Designing an Online Learning Environment for New Elementary Science Teachers: Supports for Learning to Teach

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Abstract

New elementary science teachers need support in learning to teach inquiry-oriented science effectively. CASES is a learning environment intended to support this group. This paper discusses the design principles guiding the design of CASES. The paper discusses the role that learning theory and empirical research play in informing design decisions, and provides examples of how the CASES design is informed by both. The first design principle, called *guidance-on-demand*, states that new teachers should be allowed the opportunity to request contextualized guidance when they need it. The second design principle, called *images of inquiry*, states that new teachers need multiple representations of inquiry-oriented science teaching to develop understandings of how inquiry plays out in the classroom. The third design principle, called *social supports*, states that new teachers need opportunities to share ideas and see role models that can inform their practice. The paper concludes with a discussion of how this design narrative can provide guidance for other designers of learning environments.

Introduction

Elementary teachers have a tremendous impact on their students' future learning. Elementary science may be especially important since understanding science concepts is critical for developing an educated citizenry, and elementary education lays an important foundation. Yet because of the high demands put on them, elementary teachers often demonstrate weak subject matter knowledge in science (Anderson & Mitchener, 1994) and lack confidence in teaching science (Cochran & Jones, 1998; de Laat & Watters, 1995). Likewise, prospective and new science teachers face many challenges, including that they may hold little explicit pedagogical content knowledge (Lederman, Gess-Newsome, & Latz, 1994; van Driel, Verloop, & de Vos, 1998). Thus new elementary teachers—especially in science—need support, and it is critical to understand how best to provide that support. The research reported here describes our attempts to engage in this simultaneous activity of supporting and understanding the learning of new elementary science teachers. Specifically, we present a design narrative describing the Curriculum Access System for Elementary Science (CASES; available at http://cases.soe.umich.edu). CASES, a technology-mediated learning environment aimed specifically at new elementary science teachers, is grounded in three main design principles that we discuss here. Our goal is to provide considerations for others developing learning environments for teachers, and we also discuss how our design principles can be (or have been) applied in other contexts.

Our work is guided in part by the knowledge integration perspective on learning (Linn, Eylon, & Davis, in press). The knowledge integration perspective is a view of learning consonant with the ideas in the seminal book *How People Learn* (Bransford, Brown, & Cocking, 1999). In this sociocognitive perspective, learners hold a repertoire of ideas, some of which are intuitive and others that are instructed. Learners identify weaknesses in their knowledge and add new ideas to their repertoire, linking some and distinguishing between others; they also reconcile ideas that appear contradictory and reflect on their ideas (Linn & Hsi, 2000). Knowledge integration involves applying these knowledge integration processes to ideas such as scientific principles, real-world experiences, and classroom-based experiences to develop robust and usable understandings.

New elementary science teachers need to develop multiple kinds of knowledge, including subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge (Shulman, 1986). They need to integrate their ideas so they are can engage in the tasks of teaching. Yet unlike students, teachers also need to use their knowledge to make decisions in real-time. Our project investigates this learning. Furthermore, new teachers need to begin to think about themselves as teachers. In addition to investigating teachers' knowledge integration, we also investigate the development of new teachers' identities as elementary science teachers.

A Design Narrative: Supporting New Elementary Teachers

CASES is grounded in design-based research (DBRC, 2003) that connects educational theory, design, and empirical work. In our program of design-based research, we have investigated preservice teachers' reflection about their teaching (Davis, in review-a), how they critique instructional materials (Davis, 2002, in review-b), and how they interact in online teacher communities (Smithey & Davis, 2002). We have further investigated how new teachers use curriculum materials that are intended to be educative (Petish, in preparation; Petish & Davis, 2002). And, we are conducting a longitudinal study of how teachers develop as they move along the professional continuum (Feiman-Nemser, 2001) from preservice teacher to novice teacher to (somewhat) experienced teacher. The overarching goals of the research program are to better understand new teachers' learning and how that learning can be supported through technology-mediated scaffolding.

To support preservice and new elementary science teachers as they learn to teach inquiry-oriented science more effectively, CASES incorporates inquiry-oriented unit plans that are intended to be educative for teachers, as well as a personal online journal, an online teacher community discussion space, and other resources for science teaching. Unit plans are made "educative" for teachers (Ball & Cohen, 1996; Collopy, 2003; Davis & Krajcik, 2004; Schneider & Krajcik, 2002) through a variety of features that are intended to work synergistically. Some of these features include science content background, information about students' likely alternative ideas, and multiple representations of inquiry. Several of these features are described in more detail below. The core design principle guiding the design states that CASES should be both an *instructional resource* (i.e., provide curriculum materials) and a *learning environment* (i.e., provide support in learning to teach effectively). As a shorthand, CASES is referred to as a learning environment; however, providing instructional resources at the same time as promoting teacher learning is a critical characteristic of the design.

Here, we present what might be considered the first chapter of a design narrative about CASES (Bell, Hoadley, & Linn, in press). Our narrative is framed around three high-level design principles that guide our work. These guiding design principles have been refined and elaborated over the past two years. These principles are not yet as specific or contextualized as they will be later in our cycle of development. They do, however, provide a starting point for thinking about a system of support for new teachers.

We emphasize how our design has been influenced by both theory and empirical work. For each design principle, we give examples of features within CASES that illustrate our approaches to putting the principle into practice. We discuss how those features are intended to address specific challenges that new teachers face as they learn to teach inquiry-oriented science and how they are grounded in the knowledge integration perspective on learning, since specific features of CASES are intended to promote particular knowledge integration processes (i.e., adding, linking, distinguishing, and reconciling ideas; identifying weaknesses in knowledge;

reflecting). We also provide illustrative findings from our research that show how our empirical research is informing our design.

Guidance On Demand Principle

Providing learners with guidance on demand (Bell & Davis, 2000; Shrader & Gomez, 1999) allows learners to request the guidance they want at the time they want it, allowing a "just in time" approach to providing help. CASES' Guidance on Demand principle states that designers of learning environments for teachers should

> Transform an instructional resource into a learning environment through guidance-on-demand by incorporating…
> - educative curricula features such as hints about learners, instructional representations, science content, and science inquiry
> - prompts for productive reflection-on-action

What do these features look like? Educative hints provide teachers with ideas, for example, about not just *how* to enact instructional moves but also the rationales behind particular instructional decisions within a specific lesson (Ball & Cohen, 1996). Teachers need to use and adapt curriculum materials for their own classrooms, and understanding the reasoning behind particular instructional decision helps them make productive changes. This is especially important, of course, for new teachers. Figure 1 illustrates an educative hint providing a rationale. Reflection prompts, on the other hand, might provide sentence starters asking teachers to consider their objectives for a lesson or changes they might make to a particular lesson. Reflection-on-action is a critical aspect of being a reflective practitioner (Schön, 1982) and is important in learning to teach. Yet teachers, like other learners, often have trouble reflecting productively (Davis, in review-a; Hatton & Smith, 1995) and thus need support. Figure 2 illustrates CASES' online reflective journal.

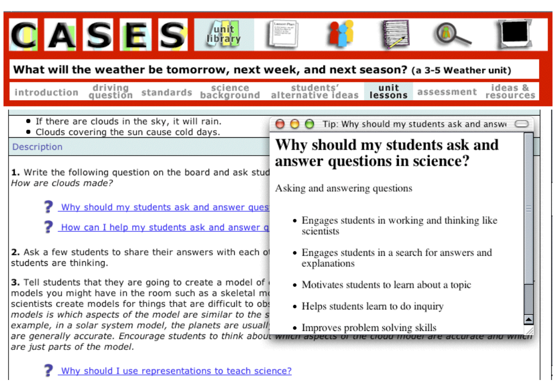

Figure 1. An educative hint providing a rationale.

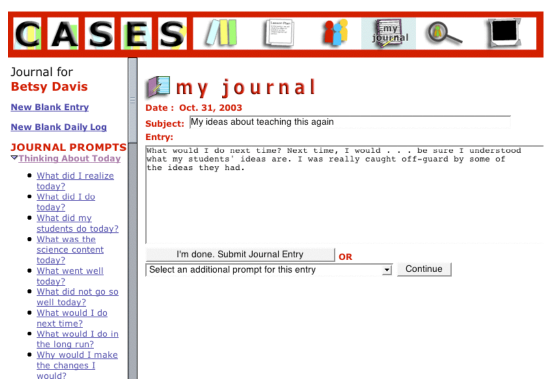

Figure 2. The reflective journal, with a prompt.

Recall that in design-based research, design is grounded in theory. How does learning theory inform our design of CASES? Although any feature of a learning environment might theoretically promote any knowledge integration process, specific features are *intended* to promote particular processes more directly. For example, the hints embedded in CASES lesson plans should primarily help new teachers add new ideas to their repertoires of ideas, and may also help them identify weaknesses in their current knowledge and link ideas. Reflection prompts, as well as the journal space more generally, primarily help new teachers reflect on their ideas, while potentially also helping them to identify weaknesses in their current knowledge.

But designs are also informed by empirical research. As an example of how empirical research informs the design of CASES from the standpoint of the guidance on demand principle, consider a study of how preservice teachers reflected on their own teaching experience using the CASES journal (see Davis, in review-a, for much more detail on this study; this and other examples included here are intended to illustrate our points, not to present detailed empirical findings). The preservice teachers were students in an elementary science methods course. The study investigated how the preservice teachers considered and integrated ideas about learners, knowledge, assessment, and instruction. The study indicated that some of the preservice teachers simply juxtaposed ideas about learners and instruction, without addressing their interactions, as exemplified by the following quote from Reyna:

> Most of them had random comments about weather and a few had random questions like "Do you play in the snow?". One child raised his hand and just said winter when I asked for questions. I asked if winter was a question or if he was telling me part of weather. He said part of weather. Then a few more questions and then someone else raised their hand and said rain. Again I said is that a question or part of weather. They said part of weather and I said right.

Reyna's discussion of learners and instruction stands in contrast to those of another preservice teacher called Susan, whose ideas about learners are instead integrated with her ideas about both instruction and assessment. Susan's ideas clearly took into account the interactions between the different considerations teachers must make. Based on this study of teachers' reflection, we determined that we should look for and promote the integration of ideas among new teachers. This integration seemed related to increased sophistication with regard to teaching decisions. In the design of CASES, this meant that we needed to develop reflection prompts that were intended to promote explicitly the knowledge integration process of linking ideas. Reflection itself promotes the other knowledge integration processes (Davis, 2003), but it should be possible to design prompts to elicit these knowledge integration processes more directly, as well.

Images of Inquiry Principle

It is important in any learning environment to provide learners with multiple representations of what the learner is intended to understand (e.g., Spiro et al., 1991). Since a main goal of CASES is for teachers to develop an improved understanding of what it means to teach through scientific inquiry, we decided to provide multiple "images of inquiry" in CASES, in narrative, graphical, and tabular form. Our Images of Inquiry design principle states that designers of learning environments for teachers should

> Provide useful images of inquiry by incorporating multiple representations of inquiry grounded in the curriculum materials themselves.

Our narrative images of inquiry involve fictional preservice and new teachers (Smithey & Davis, 2004-b). CASES provides a profile for each of the Images teachers. For example, Nancy is described as a fifth grade teacher in her third year of teaching who wants to improve her ability to build on her students' ideas. Short vignettes about one or two of these teachers are incorporated in each lesson on CASES. Each vignette describes how the Image teacher taught the lesson. For example, in one lesson, Nancy discovers that her students have trouble connecting a model to the real world, so she provides some structuring artifacts for her students. The narrative images describe real challenges new elementary teachers face, such as anticipating students' ideas (Smith & Neale, 1989) or understanding the science content themselves (Anderson & Mitchener, 1994).

A second type of image of inquiry, also embedded in each lesson, presents a simple graphic that illustrates the inquiry focus of the lesson. CASES presents inquiry as comprising three essential features (based on five essential features described in NRC, 2000): questioning and predicting, explaining using evidence, and communicating and justifying findings. This simplification helps to make the notion of inquiry more accessible to new teachers who may have never experienced inquiry-oriented teaching or learning.

The third type of image of inquiry involves an "inquiry continuum customization table." Teachers need to be able to adapt existing curriculum materials to be best suited for their own classrooms (Ball & Feiman-Nemser, 1988; Remillard, 1999). Yet new teachers are often unsure about how to make pedagogically and scientifically appropriate changes to existing curriculum materials (Davis, in review-b). The customization tables in CASES provide guidance on how to make such changes. They build on the notion that inquiry practices fall along a continuum of more to less teacher-directed (NRC, 2000). The tables are designed to address new teachers' lack of clarity of what inquiry-oriented science teaching might entail while helping them consider how to adapt a lesson to meet their own needs. Figure 3 illustrates the three types of images of inquiry.

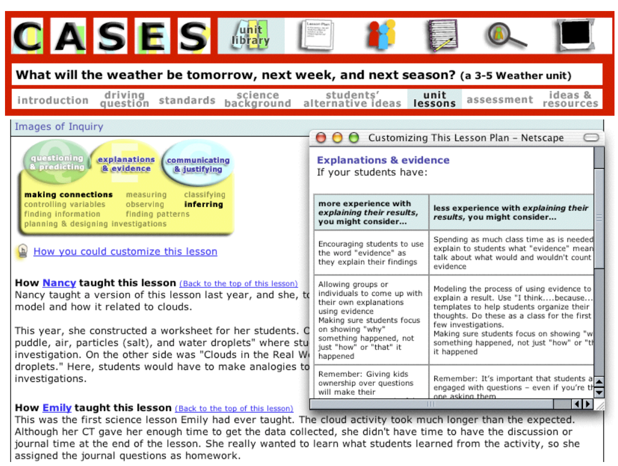

Figure 3. Narrative, graphical, and tabular images of inquiry.

How do each of these representations draw on the knowledge integration perspective on learning? The narrative images can promote any of the knowledge integration processes. They are very dependent on the specific content of a given narrative. For example, images of new teachers struggling with aspects of an inquiry-oriented lesson can promote reflection. Other images may add ideas to a user's repertoire through modeling exemplary practice. The inquiry features graphic, on the other hand, is intended to help new teachers distinguish between ideas (such as different inquiry abilities that might be fostered by a lesson plan), link ideas (e.g., connecting a feature of a lesson plan to principled knowledge about engaging students in questions), and reconcile ideas (such as seeing that collecting data and making inferences, for example, are both part of a larger feature of inquiry in which students make explanations based on evidence). Finally, the inquiry continuum customization tables are intended to help new teachers add new ideas to their repertoires and distinguish between ideas (such as between supporting student-directed inquiry and simply allowing unproductive discovery learning).

How can empirical work inform the design of CASES from the standpoint of the images of inquiry design principle? Consider a study completed *before* the images of inquiry were incorporated into CASES. The preservice teachers were given a science activity to critique at the beginning and end of an elementary science methods course (see Davis, in review-b, for much more detail). One theme at the end of the semester was that many of the preservice teachers determined that they wanted to allow the children to design their own experiments, rather than following the teachers' instructions for completing an experiment. One recommendation that emerged from this study was that preservice teachers needed support in understanding just what is entailed in having students design their own investigations. The prospective teachers seemed naïve about how difficult it might be to accomplish this goal. As such, we determined that we needed to develop images of inquiry—narratives and customization tables—that would illustrate new teachers' successes and struggles with student-designed investigations as well as describe suggestions for how, pragmatically, to accomplish this in one's own classroom.

Social Supports Principle

Social supports are essential for teacher learning (Putnam & Borko, 2000). Teacher communities provide opportunities for expertise development (Grossman, Wineburg, & Woolworth, 2001) as well as identity development (Overbaugh, 2002). When a community has access to diverse perspectives, distributed expertise can develop (Brown et al., 1993; Smithey & Davis, 2002). CASES' Social Supports design principle states that designers of learning environments for teachers should

Provide social supports for learning by incorporating…

- a supportive community grounded in the study of practice
- images of role models struggling with and solving new teachers' typical problems

We provide a supportive community in CASES through the use of an online discussion tool. The tool, a web-based threaded asynchronous discussion program, allows teachers to post threads at the same level as the course instructor or CASES administrator. In addition to providing social supports through community, we provide images of role models through the use of the narrative images of inquiry discussed above.

How is this design principle about social supports informed by learning theory? First, online discussions may help teachers add new ideas to their repertoires (from hearing how others think about similar issues), reflect on their ideas (as they think about the issues from the discussion in terms of their own science teaching), and identify weaknesses in their current knowledge (in response to questions or prompts from the instructor or their peers). Narrative images of inquiry, as discussed above, can promote multiple knowledge integration processes.

And how is this design principle informed by empirical research? We investigated the nature of preservice teachers' online discussions in CASES (see Smithey & Davis, 2004-a, for much more detail). We analyzed their posts to see how preservice teachers talked about inquiry-oriented science teaching and developed their professional identities as science teachers. In one type of discussion thread, preservice teachers responded to prompts designed by course instructors about teaching elementary science through inquiry. For example, the preservice teachers discussed a dilemma-based prompt about Ms. Watterson, a teacher struggling with how to plan ahead in science class but still be guided by her students. One preservice teacher who was typical of others, for example, compared her situation to that of Ms. Watterson by talking about the difficulties she and her partner had in planning for inquiry while still attending to their students' ideas. In these instructor-initiated threads, the preservice teachers struggled to define inquiry. An important theme was that inquiry can occur along a continuum (NRC, 2000)—showing that very different kinds of instruction can still be considered inquiry-oriented, and thus implying that preservice teachers with different confidence levels and beliefs about science teaching can still envision themselves as becoming inquiry-oriented teachers.

While rich discussions around inquiry took place in threads that the course instructor initiated, there was little explicit talk about identity. In contrast, in threads that the preservice teachers initiated themselves, there was almost no discussion of inquiry but much evidence of identity development. Many of these conversations centered around the preservice teachers' concerns about becoming practicing teachers. As the preservice teachers neared the end of their university coursework, they began to develop an appreciation for the complexities of teaching. This brought about personal anxiety as teachers imagined themselves in the position of being a "real" teacher. For example, a preservice teacher called Teresa expressed her concern in the following typical response to a peer's thread:

> I look at some of the [cooperating teachers] I've had in the past two years and especially my Mom (who has been teaching for 15+ years) and I wonder, "HOW AM I GOING TO DO THIS?" It is extremely intimidating. …

Online discussions allow a unique forum for preservice teachers to develop their own ideas about course content, especially in a way that encourages teachers to envision themselves teaching in ways consistent with those presented in the course. However, threads initiated by the preservice teachers themselves also provide them with opportunities to imagine themselves as practicing teachers. For CASES design, this means that it is important to develop a teacher community that is flexible. There should be opportunities for both instructors and preservice teachers (or, likewise, designers and practicing teachers) to shape the conversations that take place. To meet these needs, the CASES teacher community space is divided into several sections. One is for preservice teachers; within that section, students in the methods courses can respond to instructors' threads and initiate threads of their own. In the section intended for the practicing new teachers, there are spaces that are designated for informal conversations with friends and others designated for talking about science teaching.

Conclusions

New teachers face many challenges when it comes to designing and enacting inquiry-oriented science instruction. These challenges may be compounded for new elementary teachers.

In CASES, we have incorporated support in three main ways. We provide guidance on demand to help teachers obtain or construct answers to the many questions they have about inquiry-oriented science teaching and to foster productive reflection. We provide multiple images of inquiry to illustrate what this instructional approach can look like in a variety of situations and to help them imagine what it might look like in their own situations. And we provide social supports to help new teachers learn from one another and from others more expert than they are.

We described this work as "chapter 1" of a design narrative. In the narrative we have presented here, we have discussed how learning theory—particularly, the knowledge integration perspective on learning—and empirical research have informed our design decisions. This aspect of the design narrative is critical, as it allows other designers to build on our work as they design other learning environments intended for teachers. Yet we have not yet engaged in extensive empirical research on teachers' use of the design features themselves (with a few exceptions; see, e.g., Davis, in review-a; Petish, in preparation; Smithey & Davis, 2002, 2004-b). In particular, we need to investigate areas like how our prompts for teacher reflection—aimed at specific knowledge integration processes—work to promote teacher learning. We know already that even carefully designed prompts can lead to unexpected consequences (Davis, 2003). We also need to investigate how teachers use different types of guidance on demand. For example, do teachers ever choose to obtain hints about the rationales for instructional decisions, or do they focus mainly on how to enact instructional moves? At a broader level, we need to investigate whether the different features that are intended to promote specific knowledge integration processes are actually doing so, and how. Furthermore, we want to investigate how new elementary science teachers with different characteristics—of their teaching contexts, for example, or of their beliefs about science teaching—use and learn from the scaffolds we have incorporated into CASES.

The design narrative we have presented here tells the story of a system of supports intended for a very particular group—new elementary science teachers. How generalizable are the design principles we have articulated here? Take, for example, experienced teachers rather than new ones. Knowledge Networks on the Web (KNOW), an online space designed to complement ongoing professional development for middle school science teachers in Detroit, provides important social supports and guidance on demand for the teachers (Brunvand, Fishman, & Marx, 2003; Fishman, 2003). For example, the "lead teachers" use the online discussion space within KNOW to promote productive discussions among the teachers who are newer to the ideas being espoused in the professional development setting—though not new to the practice of teaching. KNOW also provides these experienced teachers with examples of student work—an important form of guidance on demand that could help both new and experienced teachers.

Next, consider secondary teachers as opposed to the elementary teachers who use CASES. Secondary teachers tend to have stronger science subject matter knowledge (Anderson & Mitchener, 1994). They might, therefore, need different kinds of guidance on demand. In CASES, some of the guidance on demand is focused on subject matter knowledge. For secondary teachers, this might be less of an emphasis—but there might be a concomitant increase in emphasis on, for example, using formative assessment in addition to summative.

Third, what would be the effect if one were designing a learning environment for teachers of a subject other than science? CASES is aimed very purposefully at helping teachers learn to teach inquiry-oriented science. The images of inquiry present the clearest example of this. Might teachers of other subjects benefit from images of inquiry tailored to their own subject areas? We hypothesize that they would, since teachers of many different subject areas should engage their students in inquiry (Stevens et al., in review). Clearly, however, the images would need to be developed to highlight the salient features of inquiry for that particular subject, rather than necessarily the questioning, explaining, and communicating features (and their associated science-specific details) highlighted in CASES.

Finally, consider the extent to which these design principles are specific to teachers as learners, rather than students. Students do benefit from guidance on demand (Bell & Davis, 2000) and from social supports (Linn & Hsi, 2000; Linn, Davis, & Bell, in press). Might they benefit from some form of images of inquiry? Would students learn more about how to engage in inquiry if they read stories, for example, about a scientist conducting an investigation? Palincsar and Magnusson (2001) call this "second-hand investigation" and demonstrate important learning benefits for students who experience such images of inquiry in conjunction with the more typical first-hand investigations.

We have provided some ideas about how we use these design principles to guide our designs for new elementary science teachers and about how one could apply the design principles to the design of learning environments for other groups of learners. In some cases, clear extending examples exist already. In others, though, we would need to test how the design principle would actually play out in practice. Extending design-based research like the work reported here and testing the ways in which ideas are generalizable or, alternatively, highly context-specific is an important area of work for the learning sciences.

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