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Mentor Advice Giving in an Alternative Certification Program for Secondary Science Teaching: Opportunities and Roadblocks in Developing a Knowledge Base for Teaching

Leslie Upson Bradbury · Thomas R. Koballa Jr.

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Abstract Mentoring is often an important component of alternative certification programs, yet little is known about what novices learn about science teaching through mentoring relationships. This study investigated the advice given by two mentor science teachers to their protégés. Findings indicate that mentors gave more advice related to general pedagogical knowledge than science-specific pedagogical content knowledge. Specifically, there was little to no advice related to the topics of inquiry, the nature of science, or the development of scientific literacy. Implications call for an increase in communication between university teacher education programs and school-based mentors, the development of benchmarks to help guide mentor–protégé interactions, and the importance of a multiyear induction process.

Introduction

During the previous decade, there has been an increase in the number of alternative certification programs to recruit new teachers to fill projected shortages, especially in high-needs areas, such as mathematics, science, and special education (Feistritzer 1994; McKibbin and Ray 1993). Typical components found in such programs include paid or unpaid teaching internships, intensive internship supervision, and education course work taken both prior to and in conjunction with the internship (Eifler and Potthoff 1998; Fenstermacher 1990). A strong mentoring component is often included as an important aspect of alternative certification programs (Chapelle and Eubanks 2001; Chesley et al. 1997). Because alternatively certified teachers

L. Upson Bradbury (✉)
College of Education, Appalachian State University, Boone, NC 28608-2047, USA
e-mail: upsonlk@appstate.edu

T. R. Koballa Jr.
College of Education, University of Georgia, Athens, GA 30602, USA

have little to no experience in the classroom other than their own previous experience as students, their relationships with mentors can be an important part of their transition into the teaching profession (Chesley et al. 1997; Dill 1996). Under the guidance of veteran science teacher mentors, interns have the opportunity to develop more complex understandings of their knowledge about science content and pedagogy as they apply what they have learned to new situations they encounter in the classroom (Brown et al. 1989).

Though opportunities for knowledge construction and reflection abound in mentoring relationships, field experience, in which a beginning teacher is paired with a science teacher veteran, does not guarantee professional growth for novice science teachers (Carter and Francis 2001; Franke and Dahlgren 1996). In the project described here, we explored the conversations between two mentor–protégé pairs in an alternative certification program for secondary science teachers to determine the types of advice given by the mentors to their protégés. In this article, we define advice as the recommendations and guidance given by one teacher to another in an effort to guide thinking and science teaching practices. This advice can flow from mentor to protégé or vice versa, or it can be a joint construction negotiated by both members of the pair. In the context of this project, advice of interest is that flowing from the veteran science teacher mentor to the science teacher protégé.

Purpose and Research Questions

Mentoring relationships are an integral component in alternative certification programs. While there is a large body of research that supports mentoring as a way to assist with new teacher induction, much of it is found in position papers, rather than empirical studies (Danielson 1999). There are currently few studies that directly investigate advice giving between mentors and protégés; those that do are not specific to science teaching (Hawkey 1998; Wang 2001). Wang's study explored mentor–protégé interactions between 23 elementary, middle, and high school teachers from three countries and a variety of content areas, none of them science. Data for the study included interviews and mentor logs of conversation, but not direct observation of mentor–protégé interactions. Hawkey's (1998) study focused on secondary history teachers, but did use analysis of audiotaped conversations between mentors and protégés. While these studies are informative, they do not relate specifically to science teaching, a discipline with its own documents, such as the National Science Education Standards (NSES; National Research Council [NRC] 1996) and Science Teacher Preparation Standards (STPS; National Science Teachers Association [NSTA] 2003), which seek movement toward reform-based science teaching practices. These documents provide a framework for the topics that would ideally be addressed in conversations between science teacher mentors and protégés. Thus, the purpose of this study is to understand the advice given by science teacher mentors to protégés entering the science teaching profession via alternative certification. Our research questions were as follows:

1. What is the nature of advice given by science teacher mentors to their protégés?
2. How did advice giving compare between the two mentors?

Theoretical Framework

The importance of the science classroom context to the development of a novice teacher's professional knowledge, and the central role of the mentor–protégé relationship in this development, led us to base our study on literature from three areas. These included situated cognition, knowledge bases for science teaching, and teacher mentoring.

Situated Cognition

As prospective teachers complete the process of initial teacher certification, they leave the culture of their previous jobs or careers and enter the teaching profession. They are guided in the process of science teacher development by interactions with their mentor teachers. One of the key tenets of this arrangement is the notion of situated cognition, the idea that learning is a social process inextricably linked to and dependent upon the context in which it occurs (Brown et al. 1989; Lave and Wenger 1991; Rogoff 1990). According to Brown et al., "The activity in which knowledge is developed and deployed... is not separable from or ancillary to learning and cognition. Nor is it neutral. Rather, it is an integral part of what is learned" (p. 32). This viewpoint emphasizes the importance of learning in situ; knowledge about science teaching is developed through the process of teaching science, watching other teachers, and discussing and reflecting on the act of teaching. While there can be many sources that contribute to a protégé's developing understandings about teaching, individuals cannot truly learn to teach effectively outside of the context of teaching experience in a real science classroom (Feiman-Nemser and Remillard 1995). What is learned is heavily dependent on the social situation in which the learning occurs (Druckman and Bjork 1994, as cited in Abell 2006). The advice given by a mentor teacher can form an important component of this learning.

Knowledge Base for Science Teaching

The overall goal of the interaction between mentor and protégé within the context of the field experience is the in situ development of the pedagogical content knowledge (PCK) and general pedagogical knowledge (GPK) of both members of the pair. First described by Shulman (1986) as a unique construct involving the knowledge of "subject matter for teaching" (p. 9), PCK has since been defined in a variety of ways. Though various authors have described the term differently, two themes emerge from these definitions: the transformation of various types of knowledge specifically for teaching and the understanding of common areas of difficulty for students (van Driel et al. 1998).

Because PCK is defined in different ways by different researchers, it is important to describe the conception of the term used in this project. Loughran et al.'s (2004) definition of PCK for science provides an overarching understanding of the term. They described science PCK as "the amalgam of a teacher's pedagogy and understanding of (science) content such that it influences their teaching in ways that will best engender students' science learning for understanding" (p. 371). Magnusson et al. (1999) outlined a more specific set of components included in the PCK of a science teacher. Their model is composed of five parts: orientation to teaching science, knowledge of science curricula, knowledge of students' understanding of science, knowledge of instructional strategies, and knowledge of assessment of scientific literacy. In this conception of PCK, a person's orientation towards teaching influences the development of the other four components of PCK.

PCK is only one component of teachers' knowledge. Borko and Putnam (1996) developed a system that included GPK, PCK, and subject-matter knowledge to organize research related to learning to teach. These authors defined GPK as "knowledge and beliefs about teaching, learning, and learners that transcend subject-matter domains" (p. 675). Classroom management, instructional strategies for conducting lessons, and knowledge about learners and how they learn constitute topics in this domain. The STPS call this area of knowledge *general skills for teaching* and focus on the necessity of using a variety of teaching strategies to meet the needs of the diverse needs of learners (NSTA 2003).

Mentoring

While there are many possible sources for teacher knowledge, as novices reflect on their backgrounds in teacher education, they often discuss the direct experience garnered during field placements as the most important source for learning about teaching (Carter and Francis 2001; McIntyre et al. 1996). Relationships developed between mentors and protégés exert a critical influence on what the interns are able to learn (Awaya et al. 2003; Borko and Mayfield 1995; Graham 1993). The understandings surrounding the role of the mentor that the partners bring to the relationship affect the learning process for both members of the pair (Abell et al. 1995; Franke and Dahlgren 1996; Wang 2001). In some cases, mentors view their role as providing teaching tips or survival strategies; interns may come to the mentor with a specific problem and expect to be provided with a quick solution (Awaya et al. 2003). Being partnered with a mentor who adopts this "quick fix" view can encourage novices to replicate existing models of teaching, rather than to implement more reform-based practices (Ballantyne et al. 1995; Evertson and Smithey 2000; Gratch 1998). In these types of relationships, conversations focus on the "how to" of teaching, rather than delving into questions related to why teachers choose to teach a particular topic in a certain way (Franke and Dahlgren 1996). In other relationships, mentors encourage a more reflective, egalitarian relationship with their protégés. In this kind of partnership, mentors and protégés work together to engage in such activities as "keeping up with scientific breakthroughs in the pedagogy of learning, rekindling the purpose and passion of teaching, and working with others to bring about positive reforms in education" (Hargreaves and Fullan 2000, p. 52). These understandings about roles can influence the frequency and topics of conversation in which mentors and protégés engage.

Studies examining the topics that interns and mentor teachers discuss during the field experience find that prevalent topics of conversation include teaching strategies and general pedagogical issues, such as the flow of the lesson and student understanding of the lesson (Borko and Mayfield 1995; Hawkey 1998). In a study comparing mentoring practices in three countries, Wang (2001) found that for preservice teachers in the United States, issues of curriculum and pedagogy were the most frequent topics of conversation between novices and their mentors. In an analysis of 64 conversations between mentors and protégés, Strong and Baron (2004) indicated that mentors were reluctant to give direct advice to their protégé. Rather, mentors shared advice in the form of possibilities or questions. While knowledge related to general pedagogical topics and format of advice giving are important, often lacking in these discussions are conversations related directly to the development of pedagogical content knowledge (Borko and Putnam 1996; Shulman 1987).

Research Methods

In the following section, we describe the context of the study, including a description of the participants and an overview of the methods of data collection and analysis. The process of data analysis led to the development of a model of science teacher knowledge bases for teaching based on current literature and data from the study.

Research Context

The two protégé participants for this study were enrolled in the Program for Alternative Certification in Secondary Science (PACSS). This is a four-semester certification program in place at a major university in the southeastern United States to facilitate the transition of those who have a strong science content background into grade 7–12 science classrooms. The program includes evening and summer courses in science teaching methods, science curriculum, technology use in the science classroom, professional development needs of science teachers, and teaching science to students with special needs. In addition to science-focused pedagogical courses, students take an introductory educational psychology class. In conjunction with their course work, students enroll in a supervised internship and are assigned a mentor teacher. The majority of students in the program elect to begin teaching immediately on a provisional certificate; others opt to complete a yearlong internship with an experienced teacher. The internship option requires that students spend a minimum of 20–25 hours per week in the classroom over the course of two university semesters. Participants in this study chose the internship route with close collaboration in the classroom of a mentor teacher, rather than direct entry into their own classrooms.

While engaged in the internship, PACSS participants are assigned a university supervisor who visits them in their classrooms several times per semester. These supervisors work with the mentor teachers to provide advice and guidance to the interns. Supervisors serve as a bridge between the university and the high school setting. During this study, the *researchers* were not the assigned supervisors for the interns; they were passive participants in the research (Spradley 1980).

Participants

Each intern was in her early 40s and had left a professional career to pursue a career in high school science teaching. Like the majority of participants in the program, these two interns were Caucasian females. They were different from other PACSS participants in that they were slightly older than the average.

The two mentor participants were chosen because of their strong content backgrounds, experience with previous interns, and designation by their state as certified mentors. Each mentor had a degree in biology in addition to required education coursework. Both had previously completed an extensive mentor training session leading to an endorsement for mentoring being added to their state teaching credentials. This training involved a 40-hour, week-long summer mentor training experience, online assignments, and an induction into mentoring. Prior to the summer session, mentors participated in online discussions and video conferences with university professors and each other related to required readings for the class. Participants then came together for a week for sessions on new teacher needs, inquiry teaching, making science relevant to students, assessment in science classrooms, and successful conferencing strategies. During the fall semester, each mentor worked with a new teacher or student teacher at his or her school. This fall experience was in essence an internship for the mentors. While engaged with the protégé in the fall, mentors met monthly with university personnel through a video-conferencing system and continued to exchange information through a Web discussion board.

Mentors and protégés were paired by the director of the program. Each of the mentors had worked with science interns in the past and reported a positive experience. The program director had worked with the interns during the selection process for the program and during their coursework. Using her personal knowledge of the individuals, the director made matches based on personality and content background. Table 1 provides summary information about each of the four participants. Pseudonyms are used to protect the identity of all participants.

Table 1 Introduction to study participants

Pair 1: Pam and Linda	
Mentor: Pam	Protégé: Linda
Pam is a 28-year-old science teacher with 5 years of experience at the high school level. This experience is Pam's second time serving as mentor to a science teacher intern, though she has mentored several new teachers at her school. Pam describes her view of the role of a mentor in the following excerpt:	Linda is a friendly, talkative woman whose age is somewhere in her early 40s. Her previous work experience includes stints in respiratory therapy, medical staffing, and medical-waste disposal. While she never directly articulated her views for the role of the mentor, Linda describes the protégé's role in the following passage:
I think my job is to get [protégés] to a place where they are completely competent on their own, where they feel comfortable answering questions about content, where they feel comfortable with their own knowledge. [I want them to] feel so good about what they're doing that they don't have to use the book labs or the book homework sheets. They need to go for it, because that's where a lot of real teaching takes place. I really would like to get them to that point.	*My job would be to do everything I can to make sure that I'm prepared and make sure that I'm willing to learn, see how [my mentor] does things, and see what works well in her situation—to observe and take in all I can to utilize it effectively when I have my own classroom to teach and reach all class members. I have positive expectations. I want to have a good experience and learn and do a good job.*
Pair 2: Kevin and Jodi	
Mentor: Kevin	Protégé: Jodi
Kevin is an approximately 40-year-old veteran middle and high school teacher with more than 15 years of science teaching experience. During his career, he has served as mentor to several teacher interns. Kevin describes his view of the role of a mentor in the following excerpt:	Jodi is a vivacious woman in her late 30s. Jodi's previous work experience included a one-year position as manager of an environmental lab and many years as a manager of a retail clothing store. Jodi describes her views of mentoring:
My primary job is to show them the difference between how teaching could be and how it should be. Meaning, we could give them worksheets. I think anybody could do that. As long as you're a task manager, you can get out a calendar, write down "Here's chapter one, here's chapter two, here's chapter three. Let's do worksheets. Let's do a lab. Let's do a quiz. Let's do a test." Anybody can do that. It's so much more rewarding if you change that and think of something that makes the kids learn, makes them think, engages the kids where they're actually learning the curriculum. And I'm big on real-life applications. If I can find a real-life application, let's do that. Let's make it fun for everybody in the classroom.	*I am really interested in [learning strategies] for presenting specific materials, because there are certain materials that are more effective when they are presented a certain way. What I'm looking for from a mentor is someone who sets an excellent example and then is available when I have questions. I don't think it's his role as a mentor to be responsible for my learning. It's up to me to learn and ask questions. I'm not expecting someone to take me by the hand and coddle me through it all. My job is to learn and support him and make his job as easy as possible.*

Data Collection and Analysis

Each pair was visited approximately weekly by the same researcher (Upson Bradbury, first author) for the duration of the internship period, which lasted from September through April. Interviews with each participant, archival data in the form of lesson plans and mentor observation notes, and field notes of planning periods and protégé teaching were collected on each visit. The visits to the schools were based on the idea that our purpose as researchers was to understand in as much detail as possible the experiences of these participants as they went about their daily routines together (Clandinin and Connelly 2000). The typical question used to begin each interview was, “So, tell me about what’s been happening since last week when I was here.” Later interviews provided the opportunity to share developing understandings of these mentoring relationships with participants and solicit their feedback to clarify and refine our understandings.

Field notes provided a second valuable source of data. Visits were scheduled to enable one researcher to observe the interns teach lessons and observe the interactions that occurred during the planning period after the interns’ teaching. These observations allowed for the verbal advice that the mentor provided about the intern’s science instruction to be recorded and for any written feedback from the mentor to be photocopied. Additionally, during planning-period observations, the types of advice mentors provided related to the planning of future lessons was documented.

Data analysis occurred through several stages of coding and analysis of narratives (Polkinghorne 1995). Polkinghorne described analysis of narratives as a paradigmatic way of understanding human experience. When the researcher undertakes this process, she “seeks to locate common themes or conceptual manifestations among the stories collected as data” (p. 13). Because of the nature of the interview questions, a portion of the data collected was a series of stories told by the participants. These stories were read and reread and coded according to the type of advice given by the mentor. Participants shared their reactions to the stories, which sometimes prompted further insights into previously collected data. To further support the findings, interview and field-note data were included in conjunction with lesson plans and mentor notes. This system provided the opportunity for triangulation of findings among multiple data sources (Miles and Huberman 1994).

By grouping the participants’ stories by topic, it was possible to see patterns emerge related to our question about the nature of the advice given by the mentors. To facilitate data coding, an iterative process was used to develop a model of the science PCK necessary for beginning science teachers, such as the protégé participants in this study. This model guided our continued data analysis.

Development of a Model of Novice Science Teacher Knowledge Bases for Teaching

There has long been recognition that teachers’ professional knowledge is extremely complex and difficult to categorize (Loughran et al. 2004). Because the knowledge

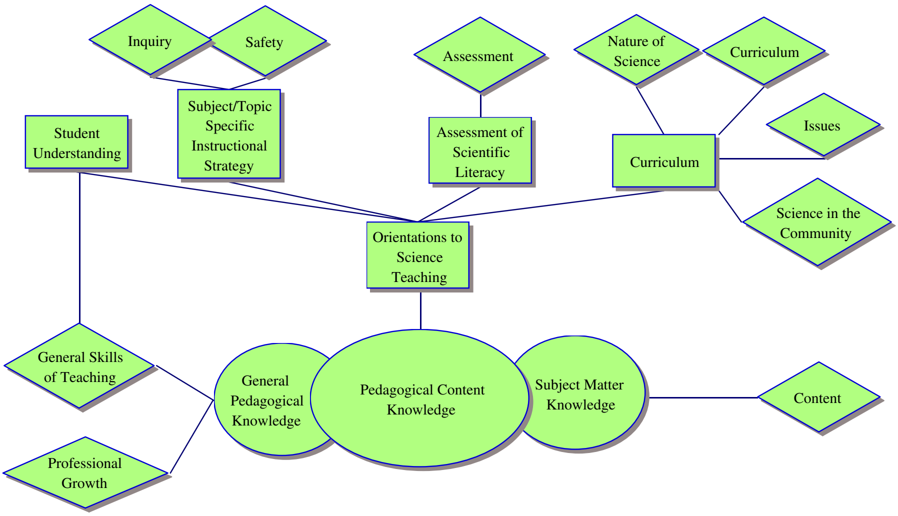

Fig. 1 Components of novice science teachers' knowledge base for teaching. *Source*. Ovals: Borko and Putnam (1996); Squares: Magnusson et al. (1999); Diamonds: NSTA (2003)

necessary for excellent teaching is an integrated and ever-evolving entity, its component parts cannot be easily assigned to discrete categories. There is a great deal of intersection among the areas of PCK, GPK, and subject-matter knowledge. It was useful in the context of this study to construct a model to facilitate analysis of advice given by the science teacher mentors. The model combines Borko and Putnam's (1996) three domains of knowledge for learning to teach, Magnusson et al.'s (1999) model for the PCK for science teaching, and elements considered important to science teaching from the STPS. The resulting model is depicted in Fig. 1.

Findings

The findings are presented as cases that highlight the types of advice given by the mentors. The advice is categorized according to the model described in Fig. 1. Then findings that show similarities and differences between the advice given by the mentors in the two cases are presented.

Pam and Linda's Case

During the course of Linda's internship, there were many opportunities to observe instances where Pam provided Linda with advice on a variety of subjects. In interactions between Pam and Linda, the majority of the conversations focused on general pedagogical issues. Pam and Linda, however, had other discussions that centered on science-specific pedagogical concerns. The following sections provide highlights of their conversations and the topics they addressed.

General Pedagogical Knowledge

Within the domain of GPK, Pam spent much time advising Linda on classroom management. Like many novice teachers, Linda struggled with this aspect of teaching. Pam wanted Linda to be a concerned and compassionate teacher, but she wanted it to be clear to her students that Linda was in charge. During a planning period, the two had the following conversation:

> Pam: Be sure you use your teacher voice at all times. We talked about that at lunch. You'll learn something—you command a lot of attention just from the way you talk and look. It takes practice. I was terrible at it at first. Work on your voice, be direct.
> Linda: Firm.
> Pam: Firm, stern, and loving at the same time. I realize it's hard to think of a way that you can be all of those at once. Be firm, stern, and direct. When you ask a question, use a compassionate voice. [You don't want to] make them feel like they are stupid. You don't want to give the impression that you're a quiet person and won't [discipline them]. One thing we'll work on over and over is your authoritarian voice. You can get a lot done with the look on your face and the tone in your voice.

Though this is only one excerpt, this type of scenario was repeated frequently over the course of the internship.

Another area of advice giving related to preparing lessons so they would be more engaging for students. Both Pam and Linda commented that Linda initially modeled her teaching on her own experiences in high school and college science classes. This pattern included a heavy reliance on teacher-focused instruction based primarily on lecture. Pam wanted Linda to include activities that allowed for more participation by students. The following excerpt from field notes exemplifies this type of conversation:

> Pam: Do you have to be the one to tell them everything?
> Linda: No.
> Pam: Any [time] that they get a chance to talk is good.
> Linda: [I] can't think of any.
> Pam: How about if you put them in groups of three and…each group has one block that they have to be able to explain and define? I'm trying to get through [that] it's about them. This is what I want to help you do.

Over the course of the year, Pam reiterated her belief that Linda should try to put herself in the position of the students and approach lessons from their perspective. She wanted Linda to understand that classes should not fall into a pattern in which the majority of time is spent devoted to teacher-driven lectures. Pam wanted Linda to think about student engagement with her lessons and whether the planned activities enticed students to be excited about the subject matter. To help Linda in this area, Pam recommended using lots of group work and varying the types of instruction in the class.

Pedagogical Content Knowledge

While general pedagogical issues are important to any novice teacher's growth in the profession, an understanding of issues related specifically to pedagogical approaches for science topics is also necessary. Within the domain of pedagogical content knowledge as outlined by Magnusson et al. (1999), Pam addressed the following domains: frequent assessment of student understanding, curriculum, fostering student understanding of specific science concepts, and subject- and topic-specific instructional strategies.

Frequently assessing student understanding and progress in a variety of ways was a recurring topic of conversation between Pam and Linda. For Pam, it was important that Linda develop strategies to assess students' understandings of the content presented each day. She wanted Linda to use this information as she planned subsequent lessons. Pam encouraged Linda to use a variety of techniques, such as a daily quiz for assessment, asking students of all ability levels questions during class, and walking around during group work to monitor student progress.

In a conversation after Pam observed Linda teaching, she expressed concern that Linda did not get to finish the assessment planned for the end of the lesson. Pam discussed her feelings about the importance of assessment in the following excerpt from the postconference:

> Pam: It's more important that you got to that assessment part to me, because now we are going to have to do the assessment at the beginning of the period. It puts more stress on you. You would have to do the assessment at the beginning of the period the next day, and then whatever they didn't understand right off the bat, go back and redo. It helps you be more prepared if you can assess before they go. Then you'll be more ready for the next day.

Curriculum was a second area of pedagogical content knowledge where Pam advised Linda. Before Linda taught lessons in Pam's class, the two discussed how the presentation should occur. Pam tried to help Linda organize logistical aspects of the lesson, as well as ensure that the necessary science content was included. For example, in a conversation prior to a lesson on symbiotic relationships, Pam provided specific direction about topics to include, as well as several examples that she felt students found interesting.

> Pam: One example [of commensalism] that I give every year—[Pam begins to draw a picture of a shark with a small fish attached just outside the shark's mouth.]—the small fish on the outside are remora fish. They don't affect the shark, but they benefit from the fact that he's a messy eater. They can catch bits of food from his meals that flow past. That's a good example to help them remember. How about mutualism?

> Linda: I'm planning to use lichens as an example.
> Pam: With lichens, tell the two organisms. [Pam then shares another example from entomology.] Termites have to have a certain bacteria in their gut in order to digest wood. As soon as they are born, the mother excretes feces and the babies eat it. There are enough bacteria in that to infect the babies for life. [The students] all say, "Eww, gross." They love that.

Pam provided advice in a third area related to fostering student understanding of specific concepts. Pam used her own experience with students to help Linda anticipate areas where students may experience difficulties with their understanding. A conversation in the middle of the internship illustrates this type of discussion. Pam and Linda conversed about an activity in which students used plastic beads to model the steps of DNA replication. Before the activity, Pam told Linda that students would want to simply build another copy of the initial DNA, rather than working through all of the steps of the replication process.

> Pam: What they'll want to do is just make one, and make another one just like it. Help them remember the steps. You need to see them untwist and unzip down the middle. Watch for things like that. You can even ask, "What's the purpose of unwinding?"
> Linda: [If it didn't unzip], it would be awfully hard to replicate and lots of opportunities to make a mistake.
> Pam: Every time you make a point to them, you should justify why it happens. You sometimes want to go through every detail. Just go through three or four base pairs. Have the nucleotides ready, it cuts down on time. Make the point that there are two new strands [of DNA constructed], half is the old strand, and half is the new strand, but it is still identical. If you want, you can tell them about mutations.

One aspect of teaching unique to science classrooms is the incorporation of laboratories. Pam and Linda discussed ways to successfully incorporate and implement science laboratories in their classes. Often these discussions focused on logistical aspects of managing safety in the laboratory setting or structuring discussions and questions so students would understand the science concepts addressed during the lab. During an observation early in the relationship, Pam explained her rationale for her decision to incorporate an inquiry-type lab into her plans for a particular lesson. This exchange was the only reference to inquiry observed during the relationship.

> I was going to show you, I have several different labs. Sometimes I choose to do one of these [inquiry labs]. I feel like they've done [photosynthesis] since elementary school, so it's okay to give them one of these labs where I give them stuff and have them solve problems.

Pam explained that she had set the stage for the inquiry lab during her class by talking about what students could choose to test and how to collect the data: "This is not honors biology. You have to set the stage so they don't get frustrated. If you make them jump too far, it becomes goof-off time. You'll have to find the line when you start teaching."

Pam provided Linda with advice on a variety of both general and science-specific topics. While data included in this section provides only a glimpse into the advice given by Pam, her advice was frequent and continuous over the course of the study. Pam guided Linda during the planning of activities, helped her modify lessons over the course of a day depending on student reaction, and provided written and verbal feedback after observing Linda's teaching. Advice related specifically to the development of Linda's PCK focused on choosing appropriate content to include in lessons, as well as providing examples that would be interesting to students. Pam tried to help Linda anticipate potential areas of student confusion so she could organize her instruction to avoid those. Pam repeatedly expressed the frustration that she felt constrained by pressure due to end-of-course testing in her area school; she felt that the pair had to exclude many laboratory activities and science projects to cover all of the content required by county and state curriculum guidelines.

Protégé Implementation of Advice

In reflecting on her experience during the course of her internship, Linda felt that she made great strides in some areas of her teaching practice. In Linda's view, her vision of what it meant to be a science teacher changed along with her ability to manage the classroom environment and engage learners in science lessons.

One important lesson that Linda credited to her experience in Pam's classroom was the change in her perspective of what it meant to be a science teacher. Linda began the year using her own experience as a high school and college student as the basis for her thoughts about teaching. She realized this model was not effective in Pam's classroom and tried to modify her beliefs accordingly.

> I wish somebody had cared this much when I went to high school, but if that's what it takes and that's what makes you a better teacher and makes students better students, [then that's what you have to do]. I guess I was envisioning what I had learned or the way I was taught, and I realized that wasn't going to work. So I guess I'm emulating Pam because I really didn't have a teaching style, or the one I was using didn't work.

One major component of Pam's teaching that Linda admired was her determination to involve all of the students in the class in the activities that occurred. Additionally, Linda cited the necessity of being adequately prepared and the importance of presenting science content in a manner that made it understandable to students. Linda felt that Pam was an excellent model for organizing content into a form that was easier for students to understand.

> [The teacher must] take difficult concepts and organize them, clarify them, and explain them so that big, huge, horrible concepts are either put into a different context or [put] on a simpler level. She does explain things in a way that they can actually understand.

Over the course of the internship, Linda felt that she made a great deal of progress. She valued the opportunity to talk with Pam about her lessons prior to implementing them. Linda felt that both she and the students benefited from Pam's insights and experience. One area in particular where Linda felt that Pam's advice had really made an impact was in the area of classroom management.

> I think I've improved a lot since I first started. [Today] I was actually able to facilitate discussions and have them interact and ask questions. And they do ask questions. I've been trying to link back to previous information and engage them and ask questions that are not so directive and leading.

For her part, Pam was not as confident that her protégé had successfully implemented the advice given over the course of the internship. Pam felt that Linda was surviving during the internship and was trying to implement the advice that Pam gave; however, she was not confident that Linda had developed a level of independence that would allow success in her own classroom. While she felt that Linda had made some gains throughout the internship, she had hoped for more progress.

Kevin and Jodi's Case

While Kevin, the second mentor in the study, provided his protégé Jodi with advice within the domains of GPK and PCK, the topics covered and frequency of advice giving were different. Kevin provided advice on a less frequent basis than Pam, and his advice did not address as many topics related to science-specific pedagogical content knowledge.

General Pedagogical Knowledge

In the case of Kevin and Jodi, Kevin shared advice related to two areas: timing and lesson closure. When Jodi began her internship, she was unsure how long certain activities would take. Jodi shared her plans for upcoming lessons with Kevin and asked for his input in this area. In the following interview excerpt, Jodi described a conversation she had with Kevin about this topic.

> On the DNA PowerPoint, I showed it to him and said, "I think this slide show is long enough where I don't need to plan anything else behind it. I think that's going to take up the whole period. We'll be lucky to get through it. He agreed. I usually get an agree or a suggestion.

In several instances during the internship, the pair repeated this pattern. Jodi shared her concerns about the timing of the lesson, and Kevin responded with his input.

In four separate interviews, Kevin addressed the importance of including closure for each lesson. Kevin wanted Jodi to regain students' attention at the end of the lesson and summarize the main points addressed. He advised Jodi to be certain to incorporate this process in all of her lessons. Jodi did not mention closure in her interviews. The following interview excerpt highlights Kevin's feelings: "The only other thing I suggested was closure, going over all this terminology that we [covered], going over the terminology just to close and say, 'Here are the important things that we need to remember.'"

Advice giving within the domain of GPK was limited to the areas of timing and closure. This advice was often given in response to Jodi's specific questions. Kevin, however, stressed the importance of summarizing lessons in his conversations with Jodi without prompting on her part.

Pedagogical Content Knowledge

There were several areas pertaining to pedagogical content knowledge where Kevin furnished Jodi with advice. Using the Magnusson et al. (1999) framework, the most prevalent topics addressed were student understanding and subject- and topic-specific instructional strategies. Within the domain of student understanding, Kevin focused his advice on gearing the level of the science content to the ability level of the students. In the area of subject- and topic-specific instructional strategies, Kevin addressed the topics of using visuals to enhance lessons and appropriate ways to conduct science laboratories.

Matching the level of science content to the ability level of the students was one type of advice given by Kevin. He used his years of experience working with students and familiarity with state and county curriculum guidelines as a gauge for the appropriate level of material. In one lesson, Jodi used a PowerPoint presentation to convey information about the structure and function of DNA. After viewing the slides, Kevin recommended omitting one because he felt the material was too detailed for his ninth-grade general biology class:

> I think I told her to cut one section on the PowerPoint presentation. She actually got into the chemical bonds and what kind of bonds there were in between the parts of the nucleotide. I said, "They're not going to get that. They're not going to remember that, so let's stick to the three major parts, the nitrogen bases and all that." She's very detailed, and that's a good thing; but right now the kids are shutting down, and I want them to get the basics. She went into that 5 and 3 stuff, which I never learned in high school. I told her to cut that down because we don't have enough time. She just wants me to look and see what I think—if [the material] is covered, if it's too hard, or if it's on the right level.

While Kevin was pleased that Jodi had a thorough grasp of the science concepts she taught in his class, in some cases he cautioned her to omit some of the detail for his students.

Another area where Kevin assisted Jodi related to subject- and topic-specific instructional strategies. Kevin advised Jodi to include visuals to help students better understand complex scientific concepts. In November, Kevin provided Jodi with specific guidance in a lecture. During a lesson that Jodi was teaching on the structure of DNA, Kevin realized that including a three-dimensional model would contribute to the students' understanding of the topic.

> Some of the kids weren't getting it, weren't understanding it. I remembered I had a 3-D DNA model [that] could untwist and [you] could show them the ladder shape. I also had the lab I did last year [with] magnetic nucleotides that you can piece together yourself. I gave her those, and we put [them] together on the board and helped demonstrate the nucleotides and how they attach and the ladder and all of that good stuff. I think that cleared up a lot of things.

In this instance, Kevin used his knowledge of available resources and ability to gauge student understanding during a lesson to help Jodi provide students with visual aids that would increase their understanding of abstract subject matter.

A second area of advice giving related to subject- and topic-specific instructional strategies for this pair included advice on how to prepare for and appropriately time laboratory activities. Though there were only a few conversations between the pair about laboratories, they did provide an opportunity for Kevin to counsel Jodi. He stressed the importance of adequate preparation and thoughtful timing to minimize potential management problems:

> Jodi saw how to set up the lab and how days ahead we had to cook all the starch solution and sugar solution and get that ready to go. [We had to] wash out the bottles and get everything set up, and that takes—it takes 2 or 3 days if you don't sit down and do it all at once. You have to be prepared well ahead. I tried to give little hints and say you have to get prepared.

Like Pam, Kevin provided Jodi with advice on several topics related specifically to the teaching of science. He encouraged her to use visuals and models to help students gain a better understanding of abstract concepts. He cautioned her to gear instruction to meet his perception of students' ability level, though she sometimes ignored the advice. While the two discussed laboratories as they planned or after the activities were completed, advice was related primarily to management issues within the laboratory context.

Protégé Implementation of Advice

There were several areas where Jodi felt that she learned as a result of her internship experience and her interactions with Kevin. These included developing a modified view of science teaching, a comfortable relationship with students, and an understanding of how to choose age-appropriate materials. Discussing her experiences with learning to gear the material she was presenting to the level of the students in Kevin's classes, Jodi conveyed the following thoughts:

> I think that what I'm learning is how to age appropriate the information because I haven't worked with a younger group like this before; always adults. I'm learning how to translate the information that [I] want to get across and simplify it in a way that they can understand it.

Jodi expressed her feelings that she had grown more comfortable in the role of a teacher as a result of her internship. She felt that Kevin's relaxed approach to the students and flexibility in incorporating students' interests had helped facilitate this change: "My major growing area has been overcoming my fears of being in the room and not knowing what it was going to be like. I'm a lot more comfortable with the kids."

Kevin felt that Jodi gained from her internship as she was able to see Kevin as a model for having students do science, rather than just hear about it. She was also able to use Kevin and his experience as she talked about planning and implementing her lessons. He was pleased that Jodi began to use visuals to help students understand complex science concepts. As a mentor, he felt that he was able to learn from Jodi's expertise in using technology to support student understanding and interest in a variety of science topics.

Cross-Case Analysis

The most obvious trend in a comparison of the advice given by the two mentors is the difference in the amount given by each. Analysis of the field notes indicates 202 observed instances of Pam giving Linda advice, 67 of which were science specific in nature. Interview data also reveal that advice giving by Pam was frequent; both mentor and intern repeatedly referenced specific advice that Pam provided. In contrast, advice giving by Kevin was observed only infrequently, even though Kevin was present in the room for most of Jodi's teaching. Additionally, Jodi and Kevin mentioned advice less frequently in interviews. Almost half of the times that Jodi mentioned advice in her interviews, she lamented on the lack of advice that she felt she received:

> We have little tidbits here and there where he'll say one or two things, and then that's it. It's dropped, and we move on. The other week, I did a couple of periods, and he made one or two comments, but very small and nothing significant. I hope he still feels confident in me. I don't know. I really don't know.

Kevin advised Jodi in response to specific questions that she asked, but advice giving was not a part of their daily interactions as it was with Pam and Linda. Kevin's advice to Jodi, as in the case with his recommendations about lesson closure, was based on techniques incorporated into his own teaching and provided an opportunity for him to guide Jodi by comparing the strengths of his own classroom practice with areas where he felt she had not developed expertise. One explanation for this lack of voluntary advice on Kevin's part could have been his initial perception that Jodi was extremely competent in her role as a science teacher intern. Another possible explanation could be that Kevin's absence of detailed advice giving was due to his philosophy of mentoring based on a modeling relationship. Kevin repeatedly stressed that he expected Jodi to learn by watching him teach and by participating collaboratively in the planning and implementation of lessons. Jodi, for her part, indicated that she did agree with some of Kevin's suggestions, such as incorporating visuals to help students understand concepts, and did implement those suggestions. She appreciated his emphasis on having students actively engaged with science and came to see that as an important part of science teaching; however, she felt that she was not always comfortable with the level of activity in Kevin's classroom. Interestingly, while Kevin mentioned that he had advised Jodi on the importance of lesson closure several times, Jodi did not discuss this as an important aspect of the advice that she received from Kevin.

Unlike Kevin and Jodi, Pam and Linda had frequent and detailed conversations about Linda's lessons before she implemented them. Pam attempted to coach Linda to design lessons that were both engaging and meaningful for students, as well as to develop means of assessment that would allow Linda to gauge student understanding to prepare subsequent lessons. Pam often observed Linda's teaching and took detailed notes during the lessons. Kevin indicated in his interviews that student engagement and covering the state-mandated curriculum were important goals for students in his classes, whether he or Jodi were primarily responsible for the lessons. He did not, however, engage with Jodi in the type of regular, in-depth discussions pertaining to teaching observed in Pam and Linda's relationship.

While there were notable differences between the two pairs with respect to the frequency and depth of advice giving observed, there were also striking similarities in the topics that were not observed in conversations between either of the pairs. Referring to Fig. 1 and the STPS, the domains of knowledge relevant to the development of pedagogical content knowledge for science teaching that were not included, or were touched on only briefly included the nature of science, inquiry, issues important for scientific literacy, and science in the community. In the case of Kevin and Jodi, assessment was also lacking. In both of these pairs, mentors indicated that exposure to authentic science experiences for students were limited by the pressure exerted by end-of-course testing. While Pam consistently encouraged Linda to provide various types of assessment, these conversations were not observed in the other pair of participants. Much of the advice observed related specifically to science as both pairs focused on the type and level of content to be included. For one pair, these conversations sometimes included ideas for ways to organize and present the material, with a focus on student involvement and understanding. In the other pair, these conversations were absent.

Discussion

Data from this study describe the types of advice given by two credentialed, experienced mentors to their protégés in an alternative certification program for secondary science teachers. A comparison of the areas of advice given by these two mentors to the topics addressed in Fig. 1 reveals that, while several of the areas comprising a knowledge base for novice science teachers were addressed, others were completely omitted.

One of the three foundational domains of the model is GPK (Borko and Putnam 1996). Much of the advice given by both mentors centered on this area. Pam spent a great deal of time in conversations with Linda that dealt with Linda's management of the classroom environment and her persona as a science teacher. In the description of the general skills of teaching found in the STPS, using a variety of teaching strategies and methods to engage diverse learners in a classroom is a crucial aspect of this area of competence. Therefore, it is not surprising to see the emphasis on this topic. Repeated conversations between the two related to managing the classroom and engaging students indicate that they were themes throughout the course of the internship. In contrast, while Kevin did include advice to Jodi related to GPK, the guidance was more sporadic and pinpointed specific topics, such as the pacing of lessons and including some form of closure.

A second core aspect of the model based on Borko and Putnam's (1996) work was subject-matter knowledge. Interestingly, this domain was completely absent in the conversations observed between mentors and protégés in this study. One possible explanation for this lack of emphasis on content knowledge could be the mentors' perception of their roles in working with these protégés who brought extensive science backgrounds to the relationships. When Pam and Kevin described views of their mentoring roles, as illustrated in Table 1, they focused on ideas about helping the protégé become a competent teacher. They may have felt that the protégés' science degrees and experiences provided backgrounds that would be sufficient for the high school classroom. The focus of the mentors could instead be the development of the protégés' science PCK.

The third foundational domain of the model, PCK for science teaching, is the most complex of the three areas. In Magnusson et al.'s (1999) view of PCK, a teacher's orientation "represents a general way of viewing or conceptualizing science teaching" (p. 97) that is related to the teacher's beliefs about the goals for science teaching at certain grade levels. These orientations, in turn, can shape the other four areas that include teachers' knowledge and beliefs about (a) students' understanding of specific science concepts, (b) instructional strategies for science teaching, (c) assessment in science, and (d) science curriculum. While it is possible that the protégés could infer some understanding of their mentor's orientation towards science teaching from observing teaching and interactions with students, these orientations were not explicitly articulated. In addition, the mentors did not discuss the orientations that the protégés brought to the relationship based on their own experiences.

Within the four categories related to teachers' orientations towards science teaching, student understanding of specific concepts was addressed by both mentors. In both cases, the emphasis was on organizing and presenting instruction so students could understand the basic concepts being addressed. In the case of Kevin and Jodi, incorporating visual representations of abstract phenomena and gearing the level of the material to the student's level of understanding were the foci. Pam also emphasized using models and visual representations to assist students. In both cases, the mentors used their expertise to help protégés anticipate areas where students were often confused or had difficulty developing an understanding of the concept. As was the pattern in these relationships, Pam's advice giving was more frequent than Kevin's; however, this was an area where the mentors provided advice that addressed the tenets outlined by Magnusson et al. (1999).

The second category within orientations to science teaching addressed by the model was the use of subject–topic specific instructional strategies. The focus here is on techniques that are unique to and broadly applicable in science classrooms, as opposed to other school subjects. Included in this category are strategies for effectively teaching particular science concepts. One method that fits this description is the use of laboratory experiences for students. Incorporating labs in the science classroom was covered by both mentors. However, in the majority of cases, the advice was related to the management of traditional types of lab experiences, such as extracting DNA or testing foods for the four types of organic molecules. Only one conversation was observed in which Pam, the mentor teacher, discussed her rationale for incorporating an activity that she described as inquiry into her teaching. Safety was discussed only minimally by both mentor teachers.

Magnusson et al. (1999) described two components that are important related to the assessment of students: knowledge of the various types of assessment that are possible and their advantages and disadvantages and knowledge of which topics are important to address in assessing students. The STPS description of this category is similar, but in this document there is an additional emphasis on using assessment to modify instruction and to help students analyze their own learning. Within this category, advice giving by Kevin was absent from the observations and interview responses. In contrast, Pam and Linda discussed various methods of assessment and rationales for when and why they should be used. Pam emphasized the importance of gauging the understanding of students with a range of ability levels and modifying the instruction accordingly.

The focus of the curriculum category is the mandated goals and objectives required by states and school districts, as well as the various programs and materials available to meet those goals. The charge set forth by the STPS is to align the curriculum of schools with the NSES by incorporating such topics as the nature of science, science in the community, and knowledge of issues necessary to become an informed-citizen decision maker. Findings from this study in relation to this area are the most troubling. In both cases, these topics were almost completely absent from conversations in both pairs.

Implications for Science Teacher Education

Often the call in teacher education is for more time in schools. Certainly, there is heavy emphasis in alternative certification programs on the importance of school experience. Within the context of the PACSS program, protégés experienced two full semesters of supervised internship with trained and experienced mentors. While the situated experience of learning to teach within the context of real classrooms is vitally important, the findings of this study lead us to further question the nature of what is learned through these experiences. As a result of the experiences of these two pairs of participants, the internship component of the PACSS program was restructured to allow interns to have more experience in the classrooms of several science teachers in the fall semester before settling into one classroom full time for the spring semester. Part of the rationale for this choice was so interns could experience multiple perspectives on science teaching, but also so they could potentially meet an experienced teacher with whom they wished to be paired for their student teaching experience. In this way, they would already have experience in a particular classroom and would have a compatible personality match with their mentor teacher.

Secondly, findings of this study indicate the need for increased communication and a closer partnership between university and school-based teacher educators. This study is not meant to be a critique of the practices of these mentors who serve a valuable role in science teacher education. Rather, the results should prompt further reflection on the nature of the relationship between university science educators and classroom science teachers. In our experience, university personnel had developed expectations for the type of experience they wanted for the interns in their field placements based on reform documents, such as the NSES and STPS. However, these expectations were not communicated in an explicit manner to mentor teachers participating intimately in the novice teachers' learning. University supervisors and school-based mentors did not develop a relationship that allowed protégés to receive reinforcing messages from both sources. Additionally, university supervisors working with these pairs were able to visit only a few times per semester. The university supervisors were people assigned to each pair, whose job was to evaluate the progress of the intern and offer advice and feedback. (The supervisors were different from the researchers who authored this paper.) It is only through the development of true science learning communities that these problems can be addressed.

In contrast to the nature of the experiences reported here, we recommend another possible role for the university supervisor: These supervisors should model reflective conversations on reform-based topics with the classroom mentor teacher. The prevailing culture of schools includes isolation and an avoidance of telling others how to operate in their classroom; this culture may make mentors reluctant to adopt a critical stance in the advice given to their protégés (Ballantyne, et al. 1995; Gratch 1998; Kay 1990). Teachers typically have had few opportunities that provide experience with, or models for, discussions of teaching practice or the support necessary to conduct them (Gratch 1998; Stanulis 1994). While experienced teachers have built up a large "wisdom of practice," they often have little experience in making that knowledge explicit (Connelly and Clandinin 1988; Stanulis 1994). University supervisors can provide the bridge that supports and promotes meaningful conversations related to the developing pedagogical knowledge for mentoring pairs.

Given that the topics lacking in the conversations of both pairs were several of the core topics found in reform documents in science education, such as inquiry and the development of scientific literacy, greater thought must be given to how to help novice science teachers develop the knowledge and skills to incorporate those topics in their teaching. To support conversations based on desired reform-based practices, it may be necessary to develop benchmarks to help the mentor teacher and university supervisor focus the topics of their advice giving. These benchmarks could be based on the topics found in reform documents, such as the NSES and STPS. If mentor teachers are unaware of the expectations highlighted by the STPS, they cannot incorporate those topics into the advice they give. In addition, these benchmarks could provide a common language of practice that would facilitate the development of the university supervisor, mentor teacher, and science teacher intern as a learning community.

Finally, this study revealed the importance of a multiyear induction process, as opposed to a 1-year mentoring experience. The situated nature of the field experience is often the point in new teachers' development where they come to fully appreciate the complexity of science teaching. There is a need for time to be spent on general pedagogical issues, and it is important that those topics are addressed. Mentors must address the developmental level of the intern with whom they are working. Therefore, general pedagogical topics must be addressed in conjunction with other issues related specifically to science teaching, such as frequent assessment of students' understanding of specific science content and the inclusion of authentic science experiences. It is unrealistic to think that novices can become proficient in both GPK and PCK specific for science teaching in such a short time. Viewing mentoring as a short-term remedy to help novice teachers survive their student teaching and 1st year on the job diminishes the impact that these relationships can have. Continued support from other science teachers through the early years of teaching is an important stage in the developmental process. These relationships over time can allow for deeper conversations related specifically to the pedagogical content knowledge needed to address specific science concepts.

The findings highlight the need for further studies that investigate the protégés' reaction to the advice they are given. Additionally, current mentoring literature suggests that the ideal model for mentor–protégé relationships is an egalitarian one in which both partners reflect deeply on their teaching and both contribute equally to their professional development (Hargreaves and Fullan 2000). The advice giving observed between the participants in this study flowed primarily in one direction, from mentor to protégé. Further investigation is needed to determine mechanisms to support this more reform-based approach to mentoring.

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