

One Teacher's Journey Toward Reformed Teaching

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Karen, an energetic secondary science teacher in the southeastern United States, has always focused on student learning. Her current professional goal is to better incorporate the nature of science into her teaching. The nature of science is the set of underlying principles describing what science is and is not and the rules by which scientific knowledge is gained. For instance, the nature of scientific knowledge is tentative, based on empirical evidence, and situated in a historical and cultural context. These characteristics distinguish science from other ways of knowing, such as aesthetics or religion. Scientific knowledge is gained through gathered evidence on which explanations are based. These explanations are then presented to the scientific community for consideration. Knowledge about the nature of science is a central aspect of science understanding, is a characteristic of being scientifically literate, and is emphasized in the National Science Education Standards (NRC 1996).

Karen had her students read a newspaper article describing how snakes had entered a room in the Navajo Tribal Administration Building on the reservation. The Navajos were worried by the presence of the reptiles—understanding snakes to be the messengers of bad news. A medicine man was called in to rid the building of the messengers as the employees prayed and carried out other spiritual ceremonies. An animal control officer explained that because of drought the snakes entered the buildings for water and cooler conditions.

The following is an excerpt from the discussion of the article in Karen's classroom:

Karen: Is one explanation more right than the other?

Student: No.

Karen: Why not?

Student: 'Cause I don't know. They sayin' two different things.

Karen: What's the Navajo belief based on?

Student: They tryin' to give a message.

Karen: Yes, but what's it based on?

Student: Myth.

Karen: You think it's based on myth, legend, cultural stories that have been passed down?

Student: Yeah, yeah.

Karen: What do you think the explanation of the animal control person is based on?

Student: Background.

Student: Prior knowledge with the animals.

Karen: His knowledge with animals. She said it was because of his scientific background.

Student: One is more scientifically correct than the other one.

Karen: What did we say we need...?

Student: Evidence.

Karen: Evidence. Which one is more likely to have evidence to back it up?

Student: The animal control officer.

Karen: Do you think that one is just as right as the other?

Student: No.

Student: Yeah.

Karen: So when we look at the science of it, is one explanation more valid than the other?

Student: Yeah. Ours would be more valid.

Student: One's more logical.

Karen: Which one do you think is more logical?

Student: The one about them being hot and dry and needing water.

Student: Yeah.

Karen: All right, what's not logical about the fact that the snakes may be bringing a message?

Student: How can they bring a message? They ain't got no evidence that they bring a message....

Karen: OK. Now, let me ask you this, because now we're talking about Navajos, right? Your belief systems are different than theirs. But let's say that we were talking about whether or not you catch a cold if you go outside with your head wet. Let's say that your grandma's explanation is, yes, you catch a cold if you go outside with your hair wet.... The nurse comes along and says that's not why you have a cold. You have a cold because you were exposed to a virus. It made you sick.

Student: My grandma is right.

Karen: Why is it that now I am talking about your culture and your grandma, they are right, but the Navajos were not.

Student: They're superstitious.

Student: You might get a cold when you didn't go outside and someone might go outside with hair wet and be fine.

Karen: So, again, what you all are saying is now that I'm talking about your culture, the explanations are equally valid, but when I'm talking about somebody else's culture, they're superstitious and it's not valid because you don't have any evidence. Now, here I go, what evidence do you have that going outside with your head wet will give you a cold?

This discussion was characteristic of Karen's interactions with her students; she listened carefully and followed students' initial responses with questions encouraging elaboration. Karen also connected class material with students' past experiences. Are their grandmothers' cautions about covering a wet head different from the Navajos' belief that snakes are a warning? Karen wanted her students to wrestle with comparing the basis of different knowledge claims. In so doing, Karen's students could rethink their ideas in light of the new ones, take a stand, and make sense of new information in the context of their own experiences.

We believe that teachers like Karen are at the heart of school reform. Current reform efforts focus on scientific literacy for all students. To be scientifically literate is to understand the fundamental ideas of science, including how scientific knowledge is generated, so that it may be used to make informed personal and societal decisions. For teachers, inquiry-based teaching strategies support the learning of important science knowledge, as well as provide opportunities for students to experience knowledge construction (see Chapters 1 and 2 for additional details). This type of teaching, however, is different from what many of us have experienced as students. Therefore, teachers like Karen are central to reform. If science teaching is to change, teachers must change. Karen has accepted the challenge to change her teaching in order to improve student learning.

Since inquiry teaching in any of its forms (Abrams, Southerland, and Evans 2008) is not the norm of most university instruction, supporting changes of this type will largely occur in professional development settings. How did various professional development experiences help shape Karen as a teacher? Which experiences proved fruitful? And what might we take from Karen's experience as we explore ways to expand and further develop our teaching? This chapter chronicles a teacher's pursuit of learning about her classroom practice and provides one example of teacher change.

Karen's Teaching Path

Who is Karen? What drives her to experiment with her teaching? With a bachelor of science degree in biology, Karen pursued a teaching career because she was good with teenagers and found explaining things easy. She completed her student teaching in a large, urban school with a diverse student population. Here, she taught in ways similar to those experienced in her university methods courses and in her own learning as a student: She lectured, used questions from the book, and gave tests. Karen's first teaching position was in a seventh-grade science classroom in a large, urban school, where she was supported by a close-knit team of teachers. Teaching was a focus at this school, and teachers commonly talked about and shared ideas. Although the teachers periodically participated in one- or two-day inservice workshops, Karen did not view these experiences as particularly memorable. Karen explained, "These short-term inservices give you nice little strategies and things to use. But I don't really see them changing your teaching. I think what is needed to change your teaching are things that make you look at your classroom differently."

Three years later, a family move necessitated Karen's transfer to a much smaller, rural middle school with a large African American population and a large percentage of working class and working poor students. Karen was one of two science teachers, and her colleague was not interested in working collaboratively. This was unfortunate, as Karen was beginning to recognize that the traditional textbook, lecture, and test methods in use did not serve the student population well. Despite incremental improvements, after six years, Karen was feeling burned out. "There were some very bright students there," Karen emphasized, "but we were losing them—they were bored, they were dropping out." Karen left the school because she could not be as successful there as she wanted to be. She decided to move to a high school in the city. In this new position, Karen said, "I feel effective here, I feel as though I make a difference. I also believe I am a role model for the students. By bringing science *to* my students, I help them to see its relevance in their lives."

This story presents Karen as an individual who believes in herself as a teacher and in the capabilities of her students. Those beliefs acted as drivers for her to

seek continual improvement as a teacher and to expect her students to achieve more in school. Leaving her former school was, in part, fueled by her confidence in her abilities and expectations to positively impact her students. This sense of high expectations of one's teaching is termed "teaching self-efficacy." Her discontentment with her former school and her own teaching approaches combined with her high personal expectations pushed Karen to seek additional professional development experiences. The short-term, activity-based experiences offered in her schools and district were not helping her better craft her teaching. Karen explained,

When I was working in this rural school, I found myself thinking "I know there has to be more." So I needed to find what I need to do to teach my students better. I always knew there was more and I wanted to try to learn more. And I also wanted to be able to pass on what I knew to other teachers.... [So I said to myself] "OK, it's time for me to go back to school, because if I am going to do this then I need to know how to teach other people better."

Three Professional Development Experiences Dovetail

To improve her teaching, Karen sought professional development experiences that allowed her to better understand her own teaching and student learning. She found a number of experiences at her local university that were closely aligned in intent. Karen selected experiences that revolved around two central aspects of science education reform: inquiry and the nature of science. In this section, we'll describe how three such experiences interacted to help Karen refine her understanding of classroom inquiry.

Inquiry in a Graduate-Level Course

A graduate course in science teaching and learning introduced Karen to broader conceptions of inquiry and addressed conceptual change theory and the nature of science. Through a student interview assignment about a scientific topic, Karen was better able to uncover student thinking, including prior conceptions. She used this information to craft an instructional experience to help students change their science ideas. Through discussions in this course, Karen came to see science in ways that made sense, particularly as she thought about teaching. This view of science, however, was very different from her prior thinking about science. Karen's exposure to inquiry and the nature of science was at odds with other college experiences.

Even though I majored in biology, no one ever dealt with what is science and what it actually does, and the very nature of what science is. I used to think of science as the scientific method, and when the professor started describing aspects of the nature

of science, I thought, "Well, OK. That's different. That's a new way to think about science." I mean, I thought you just wrote up your lab reports and that was it.

A Field-Based Research Experience

During the next summer, Karen participated in a five-week marine ecology program offered for teachers by the university. In it she learned about marine organisms and conducted scientific research. Karen was, in a sense, primed to examine her research experience because of the more theoretical lens she had developed in her graduate course. The scientific inquiry in the program was now informed by a more sophisticated understanding of learning and the nature of science. The experiences in the program emerged as an example of inquiry that could be used to shape her teaching.

The following school year, Karen introduced an inquiry-based lesson in which her high school students examined three different types of soil: peat moss, compost, and clay. Students were asked to record observations with a focus on color, texture, overall appearance, and any other observations other than tasting the soil, which she advised against. Using their observations, Karen helped her students craft questions about soil and turn them into experiments addressing the question, "How much water do these soils absorb?" As Karen reviewed the four-day unit with Meg (a doctoral student who was studying Karen's teaching as part of her dissertation research), they noted that Karen seemed reluctant to let students make mistakes in their experimental design. In one case, students wanted to use filter paper under their funnel. When Karen couldn't get the students to figure out where to place the filter, she finally told them where to place it.

A Structured Reflection on Classroom Inquiry

Following the analysis of Karen's inquiry-based teaching, Meg created a set of questions designed to uncover Karen's understanding of classroom inquiry and the basis of her instructional decision making. Meg explored Karen's reluctance to let her students pursue lab procedures that would not be productive. Karen told her,

When I first heard about inquiry it was years ago at a one-day workshop. It was the new thing and people around me were doing it.... I remember thinking that it was a ridiculous notion for me, because of the way it was described. The teachers just kind of "turned students loose" in the classroom, and the students were just supposed to discover these things on their own with no leadership from the teacher. I thought inquiry-based activities were supposed to be based only on the knowledge and experiences that the students already had. Toss the book out the door, and you let the kids go for it.

Karen had difficulty making sense of this description of inquiry. Why would she not play a part in helping students learn? This residual memory affected Karen when she taught future inquiry lessons. Having students set up the soil labs in ways that were not correct or productive felt wasteful or somehow not reasonable to Karen. But she was willing to reconsider her attitude.

It wasn't until I took the graduate-level Science Teaching and Learning class that I saw inquiry as a continuum and got a better understanding of it. There is a continuum in there where you can work based on how you feel your students can handle [the experience] and make progress and so on and so forth. It then made more sense to me.

The Interactions of These Three Experiences

These three experiences were interwoven. Karen participated in a five-week research experience while she carried out inquiry-based activities prompted by the experience in her classroom. She resisted lesson elements that might make the activity more open-ended. In this case, she prevented her students from pursuing unproductive experimental designs. Although Karen had gained more holistic views of open-ended inquiry in her graduate course, she was still dealing with her initial negative impressions and feelings while simultaneously rethinking what inquiry meant in the context of her classroom. It was only as Karen worked to make sense of her many professional development experiences and the ways they were interrelated that she began to understand classroom inquiry more deeply, and she began to understand the various forms inquiry can take in a science classroom. She began to see that classroom inquiry requires a shift in responsibility for knowledge construction. After more than a year of exploring these issues, Karen continued to struggle with instructional methods that allowed her students to take more responsibility for their own learning.

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What Kind of Professional Development Is Needed?

Karen's case reveals both good news and bad news about professional development and reform. The good news is that teachers can make low-risk changes in their teaching and evaluate the results. Karen's lesson described at the beginning of this chapter is such an example. This one-day activity required little in the way of planning, materials, or class time. The bad news: Science education reform will not occur by simply adding occasional new activities to your teaching repertoire. Reform requires thought, work, and persistence. Karen explains:

*[Short-term inservice sessions] give you nice little strategies and things to use. But...I don't see them really changing your teaching.... I think what is needed to change your teaching are things that make you look at your classroom differently. **Teachers need ... not new things to do, but new ways to see their classrooms.** [Boldface added for emphasis.]*

Reform requires us to rethink our teaching, to view teaching through different eyes. Such change requires professional development experiences that are long term and sustained. The experiences must challenge teachers to consider new ways of thinking about teaching, as opposed to merely providing them with new activities. As Karen elaborated,

*You have to have time to digest these ideas, to think about them. You can't just read an article, then produce some new [instructional] product. You have to think about your teaching, your students, and all that takes time. If you're just given new activities to do, then you're pretty much just doing the same thing. You are just changing the things that you do. **You're not changing the way you perceive the class and how it should and can go.** [Boldface added for emphasis.]*

For Karen, what made the difference was participating in a variety of professional development experiences that focused on her *own* teaching. This mixture of graduate classes, research experiences, and reflections was essential in providing Karen with an extended opportunity to consider her classroom. As part of these experiences, Karen developed a network of colleagues who provided support as she attempted to rethink her teaching practice. These experiences are similar to those suggested in Chapter 2.

Karen's case allows us to see that there is no secret recipe for professional development (e.g., take a graduate class, followed by a research experience, topped off by a year of dissertation research in your classroom). Instead, it is important to recognize that reform takes time. It takes sustained effort. It takes the goal of better understanding your classrooms and your teaching. Profound professional development starts from and ends in experiences that are applicable to the classroom.

For Karen, analysis of learning theory—combined with seeing the ways learning theory played out in classrooms—caused her to think about teaching in new ways. Professional development does not need to follow the path Karen took, however. A well-selected series of workshops, virtual courses, or attendance at science teacher conferences can allow for similar shifts in our teaching. A long-term book group with teaching colleagues can also be transformative. Additional ideas for transformative professional development opportunities can

be found in Loucks-Horsley et al. (2003). The learning opportunities you select are less important than recognizing that crafting your own circuitous route to reform takes time and sustained effort. Your goal must be to better understand your teaching.

What Kind of Teachers Seek to Reform Their Practice?

Most science teachers know that what a student learns depends on what that student already knows and how willing that student is to engage with a new idea. Teachers are no different. Karen's case demonstrates how her learning from a professional development experience was influenced by her prior knowledge and degree of engagement with the material. Karen's learning in the research experience was shaped by her own evolving knowledge of learning theory, conceptual change, and classroom inquiry. This knowledge allowed for Karen's deep engagement with the material, an engagement fostered by a five-week intensive research experience and the availability of someone (Meg) to help her make sense of her teaching. This knowledge and deep engagement—the willingness to continue working and refining until she was pleased with the result—allowed Karen to learn more from her experiences than other teachers who were more superficially involved in courses and professional development.

Karen's story also allows us to see how a teacher's sense of self shapes learning. Karen held high expectations for her students and high teaching self-efficacy. She expected to teach effectively. These characteristics were combined with a sense of discontentment with her teaching. Although Karen knew she was able to teach well, she recognized that she did not always teach well. Indeed, Karen recognized that not all students were learning as well as she expected, a responsibility she reflected back onto her teaching. High teaching self-efficacy combined with teaching discontentment made Karen a prime candidate for learning from sustained professional development. If Karen didn't have high expectations of herself and of her students, she may not have attempted the new ideas presented in professional development. Alternatively, if she thought she *was* already teaching as effectively as possible, she probably would not have seen the value in applying the ideas presented in the professional development.

Implications for Teachers, Professional Developers, and Policy Makers

Karen's case clarifies several points about professional development:

- * No single professional development experience is sufficient to produce change in a teacher's understanding or a teacher's practice. For this reason, teachers need a variety of professional development experiences to support them in their progress toward reform-based science teaching.

- * The effectiveness of professional development experiences will vary as a result of a teacher's emotional readiness to learn from such an experience. For optimal learning to occur, teachers must believe that they can teach well and yet be unsatisfied with some aspect of their teaching. As a result, not all teachers will learn to the same degree as a result of a professional development experience. Forcing teachers to participate in unwanted professional development experiences may not be an effective use of limited time and resources. Instead, teachers need support to engage in experiences they recognize as potentially useful.
- * The effectiveness of a professional development experience will depend on the cognitive readiness of the teacher to learn from the experience. Professional developers and policy makers must carefully consider the optimal sequencing of experiences to impact teachers' learning.
- * Finally, reform-based teaching practices take a great deal of time and effort. There are no quick fixes. As Karen reminds us:

Teachers have to have time to digest these ideas, to think about them. You can't just read an article, then produce some new [instructional] product. You have to think about your teaching, your students, and all that takes time.

Recommended Resources

Abrams, E., S. A. Southerland, and C. Evans. 2008. An introduction to inquiry. In *Inquiry in the classroom: Realities and opportunities*, eds. E. Abrams, S. A. Southerland, and P. Silva, pp. i–xiii. Greenwich, CT: Information Age Publishing. Discusses the various forms inquiry can take in the science classroom and provides teachers with a way of thinking about the form of inquiry that may be most appropriate for their particular classrooms.

Hammrich, P. L., and K. K. Blouch. 1998. A cooperative controversy lesson designed to reveal students' conceptions of the "nature of science." *American Biology Teacher* 60 (1): 50–51. Looks at "cooperative controversy," an instructional strategy that examines students' conceptions of the nature of science by presenting situations in which one person's ideas, information, conclusions, theories, or opinions are incompatible with those of another.

Horner, J. K., and P. Rubba. 1978. The myth of absolute truth. *Science Teacher* 45 (1): 29–30. Discusses the nature of science and addresses the question of why scientific knowledge cannot be absolute.

Loucks-Horsley, S., N. Love, K. Stiles, S. Mundry, and P. Hewson. 2003. Designing professional development for teachers of science and mathematics. 2nd ed. Thousand Oaks, CA: Corwin Press. Discusses the important interaction of content, context, and design needed for effective mathematics and science teacher professional development.

McComas, W. F. 1996. Ten myths of science: Reexamining what we think we know. *School Science and Mathematics* 96 (1): 10–16. Describes students' and teachers' common misconceptions regarding the nature of science.

Michaels, E., and R. L. Bell. 2003. The nature of science and perceptual frameworks. *The Science Teacher* 70 (8): 36–39. Provides an analysis of the tentative nature of science and portrays science as a dynamic and human endeavor. Includes a discussion about how such topics can be addressed in the classroom.

Nott, M., and J. Wellington. 1995. Critical incidents in the science classroom and the nature of science. *School Science Review* 76 (276): 41–46. Provides examples of critical incidents that can promote discussion and reflection on the nature of science. Discusses teachers' views on critical evaluation of practical work, reliability, and replicability of experiments, accepted scientific explanations, scientific evidence, religious beliefs, and moral dilemmas.

Smith, M. U., and L. C. Scharmann. 1998. Defining versus describing the nature of science: A pragmatic analysis for classroom teachers and science educators. *Science Education* 83 (4): 493–509. Provides a useful discussion of the central components of the nature of science as well as practical advice for how these ideas can be addressed in a classroom.