list of things we knew about air. (The "K" or "Know" portion of the modified KLEW chart.) While performing various experiments, we were required to make predictions and conclusions based on what we observed. When the class reconvened for a science talk, class members shared things they learned about air ("L") and their evidence ("E") to support their claims. This led the class to generate new wonderings ("W") in light of what we learned. (Sarah, v. 1, justification of evidence for claim #1)

In contrast, in her final version, Sarah developed extensive and explanatory justification statements for the evidence used to support specific claims. The justification statement below refers to the use of journals as a way for teachers to mediate children's science experiences:

> In both my own fourth grade classroom and Y's second grade classroom, children record their thoughts, predictions, observations, and conclusions in science journals. In providing children the opportunity to use science journals, teachers are providing their students the opportunity to reflect on their own actions and thoughts. In recording predictions, for example, students are creating a record to which they can refer later. Students can then compare their thoughts before and after a science activity, thus reflecting on and learning from their own action. Promoting student reflection is another quality of the teacher's role as mediator. (Sarah, v. 3, justification of evidence for claim #5)

In this justification statement, Sarah explained how students engaged in reflection when they developed science journals. She connected the evidence with the claim by stating that engaging students in reflection is one aspect of the teacher's role as mediator.

Jane made strong connections between the evidence and the claims through her justifications in the first version of her philosophy, but her statements were more reflective than evaluative in their nature. In particular, she commented on how each piece of evidence contributed to her own learning but she did not explain how the specific evidence supported the associated claim. The example that follows is the justification statement that Jane developed about *Oobleck* in support of the claim stating that children learn science by being challenged to reflect deeply on science observations:

> We not only observed and considered possible explanations for the Oobleck's behavior, but we also tried to find evidence for these explanations. Because we were able to think beyond the observable and reflect on the whys and hows, I was able to learn about much more than the properties of liquids and solids; I learned about science as a process. (Jane, v.1, justification of evidence for claim #3)

Like Sarah, Jane developed more explanatory justification statements in the third version of her philosophy. In order to justify a piece of evidence from the book *Talking Their Way Into Science* (Gallas, 1995) used to support her claim that teachers learn science by asking questions, Jane stated:

> This piece of evidence supports my claim because this reading includes examples and substantiation of why using open-ended questions is important for a child's scientific development. The section discusses how much more thinking and synthesizing occurs when open-ended questions are used instead of closed-ended. The following is an example from the book. If someone asks, "Who made the first clock?" the conversation is over when this inventor's name is found. Not only this, but the bulk of the conversation would involve students trying to recall possible names, not deep analytical thinking. Think instead about students discussing possible reasons for why a clock works. The scientific ideas generated would increase ten fold. By asking students a question that is not expected to elicit a correct answer, students are able to think, analyze any data they have, and make a prediction without fear that they will be wrong. Through examples such as these and testimony from researchers in the field, the Gallas reading attests to the many benefits of asking open-ended questions for science learning. (Jane, v. 3, justification of evidence for claim #1)

In this justification statement, Jane described how the author of the book discusses the value of asking open-ended questions in supporting children's learning.

The fact that both of the participants moved from being descriptive to being more explanatory in their articulation reveals that the development of evidence-based claims proved to be an important element of the task and a good strategy for supporting their ability to distinguish evidence from explanation. Having to craft justification statements, prospective elementary teachers had to explicitly distinguish between the claims they made, the evidence they used to support their claims and the explanation used to back up their evidence. The above finding is important since several lines of research (e.g., Kuhn, 1991) have found that people have difficulties in making distinctions between the respective roles of explanation and evidence in an argument. Explanations and evidence are essential to our understanding and evaluation of claims (Brem & Rips, 2000).

In addition, the development of justification statements appeared to be a powerful technique for engaging prospective teachers in meaningful reflection since they required explicit and justified connections between the claims and evidence used to support them. According to Nettles and Petrick (1995), writing a rationale allows prospective teachers to reflect on their work, both in deciding for which outcome the artifact provides evidence and in realizing their proficiency in that particular teaching strategy or skill.

***Engaging in reflective and metacognitive activities.*** In addition, prospective teachers engaged in metacognitive activities while developing their reflection statements where they had to discuss about the changes they had made in each newer version of their philosophies. Jane commented on how her teaching experience with *Shadow Lessons* helped her develop a better understanding of teaching science as inquiry. Specifically, she stated in her reflection statement:

> Three pieces of evidence are my shadow lessons as a whole and one of the pieces of evidence is the free exploration station…teaching and preparing the shadow lessons really opened my eyes to the possibilities of inquiry in science. It was this reason that I used my shadow lessons as evidence for all fours claims. (Jane, first reflection)

In Sarah's reflection, it becomes evident that she was aware of the way in which her web-based philosophy had been changing. In the reflection statement she crafted at the end of the semester she pointed out how her philosophy had evolved:

> As I was working on version 3, there were several things I noticed about how my philosophy is taking shape. First of all, the majority of my claims (four out of five) deal with how children learn science, and only one deals with what teachers can do to support children's science learning. I think that this reflects a very general principle of my philosophy of education—that the focus should be on children and not on the teacher...I believe that a strong focus on children and how children learn naturally leads to child-centered practices. (Sarah, second reflection)

The development of a reflection statement on how their personal science teaching philosophies were taking shape required prospective teachers to think about their knowledge, understandings, ideas and beliefs about learning and teaching. This is important because research suggests that it is very difficult to move prospective teachers beyond focusing on surface level ideas to engaging in more substantive reflective practices, such as analyzing and evaluating their planning and teaching (Borko, Livingston, McCaleb & Mauro, 1988). Dollase (1996) agreed, pointing out that prospective teachers have difficulty reflecting on their experiences, understanding teaching goals, and developing an adequate rationale for their lessons.

## Participants' Understandings About Teaching Science

***Becoming sensitive to children's thinking.*** The first trend that was apparent through the different versions of the participants' web-based philosophies was that they became more sensitive to children's thinking and learning and emphasized a student-centered approach. Sarah argued about the importance of *Science Talk* in one of her justification statements: "…it gives the teacher a window of insight into the children's thinking. It allows teachers to listen to their students, find out about their preconceived notions, their thought process, and their understandings of previous concepts" (Sarah, v. 2, justification of evidence for claim # 3).

Similarly, Jane described how students learn through reflecting on observations:

> While students didn't always answer that question to me, their minds were definitely reflecting, as was shown by their actions. For example, one student was observing how the shadow size of scissors changes when the scissors are moved towards and away from the light source. She was merely moving the scissors back and forth, making up sounds as she went along. I then asked her why she

> thought this was happening. She stopped for a minute, shrugged her shoulders and said, "I don't know." At this point she wasn't reflecting very much. As she continued the exploration I pushed more questions and then asked how we could find the answer to these questions. After a number of questions and ponderings, the student formed a hypothesis. (Jane, v. 3, justification of evidence for claim #3)

Sarah commented on the importance of the *Science Talk* in gaining an insight into the children's thinking which reveals her sensitivity to their knowledge and thinking. Jane explained the importance of reflecting on observations in support of children's learning with the use of an example from her own teaching experience. Through Jane's statement it is shown that she was considering how to support the specific student's reflection. Both of the participants seemed to be sensitive to their students' thinking about science. This finding is significant because it stands in contrast to the literature that suggests that prospective teachers view themselves as the transmitters of knowledge to the children (Aguirre & Haggerty, 1995; Aguirre, Haggerty & Linder, 1990; Cohen, as cited in Prawat, 1992).

***Connecting physical engagement of children with conceptual aspects of learning.*** Another trend that was noticed was that in the later versions of their philosophies, the participants of this study began to recognize a connection between physical engagement in activities and more conceptual aspects of learning. They explicitly stated that it is not enough to engage children in hands-on activities to support their learning. Sarah stated that: "Hands-on/minds-on activities go a step beyond traditional hands-on activities, asking children to think about and explain science concepts…the activity moves beyond the realm of hands-on and requires students to apply their minds to the activity" (Sarah, v. 3, justification of evidence for claim #1).

In a similar way, Jane explained: "Students need to experience science concepts by using their senses to see first hand how science works. However, just the experiences aren't enough. Students also need to be able to think about the hows and whys of the science" (Jane, v.3, claim #2).

The nature of the claims that the participants developed in the initial versions of their philosophies supports the findings of previous studies reporting that beginning teachers tend to emphasize the physical engagement of children in activities (Gustafson & Rowell, 1995). Both participants claimed that children learn science through hands-on activities. An example is Jane's justification statement for evidence related to a stream study, which was used to support the claim that children learn science, by relating it to the world outside through hands-on activities.

> Before the stream study I knew little about how one finds water quality of a stream and even less about macro invertebrates. Discussing this type of topic in a classroom, or reading about it in a text book would most likely be very hard to grasp. Because I was able to actually walk in the stream and catch the macro invertebrates and look up what each organism was, I felt I gained a much better understanding of the topics than I would have if my information would have come only from a book. I actually saw the bugs and went through the process of a stream study and because of this I will remember the experience for quite some time. (Jane, v. 1, justification of evidence for claim #2)

According to Prawat (1992), the emphasis on the physical engagement is firmed with a set of beliefs about teaching and learning, termed "naïve constructivism." As Prawat (1992) stated, beginning teachers have the notion that student interest and involvement (i.e., in "hands-on activities") constitutes both a necessary and sufficient condition for worthwhile learning. However, as it becomes apparent through the participants' statements, they were aware that to make the physical engagement of children in activities meaningful and beneficial, they had to engage them in thinking about them as well.

***Focusing on teaching science as inquiry.*** A pattern that was observed throughout the participants' web-based portfolios, and particularly within their justification statements, was that they became more focused on the essential features of inquiry (National Research Council, 1996, 2000). When Jane justified a methods course investigation in which she and her peers participated as science learners, in support of her claim stating that children learn science by asking questions, she emphasized the fact that they were given some information and they had to figure out how to use it to provide explanations for the dinosaurs:

> The questions asked during this activity helped my peers and I take learning into our own hands and search for answers to our own questions. During the dinosaur unit activity our group was given information and was then challenged to figure out what this information meant. If we were merely spoon fed the information through the letters from the paleontologists it would be passive learning. But because we had to ask questions about the information we received, we probed our own understanding and then searched for more. Questions such as, "I wonder how big the dinosaur is?" caused us to postulate ways we could figure such a thing out. If the questions would have

> been asked for us it would have been us finding the "right" answer that the teacher wanted to know. But because we asked it, we searched for many different possible explanations: "We could look at his foot size, or we could measure his stride and then find out how big his legs are." (Jane, v. 2, justification of evidence for claim #1)

Similarly, in her justification of evidence from a lesson she had designed and taught about bird beak adaptations, Sarah emphasized teaching science as inquiry:

> The bird beak adaptation activity invites children to get physically involved with the science concept. They become birds, have beaks, and must experiment to find out which food they can acquire most easily with their beak. However, the simulation does not end there. The students must collect and organize data on their trials, and think about how to analyze that data. The students must form hypotheses to explain the data they have gathered, and support these explanations with evidence. (Sarah, v. 2, justification of evidence for claim #1)

The emphasis on teaching science as inquiry was evident in both of the participants' justification statements that stressed question-driven investigations, the use of observational data, making connections between evidence and explanations and communicating these explanations to others. According to the *National Science Education Standards,* in inquiry, the focus is on children cooperatively investigating and developing an understanding of their world, and at the same time, learning about science and inquiry—procedures, scientific habits of mind, and significant knowledge of science content (National Research Council, 1996, p. 133).

The fact that the two participants emphasized teaching science through inquiry is important because it reveals that their views were becoming more consistent with contemporary reform efforts in science education. Specifically, the participants explicitly discussed how teaching science through inquiry enhances students' learning. This is significant because these prospective teachers had no science-specific background and their elementary education orientation, which requires them to teach a variety of subjects, does not leave room for specialization.

***Becoming attentive to what teachers can do to support children's learning.*** Another trend that emerged through analysis of the web-based portfolios is that the participants became more attentive to what teachers can do to support children's science learning. Sarah pointed out that teachers support children's learning when they mediate their experiences. In particular, she articulated the following in relation to a science corner she started in her classroom, which she used as evidence to support her claim:

> A few weeks ago, I started a science corner in my classroom. Because of it I have learned a lot about the teacher's role in helping students learn science. I have learned that one of my roles as mediator of my students' science experiences is to provide them with informal science experiences related to their interests and to our current unit of study. For example, when I set up a "crystal cave" at our science corner the week we took a field trip to Penn's Cave, I gave them the opportunity to observe what was happening, predict what will happen, and witness change over time. As mediator, it is my responsibility to keep the science corner updated and in tune with my students' interests. (Sarah, v. 3, justification of evidence for claim #5)

Jane claimed that teachers support children's science learning best when they ask questions to probe their thinking as opposed to asking questions to elicit a certain answer. In specific, this is how she justified her Science Talk evidence for this claim:

> This piece of evidence supports my claim because it shows how much information can be gained when a student is pushed further through teacher questioning that isn't aimed at a single correct answer. When I asked questions during the science lessons I didn't want to elicit a certain answer; I honestly wanted to know what students were thinking. So when I asked questions like, "what do you think is going on here, or why do you think this is happening," I wasn't expecting a single correct answer. While I can't deny that I did have the correct answer in my mind, I didn't expect this answer, or necessarily want this answer to come out of the mouths of my students. What I wanted was a description of what the kids thought was happening so that I could have a window into the thinking of the children. This glimpse into students' thinking helped me to plan activities to foster the further development of students' understanding of shadows. (Jane, v. 2, justification of evidence for claim #4)

Through Sarah's and Jane's justifications it is apparent that they were both considering how to make science content meaningful to their students. This attitude contradicts the literature related to teachers' beliefs that suggests that they tend to view content and students in static, noninteractive terms (Prawat, 1992).

## The Role of the Task and the Affordances of Technology

***Keeping multiple versions of the philosophies and viewing changes over time.*** Web-based portfolios provided the vehicle through which prospective teachers explored their understandings of learning to teach, through the development of different versions of their philosophies. The web-based format supported the engagement of prospective teachers in reflecting on and reevaluating their ideas about teaching and learning science since it allowed them to keep multiple versions of their philosophies.

The way the task was organized and the fact that the web-based format provided the possibility to keep multiple versions of their philosophies gave prospective teachers the advantage to review prior versions of their philosophies, build on their initial ideas, revise their views about teaching and learning science, and easily reorganize their philosophies. Prospective teachers were able to view how their philosophies were changing over time, which supported a continuous engagement in metacognition, self-evaluation and self-reflection.

***Taking advantage of the hypermedia component.*** The hypermedia possibilities of the web-based portfolio allowed prospective elementary teachers to make nonlinear, dynamic representations of their science teaching philosophies. Through the hyperlinking process, prospective teachers made connections between their coursework and field experiences and between their claims, evidence, and justification statements, which resulted in an interconnected presentation of their learning experiences. Additionally, with the use of hyperlinking prospective teachers were able to reorganize their philosophies by redefining links. Specifically, this became apparent through Jane's web-based philosophy. Jane used the same piece of evidence to support multiple claims in different versions of her philosophy. She created a link that would take the reader to the specific evidence for each claim, then she changed her justification statements in each version of her philosophy to reflect the claim-evidence relationship.

The hypermedia component fosters connections between coursework, concepts, and applications because it allows the individual to designate links between ideas and themes (Morris & Buckland, 2000). Through the construction of their hypermedia science teaching philosophies, prospective elementary teachers took a more active approach to learning.

***Making thinking visible.*** Another aspect of the web-based format is its public nature since it makes the portfolio available to a variety of audiences. The web-based portfolio has the potential of being viewed by a greater number of people. Thus, greater effort and pride is taken to create a public document (Aschermann, 1999). Moreover, the public nature of the web-based portfolios makes it easier for prospective teachers to give and receive feedback from peers or professors. They are easier to share, making it possible for prospective teachers to see a variety of exemplars, view other perspectives of teaching and learning and challenge their own practices and beliefs (Morris & Buckland, 2000).

In this study, web-based portfolios provided a place where prospective teachers articulated their science teaching philosophies and presented them in a hypermedia format. In particular, web-based portfolios made participants' thinking visible and documented their growth. As Loughran and Corrigan (1995) noted, "A major focus of the process of developing a portfolio and the product is to help prospective teachers begin to articulate their understanding of what they think it means to be a teacher" (p. 17). An emerging characteristic of a teacher as a professional is this ability to articulate, evaluate, engage in, and respond to criticism about teaching, their own practice, and student learning (Lyons, 1998b). As Shulman (1998) stated, portfolios institutionalize norms of collaboration, reflection and discussion. Perhaps the most striking consequence of a portfolio process for new teacher professionalism is the creation of new norms for teachers: that is, making public discussion and debate about what constitutes good teaching (Lyons, 1998a).

## CONCLUSIONS AND IMPLICATIONS

The general conclusion to be drawn from this study is that web-based portfolios appeared to be a powerful tool for supporting the participants' learning. Engaging them in thoughtful reflection through web-based portfolio development within an innovative context, appeared to have had an impact on their conceptions about teaching and learning science. In particular, a shift in the participants' understandings about learning and teaching became apparent through the web-based portfolio analysis.

In contrast, many studies have concluded that it is very difficult to influence prospective teachers' prior ideas about learning and teaching (Aguirre & Haggerty, 1995; Calderhead, 1989; Gustafson & Rowell, 1995; Hollingsworth, 1989). Calderhead (1989) questioned whether teacher education courses really do encourage prospective teachers to reflect and supported his inquiry with the observation that prospective teachers' prior ideas are "highly influential in shaping what prospective teachers extract from their preservice training, how they think about teaching, and the kind of teacher they become within the classroom" (p. 47).

The findings of this study are congruent with the literature that suggests that portfolio development may support reflection. The justification statements appeared to be a powerful technique for engaging these prospective teachers in meaningful reflection since they required explicit and justified connections between the claims and evidence used to support them. According to Nettles and Petrick (1995), writing a rationale allows prospective teachers to reflect on their work, both in deciding for which outcome the artifact provides evidence and in realizing their proficiency in that particular teaching strategy or skill. Similarly, Schön (1983) stated:

> Practicum experiences must engage teachers in tasks where they can explore their own learning, reflect on their processes in inquiry, examine their own shifting understandings—and compare their actual learning experiences with the formal theories of learning built into standard pedagogies. Later, they might shift their attention to the classrooms in which they interact with children. Here, they would be attentive to the ways in which children's learning is like or unlike the kinds of learning they have detected in themselves. (p. 323)

Particularly, in this study, web-based portfolios served as a vehicle for these prospective teachers to reconsider and reevaluate their views of teaching and learning science in light of new learning experiences.

The development of the web-based portfolios was a constructivist process that required prospective elementary teachers to reflect on and critically examine their own beliefs and ideas about teaching and learning. The process was constructivist in the sense that prospective elementary teachers were engaged and had to make decisions regarding the organization and content of their portfolios. As Perkins (1986) illustrated, central to the vision of constructivism is the notion of organism as active—engaging, grappling, and seeking to make sense of things.

Moreover, prospective teachers engaged in metacognitive activities while developing their philosophies. The development of a personal science teaching philosophy required them to think about their knowledge, understandings, ideas and beliefs about learning and teaching science. According to Hoban (1997), prospective teachers should be encouraged to be metacognitive and become more aware of how they learn in teacher education courses with the intention of informing their decision-making as they construct their personal pedagogies.

In addition to providing an insight into prospective teachers' personal pedagogical theories, the web-based portfolios revealed the significance of the Professional Development School context and its impact on participants' learning. In this study, the professional development schools were part of an ongoing local school-university partnership. The mentor teachers in the schools where the participants were placed were actively engaged in their own professional development (e.g., taking coursework, engaging in classroom-based research, participating in methods course planning). As it became evident through the participants' science teaching philosophies, they benefited from this symbiotic relationship between their university coursework and their field experiences. According to Zembal-Saul (2001), professional development schools have the potential to foster contexts in which school-wide and classroom-based environments offer prospective teachers multiple opportunities to examine and reevaluate their personal theories of teaching and learning.

In this study, web-based portfolios served as a bridge between the university coursework and field experiences. It provided the vehicle for prospective elementary teachers to make connections between what they were learning in their science methods course and what they were applying in their practices. As one of the trends of this study suggests, the participants were making connections between university coursework and field experiences. Connecting coursework with field experiences implies transferring and applying knowledge that prospective teachers gained within one context to a different one. Research suggests that such a learning experience is supported within the context of the PDS, which enhances prospective and beginning teachers' learning by creating settings in which novices enter professional practice by working with expert practitioners (Darling-Hammond, 1994).

In conclusion, our findings strongly suggest that prospective elementary teachers' learning could be enhanced through the web-based portfolio development, which engages them in reflective and metacognitive activities about their views of science teaching and learning. The findings of this study suggest the need to rethink ways in which teacher education programs engage prospective teachers in meaningful reflection and metacognition about their understandings of science teaching and learning. We recommend that future attention be directed in the area of web-based portfolios, and specifically through the development of personal philosophies, as a vehicle for supporting such level of reflection and metacognition. This is based on the potential of web-based portfolios to engage prospective teachers in thoughtful reflection, which influences their ideas about learning and teaching.

Furthermore, in our study, specific elements of the context (i.e., the coherence between university coursework and classroom practices) appeared to be critical in supporting prospective elementary teachers' learning and deserve further attention. Future research on the effects of the context within which prospective elementary teachers develop their theories about science teaching and learning and how technology can enhance the chances of articulation and successful integration of these theories and personal teaching practices is recommended.

Moreover, examining the types of experiences that seem to be critical on the prospective teachers' development of personal philosophies is a valuable and essential form of research as we aim to support them embracing the current reforms in science education focusing on supporting learning through inquiry. Built on these implications we suggest that future research should be directed in the area of teachers' knowledge and beliefs about science teaching and learning and the kinds of experiences that influence their development to inform teacher educators about the design of effective teacher preparation programs. The ways in which technology tools can contribute to supporting prospective teachers in developing personal theories consistent with current recommendations of reform focusing on supporting learning through inquiry should also be explored.

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