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Gayle A. Buck
Valarie L. Akerson *Editors*

Enhancing Professional Knowledge of Pre-Service Science Teacher Education by Self-Study Research

Turning a Critical Eye on Our Practice

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Editors
Gayle A. Buck
Department of Curriculum and Instruction
Indiana University
Bloomington, IN, USA

Valarie L. Akerson
Department of Curriculum and Instruction
Indiana University
Bloomington, IN, USA

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Foreword

Building on Findings from Self-Studies in Science Education

The editors of this volume have sought to bring together a range of authors interested in pursuing the development of science education through self-study. As is clear, the chapter authors come with a varied range in experience of self-study methodology. That is a good thing as it offers access to ideas, opportunities and experiences from different starting points, thus enhancing the volume's value in terms of speaking to science educators at various points in their career and with different concerns and interests in science teacher education.

From the outset, self-study has been alluring to teacher educators because of its serious focus on teaching and learning about teaching, especially so from the privileged position of the teacher of teachers. That which Whitehead (1993) termed as being a 'living contradiction' was a notion that rang true with teacher educators as they recognized the importance of 'walking the talk' or 'practising what you preach' as a non-negotiable in seeking quality in teacher education practices. As a consequence, self-study blossomed as a methodology as teacher educators recognized the value of ensuring that their teaching was explicitly informed by their research, thus drawing serious attention to the notion of a pedagogy of teacher education.

At one level, the personal nature of self-study is important to teacher educators as a way of gathering evidence about the nature of their practice and how it influences the learning of their students of teaching. At another level, self-study must also speak beyond the individual and offer ideas, opportunities, innovation and critique if it is to lead to the creation of new knowledge – a defining feature of scholarship in the academy. Extending the work of Bullock and Russell (2012), this volume highlights yet again that science educators often stand out as early adopters in working with new ideas, readily accepting the challenge of sharing their 'experiments' with teaching and learning in the public domain. This volume is of particular note as the studies documented here extend well beyond researchers in the existing self-study community; further supporting the point that science educators take seriously the search for evidence and the value of creativity and challenge as fundamental shaping factors in their practice.

A crucial aspect of self-study research is the place of disconfirming data and the importance of challenging one's existing perspective. In the first instance, the nature of evidence sought needs to be such that it is convincing to the researcher, but at another level, collaboration and the support of critical friends (Schuck & Russell, 2005) matters for offering alternative perspectives on situations. In fact, a major aspect of quality in self-study hinges on the ability to frame and reframe (Schön, 1983) and to be able to illustrate that in meaningful ways in the report of the research itself. As the chapters in this volume illustrate, the value of seeing beyond the 'self' and embracing the challenge of alternative perspectives is strong and clear. As a consequence, the self-studies documented in this book demonstrate a diversity of ways in which self-study methodology has been adopted, adapted and applied to a variety of situations. As a consequence, the type of 'problems' under investigation open up new avenues for better understanding teaching and learning in science education.

It has been well noted in the literature on educational change that 'change begins with teachers'. As the authors in this volume make clear, they are at the forefront of change in their practice, for their programmes and with their students of teaching. Importantly, although not always specifically stated as so, the chapters also demonstrate how 'experience precedes understanding' and that through conducting a self-study project, outcomes that are not always expected emerge and positively shape understandings of science teaching and learning. In so doing, a sense of momentum is created that encourages one to take that learning further and to actively pursue self-study research in order to build on outcomes and become more informed about practice.

The concern for quality in science teaching and learning lies at the heart of this volume, and the studies documented herein offer insights into the range and nature of issues that influence how each of the authors is working to enhance teacher education. It could well be argued that in researching someone else's practice, programme or pedagogic efforts that the results – valid as they may be – do not necessarily lead to change. For example, like many others, Nuthall (2004) drew attention to the fact that, 'Compelling evidence indicates a continuing gap between research on effective teaching and the practice of teaching' (p. 274). However, through self-study, it is self-evident that the resultant learning will immediately impact practice – it is an expectation not a hope. In their self-studies, the science teacher educators who have contributed here have purposefully created for themselves a situation in which they have been confronted by the pedagogic experiences they have sought to create. It is therefore very difficult to walk away from the results and not do something about that which has been learnt.

As you read the chapters in this book, I trust you will be engaged with the work in ways that create questions, issues and ideas that help to push the boundaries of your own practice. Good self-studies resonate with others in ways that create an impetus for further inquiry. The outcomes should be such that there is knowledge production and that self-study goes beyond story (Loughran, 2010). If that is the case, then the profession is enhanced as the teacher education community comes to see new ways of thinking, acting and researching. In the end, that is what matters most in the pursuit of quality in science teaching and learning. It is not too much to expect that science teacher educators should be at the forefront of that work. This book is one example of how those efforts can be created, shared, critiqued and built upon. In so doing, the book creates an invitation to learn from, and act upon, the work that has been presented. I trust that for science educators generally that invitation is sufficiently enticing to be accepted.

Monash University
Melbourne, Australia
John Loughran

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Contents

Part I
Introduction: Self-Studies and Science Education

Chapter 1
Garnering the Experiences and Understandings Emerging from Self-Studies in Science Teacher Education

Gayle A. Buck, Valarie L. Akerson, and Brent Gilles

As scholars within the field of science teacher education, we understand the importance of seeking integrity between our theoretical notions of teaching and our own teaching practices. For us, self-study offers this integrity by enabling us to systematically explore our theories and practice in a reflexive manner. Although we have witnessed an increase of individuals conducting self-study research, we believe that its potential is not yet reached because, although professional knowledge is being explored by individuals within our community, the experiences and resulting understandings are not being collectively reflected upon and discussed by our professional community. Thus, the purpose of this book is to reflect upon the multiple experiences, as well as the gained knowledge about the theory and practice of science teacher education, gained through the process of self-study. The book is built on the premise that self-study research is resulting in valuable understandings that, if cultivated, will enhance the professional communities' knowledge of pre-service science teacher education. To that end, the overall goal is to garner the understandings from individual self-studies in a manner that allows us to (1) foster meaningful discussions on the complexities inherent in science teacher education and how we, as a professional community, are understanding and confronting those complexities, (2) encourage the constructing and reconstructing of our identities as science teacher educators, and (3) provide understanding, encouragement and support for science teacher educators as they question, refine and advance professional knowledge. We seek to attain these goals by situating the self-studies in this book within the professional field, reflecting on the collective experiences, and discussing the future directions that emerge from the discussion.

Although self-study as a research methodology is necessarily defined and supported throughout the book, the primary focus of the discussions is on the

G.A. Buck, Ph.D. (✉) • V.L. Akerson, Ph.D. • B. Gilles
Department of Curriculum and Instruction, Indiana University, Bloomington, IN, USA
e-mail: gabuck@indiana.edu; vakerson@indiana.edu; bgilles@umail.iu.edu

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professional knowledge that is derived from this work. We begin the discussion with this first chapter that introduces our working definition of self-study research, provides a brief overview of contemporary self-study practices in our field and introduces the self-studies in this book.

Self-Study

We are defining self-study in science teacher education as rigorous, critical inquiry in which we – science teacher educators – research our theoretical notions of teaching and how they are formed/informed by our own teaching experiences within the academy. The critical component for us, given the goals of this book, is the centering the science teacher educator and/or their teaching experiences in the research process (i.e., data collection, analysis and implications). This allows us to focus on evidence-based understandings of professional knowledge. We further elaborate on this methodological underpinning below.

Zeichner (2001) describes the five major traditions of educational action research. These are the action research traditions in the USA, the teacher-as-researcher movement in the UK, the North American teacher research movement, participatory action research in Australia, and the tradition of self-study research. Of these five traditions, self-study research has been characterized as "probably the most significant development ever in the field of teacher education research" (Zeichner, 1999, p. 8). Many authors have given different definitions for this approach. Russell (1998) describes self-study as learning from experience embedded within the teachers' process of creating new experiences for themselves and those whom they teach (p. 6). Loughran and Northfield (1998) define self-study as recognizing that the dissonance between beliefs and practice. Richardson (1994) defines self-study as a participant study of experience. It is also described as a practical inquiry that may help in improving practice (pp. 7–8). One common thread throughout all of these definitions is studying or voicing one's own teaching experience in order to express or know oneself and one's field of practice better. It is within this self-study tradition that we, science teacher educators, explore our own theory/practice relationship within the academy.

Of course, this approach to research is not new in the field of teacher education. Teacher inquiry is as old as teaching itself (Clark & Erickson, 2006). Philosophers such as Dewey (1938), Gadamer (1964), and Freire (1985) discussed the theoretical notions underlying this approach. Under the technical rationality that dominated much of the education practices of the twentieth century, however, self-study research was denied status in the academy and excluded from merit/promotion considerations (Clandinin & Connelly, 2000). Despite this apparent lack of status, many of us have persisted in researching our own teaching. Dias, Eick, and Brantley-Dias (2011), for example, found that a university professor of science education could learn much about preparing middle level science teachers from teaching inquiry science in a middle school classroom. Garbett (2011) challenged practical understandings about fostering meaningful conversations about learning to teach. Moscovici (2007) explored the power relationships in science methods courses. Trumbull (2012) explored her own understandings as she followed one of her students during her time in her class and again in her third year of teaching. We utilized the work of these scholars, and many others, to provide an overview of current self-study practices in pre-service science teacher education in this first chapter. This work showcases the challenges inherent in our teaching practice and ultimately advanced our understandings about the preparation of science teachers and teacher educators.

A Cumulative Look at Contemporary Self-Study Practices in Science Teacher Education

The number of publications in which science teacher educators explicitly categorize the inquiries as self-study is growing; albeit still a small percentage of the overall research publications (see Chap. 2). The research that science teacher educators produce that fits the definition of a self-study research approach, however, is larger. The methodological approach of this work is sometimes categorized as action research, qualitative, case study, etc. We contend that many of us are by nature focused on our teaching practices in the academy and that a wealth of knowledge about our teaching practice is inherent in our publications. In our effort to situate the discussion within this book in the professional field, we needed to capture work in this area. To that end, we identified and reviewed all of the science teacher education research publications that are labeled as self-study. From there, we eliminated some that do not fit our definition (as noted above). As a result, some research that the authors defined as self-study is not included in this brief overview of contemporary self-study practices for that research did not match our definition. Most notably, do not center the teacher educators' theoretical notions or practices within data collection and analysis. In addition, some studies that are not defined as self-study research (e.g., identified as action research, qualitative, phenomenology) are included. Because of the complexity of the latter, we structured the discussion by selecting a sampling of published work that fits our definition of self-study research. We acknowledge that there are many valuable studies that meet our definition that were not included in this sample.

As we are science teacher educators and authors for self-study chapters in this book, as well as for several of the published self-studies in our sample, we continue to write in first person throughout this chapter. Thus, 'we' refers to science teacher educators that are actively exploring our theoretical notions of teaching and teaching practices through the use of self-study research. When the work of specific science teacher educators, including ourselves, is discussed, proper names are used.

A Look at What We Are Exploring

This review of self-study research in science teacher preparation revealed that we are actively and systematically exploring: reform-based notions in science teacher education, underlying assumptions inherent in the preparation of teachers and our own identities as science teacher educators. These are elaborated on below.

Specific Theoretical Notions in Science Education

Science education is continuously evolving as it responds to new instructional technologies, understandings of student learning, increasing diversity and societal changes (to name a few). As science teacher educators, we often find ourselves preparing students to teach concepts or use pedagogical strategies that weren't a reality when we were teachers in the public schools (e.g., Akerson, Pongsanon, Weiland, & Nargund-Joshi, 2014; Buck, Trauth-Nare, & Kaftan, 2010; Capobianco, 2007; Dias et al., 2011; Goodnough, 2006; Krajewski & Schwartz, 2014). To maintain and enhance the relevancy and credibility of our teaching practices, some of us have returned to K-12 classrooms to actively explore our theoretical notions in action. For example, Valarie Akerson (Akerson et al., 2014) often emphasized the nature of science when she worked with preservice teachers. Nature of science is an integral part of current reform efforts (e.g., Achieve, Inc, 2013; National Research Council, 2012). This teaching notion was not discussed, however, when she was a classroom teacher. Later, as a science teacher educator, she believed that her former elementary students and the future students of her preservice teachers could conceptualize many of the nature of science aspects after appropriate instruction. To explore this belief, she returned to the elementary classroom and completed a self-study on her changing understandings of what it meant to be an elementary teacher of the nature of science. Similarly, Charles Eick (Dias et al., 2011) returned to the middle level classroom after more than 10 years in the professoriate. He returned to explore his own notions of inquiry teaching methods, something he emphasized in his own courses for preservice teachers. Like the nature of science, inquiry is also an integral part of current reform efforts (Achieve, 2013; NRC, 2012). Charles sought to explore his notions of this pedagogical approach by entering into a feedback loop between his beliefs about and experience with inquiry teaching methods.

Others among us have explored these or other reform-based notions in our own courses at the academy (e.g., Buck et al., 2010; Capobianco, 2007; Krajewski & Schwartz, 2014). Sarah Krajewski (Krajewski & Schwartz, 2014) explored her notions of the nature of science while implementing it into her science course at the community college. She believed that she had developed a solid understanding of the nature of science in her graduate program, but she had not taught it. When she first attempted to integrate it into her teaching, she found it difficult and awkward. To that end, she entered into a feedback loop between what the learning about the nature of science and her teaching practices in her own course. Others have completed self-studies on their reform-based teaching notions within methods courses at the academy. It is within these courses that finding the integrity between our theoretical notions of teaching and our own teaching practices is most critical as we set out to model the type of teaching we are advocating. For example, Gayle Buck (Buck et al., 2010) explored her reconceptualization efforts in preparing teachers to guide the inquiry process with formative assessment. Noting that classroom assessment is a necessary component of the inquiry teaching and learning process (Black & Wiliam, 1998; Gitomer & Duschl, 1998), she set out to systematically and collaboratively confront the complexities inherent in modeling this process within her methods course. Similarly, Karen Goodnough (2006) focused her self-study inquiry on problem-based learning. Although the origins of problem-based learning can be traced as far back as the mid-1900s (and arguably prior to that time), the constructivist nature of many reform-based initiatives have highlighted the importance of this pedagogical strategy in contemporary science education. Thus, she systematically explored her pedagogical understanding of this approach within her methods course. Brenda Capobianco (2007) also completed a self-study in a methods course. She explored her integration of instructional technology into a science methods course. Noting her own limited experience with and knowledge of technology, she explored how her use of technology in a methods course operated as a catalyst for learning about inquiry-based science teaching.

Overall, we are utilizing self-study methodological approaches to enhance our understandings and practices related to reform-based notions in science teaching and learning; notions such as inquiry, nature of science, formative assessment and technology. These teaching notions were not emphasized when we were students and teachers in the classrooms we are preparing our preservice students to enter. Thus, we are exploring and challenging our understandings of contemporary science education in public school classrooms and our own classrooms at the postsecondary level.

Underlying Assumptions Inherent in Teacher Preparation

It is not just the new notions of teaching and learning that we are exploring, but also the underlying assumptions about preparing people to teach (e.g., Aubusson, Griffin, & Steele, 2010; Faikhamta & Clarke, 2013; Freese, 2006; Garbett & Ovens, 2012; Keast & Cooper, 2012; Rice & Roychoudhury, 2003; Trumbull, 2012). Chatree Faikhamta (Faikhamta & Clarke, 2013) studied her practices associated with a science methods course at a university in Thailand. She questioned the goals of the course, the content associated with these goals, how she encouraged the preservice teachers to reach those goals and how she assessed whether they did reach them. Her self-study focused on her own understandings, questions, curiosities and practices related to pedagogical content knowledge for teaching science student teachers. Others focused on particular assumptions within their teaching practice. Stephen Keast and Rebecca Cooper (2012) explored whether or not the preservice teachers were recognizing the value of science inherent in their methods course. Dawn Garbett (Garbett & Ovens, 2012) explored her notions of peer teaching in her science methods course alongside her colleague, Alan Ovens, who studied his notions of peer teaching in his physical education program. Diana Rice (Rice & Roychoudhury, 2003), believing that elementary teachers generally lack self-confidence when it comes to teaching science, conducted a self-study to determine if her methods course fostered her students' self-confidence in regards to teaching science.

The teacher educators noted above studied the impact of a particular methods course. Others have studied the impact of a teacher preparation program (e.g., Aubusson et al., 2010; Freese, 2006; Trumbull, 2012). These inquiries are much broader in scope than one specific course. For example, Anne Freese (2006) explored understandings of fostering the development of her student's science teacher identity. She challenged her own understandings and practices by completing a collaborative self-study with a student that was struggling in her teacher education program. Freese intertwined her own understandings and practices in teacher preparation with her student's struggles, focusing specifically on his time in the teacher preparation program. Similarly, Deborah Trumbull (2012) studied one of her own students through the teacher preparation program in order to explore how she understood biology content and teaching and her development of teacher identity. Unlike Freese, however, Trumbull did not select a struggling student and also focused on her student's third year of classroom teaching. She used a constant comparative approach to analyzing the student's experiences alongside program and classroom expectations/opportunities. Aubusson et al. (2010) also explored the impact of their two-semester end-on program for students that already held at least a bachelor's degree in science. They specifically focused on the aspects of their program designed to foster the preservice teachers' reflective practices.

In sum, we are actively questioning the assumptions inherent in preparing others to teach. The foci of the studies range from one specific topic in one course to a broad understanding of students' experiences in a teacher education program. This research tends to be much more focused on student outcomes than the self-studies that fall into our other categories, but the underlying assumptions that are inherent in the design of teacher education courses or programs are evident throughout the inquiries.

Identity of a Science Teacher Educator

Whether new members enter our professional field from a K-12 classroom or the science laboratory, they often find themselves questioning the differences in this new role from the one they previously held (e.g., Beeman-Cadwallader, Buck, & Trauth-Nare, 2014; Garbett, 2012; Santau, 2012; Wiebke & Park Rogers, 2014). Unfortunately, the complexities of teaching in science education at the academy, and how it differs from their previous educational experiences, is too often left for them to work out for themselves (Feinman-Nemser, 2001). Interestingly, many of them are applying their newly gained research skills, an emphasis in many of our doctoral programs, to help them address the challenges inherent in this new teaching role. As a result, the self-study process is being increasingly used to explore the process of transitioning into a science teacher educator. For example, Heidi Wiebke (Wiebke & Park Rogers, 2014) and Dawn Garbett (Garbett, 2012) explored their new roles as science teacher educators and how they differed from the ones they held as classroom teachers. Alexandra Santau (2012) also explored how her new identity as a science teacher educator differed from her previous role. She, however, was not transitioning from the science classroom, but from the science laboratory. Her self-study focused on the tensions of what she was prepared for in her doctoral program and realities of her new academic appointment.

Of course, professional identity is fluid and we often transform our identity as we act to change structures in order to achieve our goals (Wells, 2004). To that end, self-study is not only being utilized by new science teacher educators, but more experience educators are also actively seeking to transform their professional identity. For example, Sandra Abell (2000) explored her professional identity as a collaborator with classroom teachers. She returned to a classroom to co-teach with the teacher, Beth. She shared the classroom teaching responsibilities three to five afternoons a week – positioning herself as a collaborator and not someone coming in to model the correct way to teach. Similarly, Valarie Akerson (Akerson et al., 2014) explored her identity as a teacher of the nature of science when she returned to the classroom. During her one semester in a third-grade classroom, she not only enhanced her own understanding of this notion, but questioned what it meant to be a teacher that incorporated it into the daily aspects of teaching and learning in the elementary school. Hedy Moscovici (2007), also an experienced science teacher educator, remained at the academy as she studied her identity within her secondary science methods classroom over the course of ten semesters. She explored her identity in terms of the dynamics of power. The teacher educators noted above explored their own professional identities as educators of science teachers. In contrast, Johaira Lara (Siry & Lara, 2012) studied her professional identity as one of the students that was transitioning into the role of a science teacher. Her collaborative self-study not only allowed her to voice her own transition, but also enhanced the understanding of an experienced science teacher educator in terms of fostering such an identity transformation for her teacher education students.

Overall, we are exploring our notions of professional identity. Several of us entering the field for the first time are exploring the identity of a science teacher educator while others, with more experience in the field, are seeking to transform our identities.

A Look at What We Are Finding

The review of self-study research in science teacher preparation revealed that our systematic explorations are informing our professional knowledge. Although the individual studies resulted in understandings unique to particular notions and contexts, a cumulative review of the set of findings reveal/support our understandings within the professional field. These insights, explored by the categories outlined above, are elaborated on below.

Specific Theoretical Notions in Science Education

As we explore the theoretical notions influencing our teacher preparation practices, we are becoming increasingly aware of the complexities that emerge when the reform-based ideology we introduce to preservice teachers is put into practice in real classrooms. Such findings have emerged in most of the self-studies found in this category. Valarie Akerson (Akerson et al., 2014) found herself confronting contextual factors such as administrative support, elementary student influences, and time when she explored her notion of the role of the nature of science in an elementary classroom. She noted that these contextual factors, totaling 28 instances, were the most influential in terms being a teacher of the nature of science (p. 13). Likewise, Charles Eick (Dias et al., 2011) also confronted student influences, time and additional demands of middle level teachers as he implemented an inquiry-based curriculum. The real-world dilemmas of practice he faced, as well as his overall school-based experiences, transformed his understandings of preparing teachers to implement an inquiry-based curriculum. Such complexity is also encountered when we explore specific theoretical notions of teaching in university classrooms. When Sarah Krajewski (Krajewski & Schwartz, 2014) explored her efforts in becoming a teacher of the nature of science in her college science classroom, she found herself addressing the need to do so while maintaining her attention to the biological concepts that needed to be addressed; as well as her own anxiety associated with accomplishing such a task. The understandings she developed over the course of the self-study did not result in a new notion of the nature of science, but a new notion of how to support teachers as they confront the complex realities of incorporating the nature of science into their existing science curricula. These are just three examples of how the complexities inherent in actual classrooms greatly influence the reform-based notions of our field. Such a relationship was found across multiple studies. Overall, our contemporary self-study experiences in science teacher preparation are reinforcing the fact that exploring reform-based notions in the context of real classrooms is absolutely necessary in order to fully understand them.

The complexities that emerged as teacher educators implemented reform-based notions in actual classrooms has often lead to a more modest approach to incorporating these notions into practice. For example, after confronting the complexities inherent in incorporating problem-based teaching and learning into her classroom, Karen Goodnough (2006) planned to begin with one small problem. Similarly, Sarah Krajewski (Krajewski & Schwartz, 2014) came to recognize the value of finding successes in incorporating a few aspects of the nature of science, gaining confidence and ultimately allowing for the time to discover the teachable moments as she went. Following her self-study on formative assessment, Gayle Buck (Buck et al., 2010) planned to start with smaller case-studies in the methods classroom prior to having her students utilize formative assessment in classrooms. These initial steps were developed as a result of changes to our notions of the contemporary topics emerging in our professional practice of science teacher education.

As we pull at various notions of teaching, we find them connected to many others. Often, as we explore specific teacher preparation practices, the underlying foundation of our ideas of teaching and learning are being challenged. Brenda Capobianco's self-study on integrating instructional technology into a science methods course resulted in a more reflective and collaborative relationship overall with the students in that course. As she modeled how she was making meaning of inquiry-based teaching through technology, she encouraged her students to do the same. In the process, she discovered this approach revealed the internal dilemmas her students were facing in regards to teaching science. As they were increasingly able to respond to each other's concerns, everyone became much more student focused and reflective. Valarie Akerson's self-study (Akerson et al., 2014) also resulted in a greater level of student focused. In her case, she became much more focused on the elementary students her future teachers would encounter. Charles Eick (Dias et al., 2011) shifted his beliefs away from the Piagetian structuralism espoused in prescribed curriculum toward a more culturally responsive, student-driven approach. Sarah Krajewski (Krajewski & Schwartz, 2014) shifted her teaching orientation to reflect science as a process as opposed to emphasizing the products of science.

Overall, our collective self-study research is revealing new aspects of our reform-based notions of teaching and learning. These aspects emerge from the authentic complexity we encounter as we actively seek a sense of integrity between these theoretical notions and our actual teaching practice. Self-study is not only about personal reflection and growth, but it is critical in the development of the professional field's theoretical notions of these reform-based notions. In regards to teaching practices, the authentic complexity we are finding in these theoretical notions is resulting in improvements in our practice of science teacher education and substantial challenges to the underlying foundations inherent in this practice.

Underlying Assumptions Inherent in Teacher Preparation

We are using self-study research to explore, critique and ultimately enhance our understandings of the pedagogy of science teacher education. The individual self-studies are very specific to the particular course or program. As a result, the findings cannot be generalized. The resulting conversation, however, on the professional experiences and understandings that were derived from studying our own teacher education efforts benefits the entire professional community. In regards to teaching in science methods courses, the conversations often turn to the value of making the reasoning aspects of teaching visible to preservice teachers. For Dawn Garbett (2011) this meant realizing that she had to move away from modeling an expert science teacher and become an instructor that fosters her students' engagement in conversations about the teaching and learning processes occurring in her classroom. She realized that such conversations sometime occur as the result of unsuccessful teaching experiences. Subsequently, she and a colleague (Garbett & Ovens, 2012) ultimately explored how to foster such professional conversations in their respective methods courses. This follow-up self-study explored their roles in regards to supporting teachers in conducting, hearing and responding to professional critiques and adjusting accordingly. Stephen Keast and Rebecca Cooper (Keast & Cooper, 2012) sought to identify the tacit ideas behind their teaching processes and determine if the preservice teachers were realizing those understandings. Ultimately, they realized that the open discussions that were fostered by the self-study process itself were models of the type of teaching process they sought to convey. By discussing their pedagogical decisions in the methods course, they realized they were modeling the type of discussions that they felt were so important for teachers to experience.

In regards to teacher preparation programs, we found that the conversations often include the programs' roles in addressing student resistance to putting the theoretical notions of high quality teaching into practice. In is within the larger structure and longer timeframe of these programmatic studies that we are able to understand how our efforts ultimately influence, or do not influence, the preservice teachers' practices. For Deborah Trumbull (2012), this meant determining the teacher preparation program's role in addressing the preservice teachers' resistance to addressing educational policies such as those related to standardize testing. Preservice teachers may come to view such policies as insurmountable barriers to quality teaching. Trumbull questioned the teacher preparation program's role in preparing students to understand such policies and being able to work through dilemmas that arise as a result. Anne Freese (2006) also found such resistance to be an issue in her teacher preparation program. Her study allowed her to see the fears, peer pressure, ego and attitudes that her preservice teachers experienced as they transitioned into the classrooms. Such things can impede the preservice teacher's ability to learn and are often used to rationalize lower quality teaching. Similarly, Aubusson et al. (2010) found that their preservice teachers were reluctant to reflect despite the instructors' modeling efforts. Their findings add to the conversation in this area, however, as they found that the level of resistance lessoned as the amount of actual classroom experience increased, as well as after the preservice teachers were exposed to good examples of reflection that were developed by their peers.

Overall, we are coming to understand the value of making the implicit reasoning processes of teaching more explicit to the students in our courses. Often, this understanding is realized as we engage our students in the self-study process. In other words, self-study is increasingly viewed as a high quality teaching practice. We are also coming to develop a more thorough understanding of how, and why, our students eventually resist putting the theoretical notions inherent in high quality teaching that are emphasized in our teacher education programs into practice. This enhances the discussion of the types of support that may be necessary once our students leave the program.

Identity of a Science Teacher Educator

Whether they are entering our professional field from a public school classroom or a science laboratory, new teachers educators are demonstrating that there are tensions and uncertainties inherent in the process becoming a science teacher educator (Garbett, 2012; Santau, 2012; Wiebke & Park Rogers 2014) and traditional graduate school experiences are not preparing them for this transformation (Santau, 2012; Wiebke & Park Rogers 2014). For example, Wiebke (Wiebke & Park Rogers 2014) noted that although she believed that a teacher educator is one that allows the preservice teachers the opportunity to work through the process of teaching, she found herself telling the preservice teachers in her class the right way to teach. Upon exploration, she realized that this occurred when she encountered a lack of confidence in her own ability to handle difficult situations that emerged in the practice of preparing elementary science teachers for fear of losing her credibility with students. She noted that although she observed an experienced teacher educator before she taught, she came to realize that she did not understand the how and why of her teaching decisions. When she encountered such uncertainties, she would take on the identity of the expert and tell her students. Alexandra Santau (2012) also realized that although her doctoral preparation prepared her for many aspects of her new role as a science teacher educator, it did not assure she left with the necessary preparation for teaching future teachers. She ultimately discovered that self-study provided her vehicle for such preparation, but stresses that more attention should be paid to guiding future science teacher educators toward awareness of their future role. These new teacher educators allow us to see that being a successful science teacher or scientist does not mean one automatically becomes a successful science teacher educator. Their efforts force us to confront the traditional structure of most of our graduate programs. A structure focused exclusively on research while neglecting other aspects of a science teacher educator, namely teacher of preservice teachers.

The uncertainty and tensions inherent in the identity of a science teacher educator are not only evident in the self-studies of new teacher educators, but also in the experienced members of the profession. Sandra Abell (2000) shared the tensions and uncertainties she experienced as she explored her identity of a collaborator with classroom teachers. She found that she had to learn how to intermingle her role as researcher and teacher, confront an unwanted authority status given to her, and confront her own sense of self-consciousness about her role in a new environment. Hedy Moscovici (2007) sought to become a transformative intellectual by exploring the power dynamics in her second science methods course. This was sparked by a discrepancy between what she and her students perceived to be her identity as a science teacher educator. She found that this discrepancy often resulted in misinterpretations of her actions. Both of these experienced teacher educators found themselves confronting identities that were given to them by others (e.g., collaborators and students). Coming to understand the differences in their perceived identities ultimately lead to a different understanding and practical shift in their power relationships. The resulting power shifts positively influenced classroom dynamics.

In sum, we are coming to better understand and define the identity of a science teacher educator. For new teacher educators, this understanding is ultimately realized through the self-study process, but points to inherent weaknesses in how our professional field prepares people for this role. They also came to a similar realization as the more experienced teacher educators. They needed to explore their power relationships with their students and collaborators and make necessary changes in order to assure such relationships are beneficial to all members in that relationship.

An Introduction to the Self-Studies in the Book

The 15 self-studies provided in this book support and extend this contemporary work in science teacher education. They, and the subsequent reflections on professional knowledge, are organized into four sections: content courses for preservice teachers, elementary methods courses, secondary methods courses, and preparation of future teacher educators. Thus, the studies are introduced within these categories below. A culminating reflection of the findings of these studies is provided at the end of the book.

Content Courses for Preservice Teachers

The four self-studies of this section explore theoretical notions of science teaching or underlying assumptions inherent in teaching content courses for preservice teachers. Amy Trauth-Nare (Trauth-Nare, Buck, & Beeman-Cadwaller) and Brent Gilles (Gilles & Buck) explored specific theoretical notions that were a part of their science content courses for elementary preservice teachers. Amy Trauth-Nare, Gayle Buck and Nicole Beeman-Cadwallader's chapter "Promoting Preservice Teachers' Agency in Scientific Inquiry: A Self-Study of Relational Pedagogical Practices in Science Teacher Education" focuses on Amy's personal assumptions about relational pedagogy. Noting that relational pedagogy may serve to confront the constraining regularities of a normative, homogenized science curriculum (Smith, 2007), Amy and her co-authors explored efforts to enact relational pedagogy in ways that engage students in meaningful discourse with scientific inquiry in order to help them to make sense of science concepts and phenomena in a one-semester science content course. This study illuminates the work of teacher educators seeking to foster engaging, emancipatory, and equitable methods of teacher preparation. The description of their efforts allows the reader to further understand relational pedagogy as a difficult, yet viable teaching notion. Also exploring notions of teaching preservice teachers in a content course was Brent Gilles and Gayle Buck. In light of their understanding that enthusiasm has a powerful impact on student learning (Kunter et al., 2013), but it is among the least understood attributes of effective science teaching (Schutz & Pekrun, 2007), they designed a self-study focused on the ways in which Brent demonstrated enthusiasm in his content course and how the preservice teachers taking that course responded to this attribute. In their chapter, "Exploring our Theoretical and Practical Understanding of Enthusiasm in Science Teaching: A self-study of elementary teacher preparation", they provide findings that further confirm that the pedagogical notions science teacher educators promote as integral to high quality teaching are much more complex when they are put into practice. The findings raise questions about many taken-for-granted assumptions about the role of an instructor's enthusiasm for science and science education.

The other two studies in this section focused on science teacher educators' underlying assumptions about teacher preparation. Eunice Nyamupangedengu explores her efforts to teach specific content to her secondary preservice teachers while modeling the teaching pedagogy they will be expected to use. In her chapter, "Using Self-Study to Learn to Teach Genetics for Understanding and for Teaching in Pre-Service Teacher Preparation", she points out that although research has addressed the importance of focusing on both content and how the content is taught in methodology courses, it has not addressed the importance of the teaching of the content courses. To that end, she explored her use of a modeling teaching approach (LaBoskey, 2004; Loughran, 2006) within a biology content course for future secondary teachers. In her chapter, she describes the aspects of her teaching that fostered a greater understanding of both content and pedagogy. She also shares her insight into the need to explore and discuss the preservice teachers various identities and how these influence how they viewed the classroom experiences. In the other chapter in this section, "Using Self-Study to Evaluate a Pedagogical Approach for Navigating Tensions in a Science Content Course for Preservice Teachers", Sarah Fuentes and Mark Bloom describe how they explored tensions in Mark's teaching that emerged when he realized the preservice elementary teachers' understanding of quality work differed from his own. Over the course of one semester, he used multiple data sources to evaluate his practice, seek out assumptions, and manage the conflict. Ultimately, Mark explores how he can help his students move from thinking like a student to thinking like a teacher. Throughout, the reader comes to understand the value in using reflection activities to investigate and address such conflicts in a manner that fostered a greater understanding between the teacher and students, as well as about the teaching process.

Elementary Science Methods Courses

The four studies in this section address theoretical notions and practices in teaching methods courses to preservice elementary teachers. The researchers involved in two of the studies each focused on a single methods course, while the other researchers took a more longitudinal approach that included multiple sections of elementary methods courses over several years. One of the single course studies explored a specific theoretical notion in science education, engineering design, while the other focused on exploring underlying assumptions inherent in teacher preparation through the exploration of science teacher educator identity. Brenda Capobianco explored her understanding and practices associated with integrating engineering design into one section of a traditional science methods course. Such integration is recommended by recent reform documents (e.g., NGSS Lead States, 2014), however, most science educators do not know what engineering entails or the pedagogical implications of this recommendation. To explore this specific theoretical notion, Brenda conducted a self-study on her efforts. In her chapter, "Uncertainties of Learning to Teach Elementary Science Methods Using Engineering Design: A Science Teacher Educator's Self-Study", she shares not only her experience, but also her self-doubts and uncertainties about this teaching notion. In addition, she reveals how she came to appreciate the value of exploring uncertainty in teaching, as well as risk-taking. In the second chapter focused on exploring single courses, "How Science Teacher Educators of Color Conceptualize and Operationalize their Pedagogy in Science Methods Courses", Karthigeyan Subramania, Sumreen Asim, Eun Young Lee and Kia Rideaux describe how they, science teacher educators of color, came to conceptualize and operationalize their pedagogy in their own elementary and early childhood science methods courses over the course of one semester. In this chapter, they provide predominantly White teacher education faculty insights into how they respond to the complex demands of dealing with preservice teachers' predetermined notions about science teacher educators of color. These insights are gleamed through excerpts of their focus group discussion on the individual metaphors they wrote throughout the semester.

One of the longitudinal studies in this section focused on a specific theoretical notion in science education while the second focused on exploring underlying assumptions inherent in teacher preparation. Stephen Marble, Michael Kamen, Gilbert Naizer and Molly Weinburgh explored how they individually and collectively viewed and utilized Japanese Lesson Study. They understood this pedagogical approach showed great promise (Marble, 2006), but had little understanding of how it would work in their own classrooms. Their explorations began with the implementation of this practice in three elementary methods courses and ended with a reflection of how it influenced their practice over the subsequent 6 years. In their chapter, "Our Journey of Understanding through Lesson Study", they explain the ways in which they came to more fully understand and implement this pedagogical approach. Not only do they describe the impact of this reflective process on their understanding and use of Japanese Lesson Study; but they also describe how the process of systematically reflecting on this particular teaching notion impacted their underlying notions of teacher preparation. Elizabeth Davis also completed a longitudinal study, described as a "meta-self-study". Her chapter "Evolving Goals, Practices, and Identities as an Elementary Science Teacher Educator: Tensions and Trade-Offs" looks at her work as an instructor in an elementary methods course over the course of 17 years. Her study reveals how the field of science teacher education has changed. Noting the shifts in emphasis in science teacher preparation, she describes what she views as a growth in the field. In addition, she shares her own growth as she became better adept at articulating the teaching profession and specific instructional expectations. Throughout the chapter, her reflection is guided by an analysis of her own practices alongside the artifacts of her work.

Secondary Science Methods Courses

The three studies in this section address theoretical notions and practices in teaching methods courses to preservice secondary science teachers. In their chapter, "Experiences with Activities Developing Pre-service Science Teacher Data Literacy", G. Michael Bowen, Anthony Barley, Leo MacDonald and Ann Sherman describe how they explored specific inquiry-based activities that they utilized in their secondary science methods courses. Seeking experiences that allowed their preservice teachers to genuinely experience quality teaching in an environment where engagement and not controlling students is the focus (Korthagen, Loughran, & Russell, 2006), these science teacher educators incorporated these inquiry-based activities in their methods courses. They started with the belief that the three selected activities, generally focused on data literacy, modeled the type of instruction expected of preservice teaches while at the same time provided them with experiences of actually engaging in an inquiry environment. The authors share their individual and collective reflections on the specific activities as well as on the notion of providing future science teachers with authentic experiences in developing data literacy.

The other studies in this section focus on underlying assumptions about preparing future teachers and the identity of a science teacher educator. Lindsey Connor shares how her students' reflections triggered and guided an exploration of her assumptions about and practices in secondary science teacher preparation. In her chapter, "Biology Student Teachers' Reflections in Eportfolios as a Trigger for Self-Study of a Teacher Educator", she shares how she actively considered and responded to the posts her students made in their eportfolios during a Graduate Diploma biology course, as well as to their responses during a focus-group interview conducted by her critical fiend near the end of the semester. Although initially intending to consider what her students' reflection indicated about the use of eportfolios, she found herself actively confronting and responding to their reactions to the activities she undertook in the class, as well as the implications these responses held in regards to her own identity as a science teacher educator. Nidaa Makki and Gary Holliday focused their self-study on their individual and collective selves as they studied their secondary STEM teacher education program in relation to how they integrated school experiences with the coursework. Seeking to uncover how to embed school-based practical experiences in a manner that "open(s) the possibilities for creative pedagogies" (Britzman, 2003, p. 26) they studied their graduate 1-year program that prepares recent STEM graduates and career changers for teaching in urban schools. Their findings, accumulated over a period of 3 years, reveal the tensions they encountered between the school experiences and the course instruction on the best practices in science education. Their chapter, "Going Beyond the Status Quo: A Longitudinal Self-Study of a School Based Science Teacher Preparation Program", describes how they are now reframing their understanding of school-based experiences as well as the socialization process for teacher candidates.

Self-Studies and the Preparation of Future Teacher Educators

As previously noted, self-studies are revealing that there are tensions and uncertainties inherent in the process becoming a science teacher educator (Garbett, 2012; Santau, 2012; Wiebke & Park Rogers 2014). The self-studies in this book continue to challenge the professional community's assumptions about preparing new science teacher educators. Three of the four studies centered on the experiences of doctoral students exploring their identities as science teacher educators. In the chapter, "Developing Knowledge of Practice through Self-Study: Becoming a Science Teacher Educator", Jennifer Mansfield highlights the discontent she experienced in her transition from accomplished science teacher and scientist to a science teacher educator. Her exploration of the misalignment between what she sets out to do and what actually occurred led her to a greater understanding of, and practice in, science teacher education. Similarly, Maria Wallace shares her insights derived from an extensive self-study completed during her doctoral program. In her chapter, "Trash or Treasure? Re-conceptualizing My Ruins as a Tool for Re-Imagining the Nature of Science Teacher Education", she shares her journey of becoming a science teacher educator. Her findings, and the resulting professional understandings, further complicate the conversation of science teacher educator preparation from an onto-epistemological perspective. From the inherent complexity she provides us with three recommendations for preparing future teacher educators. Anne Hume also studies her own professional continuum from classroom teacher to science teacher educator. Her journey, however, extends beyond her doctoral program and focuses specifically on her own pedagogical content knowledge for teacher education from classroom teacher to teacher educator. In her chapter, "Finding the Means to Initiate and Sustain a Teacher Educator's Pedagogical Content Knowledge (PCK) Development in Science Education", she describes how she analyzed the research articles she published over a 10-year period. She identifies and explores key themes. She uses her narrative across the themes to illustrate how research into an individual's own teaching can build a sense of self-identity and confidence during the transition into the role of science teacher educator.

The three self-studies describe above were conducted by doctoral students transitioning into higher education. Gayle Buck and Valarie Akerson also focusing on the experiences of becoming teacher educators, but from the perspective of the existing faculty in the profession. In their chapter, "Supporting New Members as They Transition into our Science Education Community of Practice", they explored how well their science education doctoral program was functioning in terms of bringing in newcomers, first-year doctoral students, into their field of practice. They reveal how their findings challenged and ultimately enhanced their theoretical and practical understandings. Not only does their study differ in terms of whose understandings are explored, but also focuses on the experiences of more than one doctoral student as they question the identity of a science teacher educator.

A Concluding Look

Self-study 'is vitally important to reconstruct universities, converting them into engaged social institutions, functioning as critical and reflective training centres for new generations of social actors' (Greenwood & Levin, 2001, p. 104). Such reconstruction is necessary as we confront the increasing complexities inherent to preparing new teachers and teacher educators to address the social, political and personal aspects of science education. The 15 self-studies in this book help to further illuminate the possible tensions that arise between teacher preparation and K-12 classroom practice. Although the individual self-study experiences cannot be generalized, they are presented in a manner that enhances our efforts to understand aspects of our teaching in areas such as identity, underlying assumptions, and theoretical notions of teaching.

We must continue to take a rigorous approach to looking at our own theoretical notions associated with preparing future teachers in order to challenge the conceptions that we hold for these practices. Such an approach necessitates meaningful discussions on the complexities inherent in our notions of science teacher education. Establishing an ongoing dialogue within our professional community is important as we move forward and confront new and diverse challenges. Taking a critical look at our own teaching offers us rich examples of experience and evidence with which to start and continue the dialogue. This book is intended to promote and support such a dialogue within our professional community by bringing together science teacher educators who wish to illustrate and promote inquiry into practice and share the insights we are attaining from its use. We designed this book to collectively story the development and impacts of the self-study experiences on our theoretical notions and practices. To that end, the 15 self-studies in this book illustrate the multiple ways we are engaging reflexively, considering and reconsidering beliefs about the nature of science learners, pre-service teachers, and teaching, and manifesting philosophies of education to be lived out in practice. The themes that arise from a collective review of the self-studies are discussed at the end of each section, as well as at the end of the book.

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Chapter 2
Self-Study in Pre-service Science Teacher Education

Allan Feldman

One of the hallmarks of self-study is the recognition and acknowledgment of who the researcher is and what he or she brings to the scholarly work. Given that, I begin this chapter on the doing of self-study in preservice teacher education by locating myself in the field. Like so many of us who are science teacher educators I began my career as a science teacher. After graduating from college I enrolled in a master's degree program in science education that included certification. I then taught for 17 years in public and private schools in New York, New Jersey, and Pennsylvania before beginning my doctoral studies. For most of that time I taught high school physics and had the opportunity to get involved in the American Association of Physics Teachers. I regularly attended their conferences and made presentations about my practice. I also published brief articles in The Physics Teacher. I also published some essays about my teaching in a journal published by the last school at which I taught.

When I began my doctoral studies I was introduced to the literature on action research. I realized that my reflection and writing on my practice as a physics teacher was action research. I also found that in much, if not most, of the literature that I was reading about teaching and teacher education, the teachers were invisible. I did my dissertation on action research and since worked with teachers engaged in action research and have written extensively about it.

I was at meetings of the American Educational Research Association (AERA) that I met John Loughran and other founders of the Self-Study of Teacher Education Practices (S-STEP) special interest group (SIG). I quickly became involved in the SIG and attended several of the Castle Conferences. That said, I always felt that I was straddling multiple disciplines – self-study, action research, and of course, science education. However, the greatest tension I felt was between my identity as a

A. Feldman (✉)
University of South Florida, Tampa, FL, USA
e-mail: afeldman@usf.edu

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science educator and a teacher educator. I explored this tension in a paper that I wrote and presented at The Fourth International Conference on Self-Study of Teacher Education Practices (Feldman, 2002). In that paper I quoted myself in an interview:

> So what does it mean to be a science educator? The way to understand it is to compare it to what it means to be a teacher educator. The teacher educator educates people, the teacher as a person, whereas science is not a person, it's a discipline. (p. 68)

In some ways there has been a similar tension between science education and self-study. When I look at my own publications in self-study, very few of them are actually self-studies of my teacher education practices. Rather, they are papers about self-study. Interesting enough, this is not uncommon among science teacher educators who have been involved in the AERA Self-Study SIG. When I searched the literature (Google Scholar and ERIC) for publications on science teacher education that made explicit reference to self-study as a form of scholarship, I found only a few in the science education journals (see Table 2.1). In addition, John Loughran and Tom Russell who are prominent in the field of self-study, write primarily about self-study rather than self-studies of their science teacher education practices. Of course I found science educators who identify with the Self-Study SIG and who extensively published their self-studies. This includes Amanda Berry, Shawn Bullock, Gary Hoban, Deborah Trumball, and Karen Goodnough (see Table 2.1).

So as I begin to write this chapter, I see myself as both an insider to the world of self-study and as an outsider. I hope that this stance is evident in my writing and helps to make this chapter enlightening and useful to its readers.

Self-Study in Science Teacher Education

In the next remainder of this chapter I present several frameworks for examining what self-study is and its methodology. I begin with a summary of Ken Zeichner and Susan Noffke's (2001) taxonomy of practitioner research as a way to locate self-study in the field of teaching and teacher education. I then review the characteristics of self-study research from Vicki LaBoskey's (2004) chapter in the <u>International Handbook of Self-Study of Teaching and Teacher Education Practices</u> (Loughran, Hamilton, LaBoskey, & Russell, 2004). As part of my look at LaBoskey's characteristics of self-study I raise the question of the definition of a self-study methodology using the work of Sandra Harding (1989). Following that I return to LaBoskey to delve into the issue of validity in self-study and how it relates to preservice science teacher education.

Zeichner and Noffke's Taxonomy of Practitioner Research

In their chapter in the Handbook of Research on Teaching, Zeichner and Noffke (Zeichner & Noffke, 2001) present a typology of traditions of practitioner research that includes traditional action research, the teacher-as-researcher movement, the North American teacher research movement, and self-study research. Traditional action research has a long history, with most seeing its origins in the work of Kurt Lewin in the 1930s (e.g., Lewin, 1946). It was introduced into education by Stephen Corey, a professor at Teachers College, in the 1950s (Corey, 1953). Corey's approach to action research had an emphasis on hypothesis generation and testing, which is not surprising given the growing influence of scientific approaches to social science research in the post-war era. As such, traditional action research tends to have a technical orientation (Grundy, 1987) that is operationalized as the defining of a problem and the trying out of potential solutions. Data is generated and analyzed to determine whether or not the tentative solution solves the problem.

The teacher-as-researcher tradition began in the UK as a way for teachers to participate in school-based curriculum development. It was developed in the 1970s and 1980s by university researchers such as Lawrence Stenhouse (1981), John Elliott (1991), and Jean Ruddick (1985). This tradition is still very active in the UK, Europe, Australia, and South America, as well as in the US. The Collaborative Action Research Network (http://www.esri.mmu.ac.uk/carnnew/) continues to hold annual meetings in Europe and the journal Educational Action Research publishes work in this tradition. A newly formed organization, the Action Research Network of the Americas (http://www.arnaconnect.org), continues and builds this tradition in North and South America. Practitioners of the teacher-as-researcher movement tend to reject technical program solving and instead take a practical or emancipatory orientation (Grundy, 1987; McKernan, 1988). Those using a practical orientation seek to understand what is happening in classrooms as a way to improve practice, rather than fixating on problem solving. The emancipatory orientation relies on critical frameworks such as critical theory and standpoint theories, with the goal of uncovering underlying causes of inequities to empower teachers and students.

While the teacher-as-researcher movement has historical links to traditional action research, the North American Teacher Research movement has distinct origins. Its beginnings are most clearly seen in the efforts to improve the teaching of writing (Atwell, 1987; BAWP, 1979; Carini, 1986; Goswami & Stillman, 1987). By bringing together teachers of writing from all levels – K12 through college – organizations like the National Writing Projects developed a form of practitioner research that recognizes the teacher as expert, that knowledge about teaching can be generated by taking actions within classrooms and writing about what happens, and that the same methods used to improve writing, such as peer and collaborative critique, can also improve the quality of what is learned through classroom inquiry. By the 1990s educational researchers had begun to use these narrative forms of inquiry in their own studies (e.g., Connelly & Clandinin, 1990).

Of the traditions of practitioner research, it is self-study that emerged most recently. Its founders came out of the teacher-as-researcher and North American teacher research movements. Therefore, it is not surprising to find that it shares characteristics with those traditions. However, in a previous analysis Zeicher and Noffke's (2001) description of self-study, my co-authors and I (Feldman, Paugh, & Mills, 2004) argued that they saw self-study as different from the other traditions in two main mains – first, the practitioners who engage in it are primarily teacher educators in institutions of higher education, and second, while there are a wide variety of methods that self-study researchers could use, they tend to prefer the use of narrative and biographical forms of qualitative inquiry.

The analysis above relates to self-study in general. However, this volume is about self-study of science teacher educators. As the editors of this book developed the prospectus for it, they found that it was important for them to settle on a definition for self-study. They examined the literature for the ways in which others have defined it, and used that to develop one for our field. They modified it as they negotiated with the Publication Committee and Board of Directors of ASTE until they arrived at

> Self-study in science teacher education is being defined as rigorous, critical inquiry in which we – science teacher educators – research our selves and our practices within the academy. This line of inquiry includes research on science teacher educator identity as well as understandings of our own teaching practices. The critical component is centering the science teacher educator and/or their practices in the research process (i.e., data collection, analysis and implications).

Methods of Self-Study

The editors' definition of self-study in science teacher education provides us with at statement of what counts as research – rigorous, critical inquiry – and the subject of that research – our selves and our scholarly practices. Previously in this section I provided two other characteristics of self-study, which come primarily from the literature associated with members of the AERA Self-Study SIG – it is done by teacher educators and they prefer to use narrative or biographical forms of qualitative inquiry. However, this really does not tell us much about what it is and how it is done. Fortunately, the self-study community has provided us with ways of defining and identifying self-study scholarship. For example, John Loughran wrote

> …quality self-study requires that it is a disciplined and systematic inquiry; values professional learning as a research outcome for students of teaching as well as teacher educators; and, aims to develop and better articulate a knowledge of practice. (Loughran, 2008, p. 9)

That is, self-study is a form of inquiry in which researchers pay close attention to the research process itself; what they value – their own professional learning and that of their students; and knowledge of their practice.

Vicki LaBoskey (2004) extends the goal of self-study beyond the individual practitioner and underscores the importance of self-study resulting in increased understanding about teaching and teacher education, and improvement in their practices as well as the educational situations in which they take place.

> The goal of self-study teacher educators engaged in such research is to better understand their practice – to generate knowledge about teaching – but the process does not end there, which is another way in which this work is differentiated from more traditional research. Self-study scholars are interested in the resolution of current problems and in the achievement of short- and long-term educational reformation. Indeed an essential requirement of this research methodology is that it results in and provides evidence for the reframed thinking and transformed practice of the teacher educator researcher. Self-study thus aims to improve teaching and teacher education and the institutional contexts in which they take place. (p. 844)

LaBoskey begins her chapter with an analysis of the epistemological, pedagogical, and moral/ethical/political bases for self-study. While these are important for anyone who wants to gain a thorough understanding of the nature of self-study, I leave that to you to read and turn instead to the remainder of her chapter, which focuses on the characteristics of self-study research design. These include that it is self-initiated and self-focused; improvement-aimed and action oriented; interactive and collaborative; qualitative; and is reliant on exemplar-based validation.

Self-Initiation, Self-Focus, Improvement-Aimed and Action Oriented

According to LaBoskey (2004), first and fundamentally self-study is self-initiated and self-focused. The self-study inquirer answers the question "Who?" by answering "I am the researchers and I am studying myself." Inherent in this is that self-study is not imposed upon someone, that the researcher steps forward and takes on the inquiry. It requires the acknowledgement both that there is something that needs to be improved, and that it is my, the researcher's practice that is the focus.

In the early years of the self-study research, it wasn't unusual to hear it being disparaged as "navel-gazing." This criticism ignores a second fundamental aspect of self-study research – it is improvement-aimed and action oriented (LaBoskey, 2004). When teacher educators engage in self-study they seek to do more than produce generalizable knowledge about the preparation of teachers. To engage in self-study is to respond to a call to improve teaching in response to a sense of responsibility for improving the world through education (Feldman, 2003). Tied to this sense of responsibility is the acknowledgement by self-study researchers that they are teacher educators, and therefore to engage in the study of teacher education to improve it is to improve one's own practice as a teacher educator. In this way, LaBoskey's first and second characteristics of self-study are entwined with another.

Interactive and Collaborative

Teacher education is an activity that is inseparable from the social sphere. While the acts of teaching and learning are innate aspects of being human (Lave & Wenger, 1991), to designate some people as teachers and to recognize the need to educate them as such, are both part of the sociocultural world. As such, teacher education is intrinsically interactive – teacher educators interact with pre- and inservice teachers, teachers interact with students, and so on, including all the possible stakeholders in the enterprise. And of course these interactions aren't just unidirectional and vertical. Teacher educators interact with other teacher educators, teachers interact with other teachers, and so on. Given all this, the engagement in scholarship to improve teacher education ought not be a solitary endeavor. As LaBoskey (2004) points out, the field of self-study is highly collaborative – self-study researchers collaborate with their colleagues locally within their own educational contexts; they collaborate with colleagues more distant with whom they share concerns about the education of teachers; and they collaborate with their students – those who will be teachers and those who will be teacher educators. In addition, self-study researchers have critical friends who support them by employing a caring approach (Noddings, 1984) that helps them to interrogate assumptions and interpretations, and for them to reframe their perspectives (LaBoskey, 2004).

Methods of Self-Study

LaBoskey (2004) next turns to the methods of self-study. Partly as a result of its aim to improve the practice of teaching and teacher education, proponents of self-study research have argued that it has no one best method; rather, they will use whatever methods will enable them to best understand and improve their practice (e.g., Hamilton & Pinnegar, 1998). That said, the vast majority of self-studies have used some form of qualitative inquiry. In LaBoskey's chapter in the International Handbook, she presents examples of self-study that use action research,[1] ethnographic, narrative, dialogical, and artistic methods. The reason, I believe, for the preference for qualitative methods like these is due to the nature of self-study as a methodology, rather than as a set of methods.

In understanding the difference between method and methodology, I find myself returning repeatedly to Sandra Harding's (1989 essay, Is There a Feminist Method? Her answer was basically no, but that there is feminist methodology. To Harding, what distinguishes one methodology from another is what they make problematic, for example, culture in ethnography, economic class in Marxist studies, or gender in

[1] LaBoskey (2004), like many other proponents of self-study, distinguishes between self-study and action research. As suggested by Zeichner and Noffke (2001) and Feldman et al. (2004), the line between them is quite blurry. By action research, I believe that LaBoskey is referring to any practice of action research that does not make the role of the researcher problematic.

feminist studies. As such she argues that there three features that distinguish feminist methodology. They are

1. "The 'discovery' of gender and its consequences";
2. "Women's experiences as a scientific resource"; and
3. "Gender-sensitive reflexivity practice". (pp. 26–28)

Harding's first feature recognizes that until gender was seen as being socially constructed, masculinity and femininity were seen primarily as biological characteristics, which were considered as possible variables in research studies, but were not themselves put under scrutiny. The discovery that gender is a sociocultural construct made it visible in new ways and opened it up as a framework for understanding who we are as human beings.

As LaBoskey (2004) argued, self-study research is focused on the researcher, him or herself, who is the teacher educator. This suggests that what might define self-study as a methodology is the focus on the self, which would then result in it having the same function in a self-study methodology as gender has in a feminist methodology.

Harding's (1989) second feature of feminist methodology is the acknowledgment of the importance of women's experiences as a legitimate source of data. Similarly, a self-study methodology would acknowledge the importance and legitimacy of self-study researchers' own experiences as teacher educators. If those experiences are not considered legitimate, then the whole idea of self-study scholarship falls apart.

Finally, Harding (1989) argues that central to feminist methodology is the

> …practice of insisting that the researcher be placed in the same critical plane as the overt subject matter, thereby recovering for scrutiny in the results of research the entire research process. That is, the class, race, culture and gender assumptions, beliefs and behaviors of the researcher her/himself must be placed within the frame of the picture that she/he paints. (p. 29)

Self-study is also reflexive. If self-study research is to be self-initiated, self-focused, and action oriented, then it is imperative that we put ourselves as well as our research under scrutiny.

This leads us directly to LaBoskey's (2004) next characteristic of self-study, its validation strategies. But before turning to that, it is important to finish this analysis of the notion of a self-study methodology. Paralleling Harding's features of a feminist methodology, self-study methodology could be envisioned as having the following features:

1. It would bring to the forefront the importance of self;
2. It would make the experience of teacher educators a resource for research; and,
3. It would urge those who engage in self-study to be critical of themselves and their roles as researchers and teacher educators. (Feldman et al., 2004, p. 959)

It should be clear from this conceptualization of self-study methodology that it has many of the features ascribed to qualitative research (e.g., Denzin & Lincoln, 2013;

Marshall & Rossman, 2006; Patton, 2002). In addition, the focus on the self can lead to an autobiographical stance, and use of teacher educators' experiences as data can lead to the telling of stories and narrative forms of inquiry, which LaBoskey named as the primary forms of qualitative methods used in self-study. Before turning to LaBoskey's discussion of self-study's validation strategies, I present the results of a brief review that I did of self-studies of preservice science teacher education to identify the methods used.

Self-Study in Preservice Science Teacher Education

My analysis of self-study methodology in the previous section supports this volume's definition of self-study in science teacher education as rigorous, critical inquiry on our selves and our practices within the academy. However, one of the problems that arises when we attempt to define a field of inquiry is that every definition categorizes what can or cannot be included within that domain. Because of the desire to be inclusive rather than exclusive, definitions like this tend to be broad. For my purposes in this chapter I found that broadness to not work in trying to identify the characteristics of self-study in science teacher education. Therefore, I limited my search of the literature to those publications that were both about science teacher education and explicitly referred to itself as a self-study. When using ERIC and Google Scholar and the search terms "science education" and "self-study" I found 22 articles or book chapters that had this focus. Six of these were published in one edited book (Bullock & Russell, 2012), and only five in science education journals (see Table 2.1). I also used ERIC to search on the names of science education journals (Journal of Research in Science Teaching, Science Education, International Journal of Science Education, Journal of Science Teacher Education, Research in Science Education, Journal of Elementary Science Education, and Journal of Science Education and Technology) and the term self-study. I found five articles in these journals that were self-studies of preservice science teacher education. The remaining articles in Table 2.1 were published in either teacher education journals or Studying Teacher Education, the journal associated with the Self-Study of Teacher Education Practices SIG of AERA.

I realize that this is a much smaller number of relevant publications than those found in Chap. 2. In that chapter the authors decipher the types of questions that science teachers are asking about their practice and the findings that they produce. My focus here is more on the methods of self-study and therefore I decided to search for those publications that label themselves as self-studies.

I read the 22 chapters and articles to uncover the methods that the authors used. In particular I looked for evidence of collaboration, the types of data sources, the analysis methods, and the style of the product. All were primarily qualitative studies with several also using surveys or questionnaires of students. I divided the publications into two groups according to the type of qualitative methodology, which I label either narrative or traditional. The narrative methods include the use of autobiography; the authors' reflective journals; and records of dialogues or discourses, either oral or written, among the collaborators or between the authors and a critical friend. The more traditional methods included the use of surveys or questionnaires; interviews or focus groups of students; document analysis, including student work; and observations of classes.

I also divided the analysis methods into narrative and traditional. The narrative methods included the authors' reflections on data, the construction of narratives, and dialogues or discourse about data. The authors using narrative methods tended to cite publications about the doing of self-study (e.g., Pinnegar & Hamilton, 2009; Samaras, 2010; Tidwell, Heston, & Fitzgerald, 2009), or those about narrative inquiry (e.g., Bullough & Pinnegar, 2001; Connelly & Clandinin, 1990; Hamilton, Smith, & Worthington, 2008). The traditional data analysis method used was the coding of data and the development of themes given that these studies were primarily qualitative. Authors cited a variety of publications that describe how to do this, including Corbin and Strauss (2007), Denzin and Lincoln (2013), and Patton (2002). There were also authors that combined traditional qualitative methods with a reflective turn. What I mean by this is that after presenting their findings they then examined what they would mean in terms of their own practice as science teacher educators. In a way, that reflective turn was the primary reason that the studies were self-studies.

Finally, I found that I could also divide the style of the product – that is the way in which the results of the study were represented in the publications – into two groups, which I again labeled narrative or traditional. A research report that is written in the narrative style is basically an "account of a series of events, facts, etc., given in order and with the establishing of connections between them" (Oxford English Dictionary, 2015). It is important to note that because narratives typically enfold temporally, there is the "illusion of causality" (Crites, 1986, p. 168). As Connelly and Clandinin (1990) explained in their seminal work on narrative inquiry, events viewed backward appear to be causally linked, while those looked forward appear to lead to a determined future. An author of a well-written narrative research report takes care to avoid this inference. A traditional report follows the norms expected in the sciences or social sciences, with sections for a literature review, methods, findings, and implications.

As can be seen in Table 2.1, the self-studies that I found are split about even in terms of the use of narrative and traditional data types, methods of analysis, and styles of report. Surprisingly, given the emphasis placed on collaboration in self-study, almost a third of them did not appear to be done that way, either with co-researchers or with a critical friend. It should also be evident in Table 2.1 that several authors are represented multiple times. For some of them, the types of methods used and the style of report appears to be tied to where it was published. The majority of the chapters in the book by Bullock and Russell (2012) tend to use some form of narrative inquiry, as do the articles in Studying Teacher Education, while only one article in a science education journal was a narrative.

Overall, my review of publications on self-studies of preservice teacher education practices appears to suggest that few science teacher educators are engaged in

Table 2.1 Methods of self-study in preservice science teacher education

Publication	Journal/book	Collaboration	Data types	Analysis	Style
Berry (2009)	T&T	No	Auto and Obs	T and Refl	Narrative
Bullock (2012b)	B&R	No	RJ	Refl	Narrative
Journell and Webb (2013)	TE&P	C	RJ and Auto	Dialogical	Narrative
Bullock and Christou (2009)	STE	No	RJ and Auto	Refl	Narrative
Bullock (2012a)	STE	No	RJ and Auto	Refl	Narrative
Loughran, Berry, and Corrigan (2001)	TQR	C	RJ and Auto	Refl	Narrative
Keast and Cooper (2012)	B&R	C and CF	RJ and Discourse	Narrative	Narrative
Moscovici (2007)	JRST[a]	CF	T and Auto	T and Refl	Narrative
Garbett (2012)	B&R	C and CF	T and RJ	Narrative	Narrative
Berry (2004)	AJE	No	T and RJ	Not described	Essay
Trumbull (2012)	B&R	No	T	Refl	Narrative
Trumbull and Fluet (2007)	STE	C and CF	T	Refl	Narrative
Nillson and Loughran (2012)	B&R	C and CF	T	T and Refl	Assertions
Capobianco (2007)	JSTE[a]	No	T	T and Refl	T and Refl
Goodnough (2006)	THE	No	T	T and Refl	T and Refl
Faikhamta and Clarke (2013)	RISE[a]	No	T	T and Refl	T and Refl
Garbett (2011)	JSTE[a]	No	T	T and Refl	T and Refl
Morrell and Schepige (2012)	B&R	C	T	T	T
Aubusson, Griffin, and Steele (2010)	STE	C	T	T	T
Trumbull and Fluet (2008)	T&TE	C and CF	T	T	T

(continued)

Table 2.1 (continued)

Publication	Journal/book	Collaboration	Data types	Analysis	Style
Garbett and Ovens (2012)	AJTE	C and CF	T	T	T
Park Rogers (2009)	JESE[a]	No	T	T	T

Notes:
Collaboration: *C* collaborative study, *CF* uses critical friend, *No* no evidence of collaboration
Data types: *T* traditional including surveys, interviews, observations, and examination of student work, *RJ* author's reflective journal, *Auto* Author's autobiography as data source, *Obs* Observation of teaching by outsiders
Analysis: T – traditional, including data coding and descriptive statistics, Refl –
Style of report: Narrative – the findings are presented in the form of a narrative, T – traditional reporting of findings, Refl – Author reflections on findings relative to his/her practice
Tradition -Type of practitioner research from Zeichner and Noffke's typology: *NATR* North American Teacher Research, *TAR* Teacher as Researcher, *Trad AR* traditional action research
Journal/Book: B and R – (Bullock & Russell, 2012), *AJE* Australian Journal of Education, *AJTE* Australian Journal of Teacher Education, *JESE* Journal of Elementary Science Education, *JRST* Journal of Research in Science Teaching, *JSTE* Journal of Science Teacher Education, *RISE* Research in Science Education, *STE* Studying Teacher Education, *T&T* Teachers and Teaching, *T&TE* Teaching and Teacher Education, *TE&P* Teacher Education and Practice, *THE* Teaching in Higher Education, *TQR* The Qualitative Review
[a]Science education journals

self-study, and that those who do either have had difficulty publishing their work in the science education journals or they have chosen not to submit their manuscripts to them. I believe that this is partially due to the issue of validity in self-study.

Validity in Self-Study

To LaBoskey "exemplar-based validation" (2004, p. 852) is one of the identifying features of self-study research designs. Citing the work of Mishler (1990), LaBoskey defines exemplars as the demonstration of normal practices within a community of scholars. Mishler drew upon Kuhn (1996) for his conception of normal practice: "the ordinary, taken for granted and trustworthy concepts and methods for solving puzzles and problems within a particular area of work" (Mishler, 1990, p. 423). Primary among these exemplars in qualitative methods in general and narrative forms of inquiry in particular, which are preferred in self-study, are the idea of "trustworthiness" (Lincoln & Guba, 1985), verisimilitude (Denzin, 1997), and credibility (Creswell & Miller, 2000). To Lincoln and Guba, trustworthiness involves demonstrating that the results of the study are credible, transferable to new situations, dependable, and confirmable. Other qualitative researchers use the terms "verisimilitude" and credibility in ways that are similar to trustworthiness. For example, to Denzin (1997 "A text's verisimilitude is given in its ability to reproduce and deconstruct the reproductions and simulations that structure the real" (p. 13).

That is, a research report, which is what is meant by the text here, is seen to be believable if it is successful in both reproducing events and taking them apart critically. Because verisimilitude can apply to any text, fiction or non-fiction, it is often used to establish trustworthiness in narrative forms of inquiry. Creswell and Miller (2000) in their article on validity in qualitative research note that among qualitative scholars there is a general consensus that qualitative studies need to demonstrate that they are credible through the use of methods such as "member checking, triangulation, thick description, peer reviews, and external audits" (p. 124). To Loughran and Northfield (1998) this all suggests that a description of what ought to be in a self-study report should have

> …sufficient detail of the complexity and context of the situation for it to "ring true" for the reader; provides and demonstrates some triangulation of data and a range of different perspectives around an issue; makes explicit links to relevant educational literature and other self-study accounts and literature. (p. 13)

The works that I cite above with their focus on trustworthiness, verisimilitude, and credibility, suggest that in self-study whether the term validity is accepted or rejected, there is the need to demonstrate how the findings, understandings, conclusions, and implications of our self-studies are constructed.

The requirement to make explicit the methods used to construct the results of a self-study sometimes appears to wane in more narrative and autobiographical forms of self-study. For example, Bullough and Pinnegar (2001) in their article Guidelines for Quality in Autobiographical Forms of Self-Study Research wrote that "The aim of self-study research is to provoke, challenge, and illuminate rather than confirm and settle" (p. 20). This suggests an abandonment of the reliance on the power of systematic inquiry, but rather on the power of narrative to convince. This can be seen in Bullough and Pinnegar's guidelines for quality in autobiographical forms of self-study. While their analysis focuses on autobiographical forms, their article is cited in most of the self-studies that I reviewed that were narrative in form. They summarize the guidelines in the conclusion of the article:

> Like all research, the burden of proof is on those who would conduct and hope to publish autobiographical self-studies. As we have said, articles need to be readable and engaging, themes should be evident and identifiable across the conversation represented or the narrative presented, the connection between autobiography and history must be apparent, the issues attended to need to be central to teaching and teacher education, and sufficient evidence must be garnered that readers will have no difficulty recognizing the authority of the scholarly voice, not just its authenticity. (p. 20)

A careful look at their guidelines suggests that the quality of a self-study is mainly made evident by the power of the narrative, although there is a need for the researchers to provide at least some evidence to establish their authority (Feldman, 2003).

Bullough and Pinnegar (2001) begin their article by acknowledging that self-study researchers have difficulty publishing their work. Their purpose in suggesting their guidelines was to increase the grounding and authority of self-studies. Although I am not aware of any study that has looked at this, my years of reading and publishing in science education journals suggest that the norms for establishing validity are quite different from what Bullough and Pinnegar suggest, and more similar to what I suggest in my rejoinder to their article (Feldman, 2003). In my article I suggest four ways to increase the validity of self-studies. They are

1. Provide clear and detailed description of how we collect data, and make explicit what counts as data in our work;
2. Provide clear and detailed descriptions of how we constructed the representation from our data.
3. Extend triangulation beyond multiple sources of data to include explorations of multiple ways to represent the same self-study.
4. Provide evidence of the value of the changes in our ways of being teacher educators. (pp. 27–28)

My primary reason for making these suggestions is that I believe that self-study needs to do more than "provoke, challenge, and illuminate". Rather, most of us as science teacher educators want our work to have direct, positive effects on teachers, students, and schools. Because education is inherently a moral and political enterprise, the results of our self-studies ought to provide evidence that they are "well grounded, just, and can provide the results that we desire" (p. 27). Returning to my analysis in Table 2.1, it appears that those self-studies that appeared in science education journals, by combining what I called traditional methods of qualitative research with reflection, for the most part have satisfied my suggested criteria.

Conclusion

My purpose in writing this chapter was not to provide a quick start for those of you who may be interested in engaging in self-study. Rather, it was to look at how others have written about the field, and how that relates to self-study of preservice science teacher education. I feel strongly that there is a place for this type of research in science education. This should not be surprising given my own work in the field of self-study, and the resemblance my conception of action research has to it (e.g., Feldman, 1994, 2007; Feldman et al., 2004). But if self-study is to have a legitimate place among the methodologies used in science education research, then it is up to us to demonstrate what Zeichner (2007) has called for.

Zeichner (2007) argued that self-study should be able to contribute to the improvement of the practice of teacher education and increase our knowledge about the types of questions that are significant to both teacher educators and policy makers. He warned that when self-study researchers underemphasize the creation of knowledge and how it can be used to inform decision-making about teacher education, then self-study would have difficulty finding acceptance among the broader research community. This could be why my search of the literature appeared to find a lack of centrality of self-study of preservice teacher education in science education. Zeichner urges practitioners of self-study to "become more engaged with the mainstream of research in teacher education and insert the perspectives and voices of practicing teacher educators more centrally into the policy debates that frame teacher education practice at the local level" (p. 43).

One of the ways in which Zeicher (2007) suggests self-study can become more central is by including them as part of research programs in teacher education. To Zeichner, a research program focuses on a particular area of interest in the field, and in which "researchers explicitly build on each other's work conceptually, theoretically, and methodologically" (p. 40). In preservice science teacher education there are identifiable research programs around the teaching of the nature of science and the use of socioscientific issues, as well as the preparation of new teachers to incorporate environmental and sustainability issues into their teaching, among others. But for this to happen, self-study methodology must increase its legitimacy in the field. I believe that this book is an important step in making this happen, and look forward to a time when self-studies are increasingly published in our journals.

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Part II
Self-Studies and Science Content Courses for Teachers

Chapter 3
Promoting Student Agency in Science Inquiry: A Self-Study of Relational Pedagogical Practices in Science Teacher Education

Amy Trauth-Nare, Gayle A. Buck, and Nicole Beeman-Cadwallader

Introduction

As countless educators have noted, it is not the level of difficulty or abstraction posed by science concepts, but the ways in which concepts are presented to students in traditional science classrooms that inhibits students from participating in day-to-day classroom activities (Lemke, 2000; Ritchie, 2002); building science identities that support confidence and motivation to learn (Brown, 2004; Olitsky, Flohr, Gardner, & Billups, 2010); and sustaining long term engagement in the subject (Olitsky, 2007). Students often describe disconnect between science and their lived experiences. As a result, students fail to see the relevant connections between science and their daily lives. For example, instead of learning about the practice implications of radioisotopes in modern medical procedures, students instead use the periodic table to count neutrons in order to determine common isotopes of an element. Students memorize the characteristics of global biomes instead of exploring the biodiversity and ecological challenges facing the environments in which they live. The disconnection between science and students' lived experiences manifests in the classroom when students express boredom or frustration with science learning, refuse to participate in classroom activities, or contribute only hesitantly to class discussions.

A. Trauth-Nare, Ph.D. (✉)
Development Center for Educators, University of Delaware, Newark, DE, USA
e-mail: anare@udel.edu

G.A. Buck, Ph.D.
Department of Curriculum and Instruction, Indiana University, Bloomington, IN, USA
e-mail: gabuck@indiana.edu

N. Beeman-Cadwallader, Ph.D.
Project Lead The Way, Inc., Indianapolis, IN, USA
e-mail: nbeeman@pltw.org

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When teachers employ transmissional modes of relaying information, scientific knowledge becomes impersonal, abstract, and incoherent to students. Research indicates that when teachers employ monologic and triadic forms of discourse and squelch cross-discussion, students operate passively (Hanrahan, 2005). Students generally provide only tentative comments and use hedges and questioning tones in their responses to teachers' queries (Adler, Rougle, Kaiser, & Caughlan, 2003). Moreover, students rarely respond to one another; instead they direct their responses to the teacher who evaluates the response before asking a follow up question or calling on another student (Adler et al., 2003). Conversely, when teachers make science dialogue a natural extension of everyday talk and relates learning to students' interests, then students have the space to actively in classroom discourse by engaging in true discussion and initiating relevant cross-discussion with peers (Hanrahan, 2005). Mortimer (1998) labeled this type of classroom discourse 'multivoicedness' – that is, the encounter between their science voice and their everyday language. Mortimer (1998) suggested that construction of science knowledge in the classroom should be a guided process in which the teacher introduces students to the discourse of science, helping them to build new meaning through active participation and the individual struggle to make sense of science concepts and phenomena.

Purpose

One goal of this self-study was to promote 'multivoicedness' (Mortimer, 1998) in the classroom by providing students with relevant and meaningful opportunities to talk and act like scientists in ways that cohered with their personal experiences. Another goal was to foster a classroom environment in which students were able to act as agents in their own learning as they participated in scientific inquiry during their formal education. The purpose of this self-study was to examine the practical implication of theories of relational pedagogy – specifically, that relational pedagogy serves as a means for confronting the constraining regularities of a normative, homogenized science curriculum (Smith, 2007). Through this self-study, the first author (Amy), explored how to enact relational pedagogy in a non-majors science course in ways that engaged students in meaningful discourse within scientific inquiry. By doing so, Amy intended to elucidate and confront the discrepancies between her personal theories and actual practice in the classroom (Cochran-Smith & Lytle, 1990). Her intention was to promote practices in which students actively:

1. Constructed scientific inquiry knowledge and skills,
2. Shared authority over the direction and focus of their own science learning, and
3. Participated in dialogical, interactive science discourse.

In essence, Amy hoped to develop and maintain a community of learning through inclusive practices and shared authority in the science classroom, while actively and systematically reflecting in collaboration with her reflective partners, Gayle and Nicole (second and third authors), on her attempts to do so.

Theoretical Framework

Relational Pedagogy in Science Teaching and Learning

A number of educational philosophers have argued the most essential aspect of education is human relations, not the production of requisite knowledge and behaviors (Biesta, 2004; Gergen, 2009; Sidorkin, 1999). Instead of experiencing education as an endless array of decontextualized activities, Sidorkin (2004) claimed students should experience an "eventness of being" (p. 251); that is, learning which promotes participatory thinking and doing through discursive social practices. Sidorkin's educational theories draw heavily on theories of discourse and language by Martin Buber and Mikhail Bahktin. According to both philosophers, discourse is the root of existential meaning. Humans can exist in a physical or biological sense, but to fully experience our humanity, we must engage in dialogue with others.

Bakhtin identified two kinds of discourse: monologic and dialogic (Sidorkin, 1999). Monologic discourse embodies a single voice, such as a teacher giving a lecture. Monologic discourse does not allow for contradiction or counter voices; it is presented as the final word. In contrast, dialogic discourse emerges in the midst of unmerged voices; it manifests the plural intersection of many voices and involves struggle, contradiction, multiple intentions, perspectives, or worldviews. Dialogic discourse is a kind of polyphony that is indeterminate and emergent. When individuals engage one another in dialogic discourse, the interplay of their utterances direct the conversation in unscripted or unforeseeable ways, yet there is still respect for the disparate voices involved (Baxter, 2004).

According the theories of relational pedagogy, education is more than an instrumental process by which students assimilate static knowledge passed on from teachers. Instead, education is a process of being, or co-being, with others. Education is a process of ideological becoming (Sidorkin, 1999) in which students develop a strong, powerful voice by actively and critically appropriately language and skills inherent to a particular community of practice, while at the same time drawing on their own cultural capital to make meaning (Matusov, 2007). Grounded in the assumption that education is a function of human relations and not certain behaviors, relational pedagogy is a means for countering the instrumental emphasis of an input-output paradigm that currently dominates education (Margonis, 1998; Sidorkin, 2004).

Relational pedagogy draws on a framework of knowledge as socially constructed (Thayer-Bacon, 2004), allowing for teachers and students to share authority over teaching and learning (Bingham & Sidorkin, 2001). Students are valued as knowers, the teacher is a facilitator rather than an expert, and learning activities build on students' prior experiences thereby fostering their legitimate positions as participants in the construction of knowledge (Gergen, 2009). Relational pedagogy also involves the implementation of curricula that foster personal connections to subject matter and the use of learning activities that build on students' prior experiences both in and outside of the classroom (Brownlee, 2004).

Several empirical studies have drawn on relational pedagogy as a theoretical construct. In an ethnographic study of a middle school science classroom, Darby (2005) found the teacher took the role of facilitator in the classroom, and this was most evidenced in her use of open-ended questions that prompted student metacognition and promoted sharing of ideas. In this way, a learning community was established where students were encouraged to be risk takers in the process of communal meaning making. Aitken, Fraser, and Price (2007) also conducted an ethnographic case study, but focused on a theater classroom. Findings from this study indicated the teacher allowed students to claim an authority role as they learned about drama; this was significant because it indicated teaching and learning do not need to be dichotomous. In this classroom, teaching and learning were liberated from traditional roles through relational pedagogy – students acted as co-teachers to determine how and when learning would take place. Finally, Brownlee (2004) explored relational pedagogy in her yearlong college psychology course and found many students made an epistemological shift in from believing knowledge to be a set of received, absolute truths to knowledge as a set of constructed, reasoned truths. Furthermore, students' epistemological beliefs were more relational in both referential and structural dimensions at the end of the course. Referential aspects showed links between self and theory, while structural aspects showed a relational organization of ideas. Students stated specifically that explicit reflections helped them to become more reflective about their beliefs.

Relational pedagogy has also been used as a theoretical framework in teacher education. Kitchen (2005a, 2005b) published his self-studies on relational teacher education and Brubaker (2010, 2012) reported his attempts to negotiate authority with prospective teachers in his courses. Drawing on his personal experiences as a preservice teacher, a teacher mentor and a teacher educator, Kitchen identified seven important characteristics in relational teacher education: (1) understanding one's own practical knowledge; (2) improving one's practice in teacher education; (3) understanding the landscape of teacher education; (4) respecting and empathizing with preservice teachers, (5) and conveying that respect and empathy, (6) helping preservice teachers face problems and (7) receptivity to growing in relationship. He asserted that these characteristics are essential for building reciprocal and authentic teacher education programs. Brubaker (2010) identified three themes in jointly negotiating authority through the course curriculum: deriving legitimacy from mutually recognized sources; working from purposes that were jointly constructed, understood and shared; and confronting students' deeply rooted familiarity with authoritarian teaching. In the course, Brubaker involved students in determining course objectives, choosing class activities that aligned with these objectives. He also had to support students as they worked through their suspiciousness and skepticism regarding democratically negotiated curricula. He found that students valued teacher-centered instruction that allowed them to develop passive learning habits. Brubaker (2012) also suggested that constructing relations of mutual interdependence were critical to the success of the course. This was achieved by involving as many students as possible in decision-making and continuously inviting participation that was focused on reasoning and critical thinking rather than singular correct answers. These studies align with the view of teaching as negotiation, which reflects the Deweyian ideal that teachers and learners jointly construct knowledge rather than related to one another as authoritative source of knowledge and passive recipient, respectively (Alexander, 2005).

In sum, these empirical studies suggest the importance of relational pedagogies that value students as knowers, provide learning opportunities that draw on students' prior experiences, and use constructivist approaches to learning about the process of science. From a relational standpoint, education is more than instrumental action; it is the process of fostering the relationships with others, the academic knowledge they encounter in schooling, and the lifeworlds in which students reside (Gergen, 2009). Relational pedagogy counters traditional educational approaches in which teacher-student discourse functions as a means for transporting or transmitting meaning. Instead, relational pedagogy highlights communicative acts that foster participation, coordination, construction, and transformation (Biesta, 2004).

Authority and Power in Classroom Discourse

Contemporary reforms assume schooling is effective when education is focused on the attainment of knowledge and skills. Yet this oversimplification of educational purposes destroys, or at least greatly inhibits, the potentialities of flourishing human relations that promote meaningful engagement in education (Bingham & Sidorkin, 2004). Inherently asymmetrical relations among teacher and students exists in traditional classrooms where teachers employ activities intended to change or shape learners. Teachers are understood to have legitimate power in the classroom because of their institutional position and their knowledge of subject matter. They are able to assert both their authority of knowledge and authority of position (Carlsen, 1997). When teachers exert authority in traditional ways, they tightly control lesson content and pacing, they attempt to transmit knowledge to students rather than allowing them to construct it through their own activities (Hanrahan, 2005). Didactic strategies such as lecturing on decontextualized content, engaging students in confirmatory laboratory experiments, and evaluating students' work without providing useful and informative feedback limit students' access to science, which serves to alienate them from the process of science and hinders meaningful learning. On the other hand, when teachers employ more inclusive and egalitarian classroom pedagogies, such as engaging students in two-way discourse about scientific ideas, responding proximally to their needs as learners, and offering authentic and relevant assignments and investigations, teachers provide students with genuine opportunities to engage in science. The teacher still acts as an authority, but shares this power with students by making instructional decisions, pacing, and participation based on students' feedback. Here a community of learning is established; knowledge is a co-construction among students and teacher (Hanrahan, 2005). When students are active participants in classroom discourse, they are more engaged in knowledge construction (Candela, 1999) and the teacher becomes a co-learner.

Evidence indicates that students' lack of affiliation with science is linked, in part, to dominant discourse practices in science classrooms. Educational reform often includes changes to instructional pedagogies or to curricula, yet it fails to address the ways in which classroom discourse can be structured to accommodate the needs of students. In most science classrooms, discourse is too often elitist and marginalizes many students, especially those whose primary means of discourse is dissimilar to the dominant ideology of science (Calabrese Barton, 1998; Roth & Calabrese Barton, 2004). Discourse in science classrooms not only transmits what is known about science, but it should also model science as a process (Carlsen, 1992). Furthermore, science is characterized by its forms of argument, and teaching science 'as argument' is more appropriate than teaching it as a body of propositional knowledge (Carlsen, 1997). Unfortunately, the stylistic norms appropriated in 'talking science' run counter to accepted techniques used in colloquial forms of communication that include engaging an audience, identifying a point of view, and making persuasive and effective arguments – all ways in which individuals relate to one another, establish their identities, and meaningfully represent the world around them. Instead, normative science discourse, with its highly technical vocabulary, emphasis on causal explanations and lack of personal reference alienates students who come to believe that they have no place in authentic scientific endeavors where knowledge appears abstract and impersonal and scientific practices seem objective, authoritative, and nonnegotiable (Hanrahan, 2005).

Discourse Sequencing and Content

Teachers often have difficulty opening up classroom talk to students due to their beliefs about the appropriate roles of teacher and students (Adler et al., 2003). Many teachers believe that they should be the disseminators of knowledge; this places students in a passive role, which is manifested in their reluctance to engage in classroom discussion. Even teachers who are aware of the importance of dialogic discussion in science teaching and learning can have difficulty in changing their beliefs and practices (Adler et al., 2003). This may be due in large part to the ways in which teachers themselves experienced science as students; they were inducted into the hegemonic discourse of science in their preservice preparation through traditional methods of science teaching, and thus did not develop the cultural capital or pedagogical skills to enact inclusive science curricula (Hanrahan, 2005).

Students learn to conform to hegemonic discourse practices of science early in their education. Because teacher talk functions both to convey science content and to manage student action, teachers rely on an imbalance of power that is well understood by students before they reach upper grades (Carlsen, 1997). This imbalance facilitates teaching but stifles active learning; it is manifested as ritualized sequences of teacher-student transactions in which teachers disproportionately maintain conversational control through questioning and evaluating, dictating conversational topics, and determining who gets to speak and when (Carlsen, 1992, 1997; Reinsvold & Cochran, 2012).

Prior research has shown structure and content of classroom dialogue heavily influences students' participation in science (Lemke, 1990; Reinsvold & Cochran, 2012). Classroom discourse follows a monologic or triadic sequence, as is evidenced in the transmission and review of course content by the teacher (Adler et al., 2003). However, monologic and triadic sequences inhibit students' participation. Monologic sequences limit students' contribution to discussion because the teacher controls the pace and focus of discourse. Triadic sequences allow the teacher to control classroom discourse because s/he asks the questions (*initiates*), orients students' *responses*, and *evaluates* their answers or provides *feedback*, also know as I-R-E or I-R-F discourse (Candela, 1999; Cazden, 2001; Mortimer, 1998). On the other hand, Oliveira, Sadler, and Suslak (2007) showed that when a teacher eliminated evaluation from teacher-student I-R-E sequences, he was able to help students articulate their conceptions of science content without validating it with his authority. Instead students were encouraged to become authoritative agents in their own explanations. Moreover, open-ended questioning that requires high level reasoning allows students to engage in productive disciplinary reasoning, provide explanations and engage in scientific argumentation (Chin, 2007; Scott, Mortimer, & Aguiar, 2006; van Zee & Minstrell, 1997).

Teacher's content knowledge also has an influence on the sequencing and content of classroom discourse. Carlsen (1992) found that when novice teachers lead science lessons that included content on which they were unfamiliar, they asked initiated more I-R-E sequences, but provided fewer strong evaluations of students' responses than when they taught familiar content. This lack of evaluation did not give students the cues they needed to assess and reorient their own thinking. When teaching unfamiliar content, teachers also asked more recall questions, did not allow enough wait time to higher level questions, and forestalled answers to students' questions, not returning to address them later. In a similar study, Carlsen (1997) conducted a self-study of his own classroom discourse practices. When teaching unfamiliar content, he also asked more low level recall questions as a means of tightly controlling classroom conversation. With familiar content, however, Carlsen asked higher level questions and required students to warrant their claims, a strategy that provided students with the rights to question and contribute meaningful answers. In summary, when teachers present unfamiliar science content, they are more likely to postpone instruction, go off on discursive tangents, evaluate students' responses ambiguously, resist students' efforts to change the topic of instruction, and tend to follow the textbook closely (Carlsen, 1992, 1997). These strategies establish an inquisitorial atmosphere in the classroom and signal to students that their own questions are unwelcome (Carlsen, 1997).

Methodology

As a form of inquiry, self-study is a broad term that encompasses forms of teacher research aimed at improving practice. Self-study research comprises a valuable source of knowledge for the teaching community not only in terms of the knowledge gained from such studies, but also from standpoint of professional development. Educators who conduct self-study have a means for transforming their teaching in important ways: they enhance their perceptions of themselves and their work, they become rich resources for other teachers, they become critical and responsive users of current research, and they are more likely to collaborate with students to answer relevant questions (Cochran-Smith & Lytle, 1990). In other words, self-study can be an invaluable source of social action as it promotes growth and transformative changes in practical knowledge and action in classrooms and the communities in which they are constituted (Pithouse, Mitchell, & Weber, 2009).

Self-study is often characterized as reflective practice in which educators examine their own practice, often in cooperation with colleagues or students (Pithouse et al., 2009). Reflective practice allows educators to become more active in formulating the purposes and outcomes of teaching, in collaboration with others, and acting as educational reformers (Zeichner, 2008). Through the use of reflective practice, it is assumed that teachers have theories that can contribute to the development of knowledge about good teaching – what Schön (1983) called 'knowledge-in-action.' The process of understanding and improving teaching must start from understanding one's own experience, and this is done through reflection on the process of teaching (Zeichner, 2008). This self-study explored the enactment of relational pedagogy as a method for engaging students in meaningful discourse within scientific inquiry.

Context

This self-study took place during one semester in two sections of an undergraduate non-majors science course called *Introduction to Scientific Inquiry*. Although the course was required for all elementary education majors, any non-science major could elect to take the course in order to fulfill a core science requirement at this university. As such, the majority of students enrolled in the course in any particular semester were elementary education majors. For this study, all students (n = 46) were invited to participate. All students enrolled in the course were provided with the same opportunities to engage in scientific discourse and practices regardless of their consent to participate; thus, all students potentially benefitted.

This self-study was intended to explore the extent to which Amy was able to foster or promote relational pedagogy through discourse in the science classroom. For this study, student participation in classroom discourse included both spoken and written forms of communication such as small group and whole class discussion, and reading and writing about science (Kelly, 2007). Rather than using a targeted intervention, this self-study expanded on established instructional strategies for the course; established curricula was implemented with some particular pedagogical techniques meant to enrich the course such as small group activities, whole class discussions, and reflective writing. From students' responses to these instructional and pedagogical strategies and my relational practices were analyzed for the extent to which they promoted student discourse and engagement in scientific inquiry.

Data Collection

Reflective Research Journal and Critical Reflective Sessions

Amy kept an electronic reflective journal in which she wrote weekly entries to document her experiences and her evaluations of the extent to which she enacted relational pedagogy through egalitarian and inclusive classroom discourse. The reflective journal served as a place for reflection-on-action (Schön, 1983) and as documentation of her experiences with promoting relational pedagogy and discourse in the classroom. In weekly entries, Amy wrote about students' collective level of cognitive, emotional, and behavioral engagement in course activities and she documented her impressions of her ability to maintain an inclusive, egalitarian atmosphere in the course. For instance, Amy regularly documented her reflection-on-action with regards to the types of discourse in which she engaged with students in order to discern her positioning and the position of her students during class activities. These journal entries were shared with Nicole and Gayle, who used them to structure critical reflective conversations with Amy on a weekly basis during the regular semester.

Written Formative Reflections

Students completed written daily reflections on learning. These daily reflections prompted students to explicate: (1) to what extent they understood the goals of the lesson, (2) whether or not they believe they achieved lesson goals, and (3) concerns about the lesson and/or concepts they didn't understand and (4) one important science concept they learned during the lesson or one science inquiry question they had related to the science content. Other reflective writing prompts allowed them to explicate their experiences with learning science content through inquiry.

Audio Taped Class Sessions

Five times during the semester (one beginning, three middle and one end of semester) class sessions were audio taped. When audiotaping, one recorder was placed on the instructor's bench at the front of the classroom and the entire class session (ca. 75 min) was recorded. As a result, the recordings reflected the entire spectrum of class activity, including direct instruction, small group activity and whole class discussions.

Student Coursework

As curriculum was designed based on students' interests and questions, the quality of their coursework (weekly hands-on activities and reading reflections) was used as evidence of engagement in scientific inquiry. The course was interdisciplinary and focused on the processes of science; as a result, weekly hands-on activities always included science inquiry, but the disciplinary content varied. Topics included water quality, biodiversity, human nutrition, the properties of water, and density. Course readings (and reading reflections) supplemented the disciplinary content covered during hands-on activities. For instance, to support their learning of human nutrition, students read a research study on food availability in urban areas (Zenk et al., 2005). Students also completed a capstone inquiry project that involved individually chosen science topic investigated through descriptive or experimental study. This design allowed students to draw on their personal interests by investigating a science topic that was personally meaningful and relevant to them. Students presented outcomes of their inquiry in a formal written report and in a poster session where their peers evaluated them.

Data Analysis

Data analysis occurred in two phases. Phase one took place during the course, as Amy analyzed students' responses to formative reflections and their written work on homework and in-class assignments. Students' reflective comments and coursework were used to shape the content and form of subsequent activities implemented in the Q200 course. For example, during a unit on nutrition, Amy discovered that many students have never used Excel to organize data or produce graphs. As a result, she purposefully developed a lesson for learning Excel skills, which students then used to analyze nutrition data they had gathered in a personal log and later for a descriptive study on college nutrition. These software skills proved critical when students completed their self-selected inquiry projects, as they were required to gather data and produce appropriate graphs. In addition, Amy provided students with individualized written feedback on their coursework and formative reflections as a way to provide support and direction to students for improving their work, and to answer questions or concerns they posed in their reflections.

Nicole and Gayle served as critical friends for Amy by critiquing her relational pedagogy practices, her interpretations of students' work and her emerging, iterative instructional plans (Shuck & Russell, 2005). Nicole acted as a critical reflective partner for Amy's interpretations of students' learning and their needs; she posed questions and propositions for Amy to consider as alternative interpretations of students' coursework and she provided Amy with feedback on her instructional plans. With an eye towards the overarching goals of the self-study, Gayle posed critical and provocative questions regarding Amy's interpretations regarding her ability to leverage relational pedagogy effectively. Gayle challenged Amy's assumptions about relational pedagogy and shared authority in the classroom and she offered suggestions for Amy to consider in the evolving framing of her own practice.

The second phase of data analysis took place after the course. All documents were compiled and organized and then analyzed by Amy using thematic analysis (Glesne, 2006). Data were coded based on the three purposes outlined for this self-study: (1) students actively constructing scientific inquiry knowledge and skills, (2) sharing authority over the direction and focus of science learning and (3) actively participating in dialogical, interactive science discourse. Once data were coded, segments of data were then segregated by codes for further analysis and description. For instance, Amy analyzed formative reflections at the end of the semester to discern trends/changes to her and students' ideas about science inquiry teaching and learning. Audio-recorded class discussions were evaluated to determine trends and/or changes to her practice, specifically her role in the classroom and the ways in which she supported interactive, dialogic discourse. Students' self-selected inquiry projects and final course reflections were analyzed to determine the extent to which the course was meaningful or useful for helping students discover the importance of science in their daily lives. Nicole also acted as critical reflective partners with Amy during the second phase of data analysis. Nicole reviewed data sources, Amy's analysis, and the themes that emerged. Nicole suggested additional themes, and she offered feedback on framing the findings of the self-study. In particular, Nicole encouraged Amy to bring her own voice forward in the findings and more clearly explicate how her teaching reflections affected her thinking about and framing of her classroom practices (Shuck & Russell, 2005).

Validity and Reliability

According to Loughran and Northfield (1998) and Feldman (2003), reliability and validity of self-studies are enhanced when the report includes sufficient detail on the complexity and context of the situation to "ring true" for the reader; demonstrates triangulation of data and a range of perspectives on the issues; and makes explicit the relevant educational literature. Moreover, Feldman (2003) contended validity of self-study is enhanced when teacher educators provide evidence of shifts in their practices, their beliefs and assumptions about teaching. We attempted to enhance the validity and reliability of this self-study through analysis of multiple data sources. Moreover, data analysis was iterative and took place during and after the course ended. During data analysis, Amy shared her preliminary findings with Gayle and Nicole, who reviewed her themes and provided alternate perspectives on the meaning of the data. Collectively, this analysis and its review informed the final set of themes outlined in the findings below. Last, Amy demonstrated changes in her assumptions and beliefs regarding relational pedagogy in the findings and discussion.

Findings

The findings presented below are based on their connection to the three purposes of this self study, which were to leverage relational pedagogy in ways that promoted students to actively: (1) construct scientific inquiry knowledge and skills, (2) share authority over the direction and focus of their own science learning, and (3) participate in dialogical, interactive science discourse. Headings reflect the study's purposes with corresponding data.

Active Construction of Scientific Inquiry Knowledge and Skills

At the beginning of the semester many students described science as an unquestionable, unchanging body of facts that could only be gained through a static scientific method. As Hollie wrote at the beginning of the semester,

> I thought there was one scientific method followed in experimentation. I had always been taught all through school that there was this 'six step model' on how to do an experiment and how to come up with a logical answer. I had always been told that if you cannot use this process, then it was not really considered science" (formative reflection, 01/21/10).

I presented them with multiple opportunities to discuss the nature of science with the expectation that they might begin to question the traditional ways in which science has been presented to them. I aimed to help them understand how scientific knowledge is derived not through a static, linear process of the scientific method, but rather a dynamic process of inquiry influenced by many, often competing sociopolitical factors and the personal subjectivities of scientists. In their final course reflections, several students stated that their ideas about science had changed as a result of the course. Melanie explained, "Science is a field of discovery that relies on observations, both qualitative and quantitative. Science can be subjective and change throughout time. I [once] thought science was objective and definite" (summative assessment, 4/29/10). Laura reiterated the idea that science was about investigating and gathering evidence:

> Scientific inquiry means investigating a question you have about the word around you in a logical way. You follow some sort of procedure, although this procedure may differ from that of others, and find evidence to support (or not support) an idea that you have. Then you use the information to draw inferences and conclusions about what you investigated. It is not confined to a lab (like I had envisioned at the beginning of the semester) and there is no set method like I used to think there was. (formative reflection, 4/29/10)

Students showed a more comprehensive understanding of the nature of scientific inquiry across the semester; this understanding was documented in their performance in class activities and their writing. To help them acknowledge the development of their own inquiry knowledge and skills, I often asked them to reflect on inquiry at the conclusion of an instructional activity, as shown in Table 3.1.

Table 3.1 Students' understanding of scientific inquiry exhibited in reflections at the end of instructional activities

Instructional activity	Students' reflections on inquiry
Oil spill activity	"In this activity, I **proposed explanations based on data** because in my letter I used data from the graphs to explain where the oil came from." (Kristina, 02/02/10)
	"We **proposed possible explanations based on data** when we looked at each graph and everyone was allowed to express their own ideas about what the data on each location meant." (Chelsea, 02/02/10)
	"I used **observation and inference** when I observed the data on the graphs and drew inferences about what the data means. I also **exhibited curiosity about the natural world** by trying to understand the different components of crude oil and how that would help me understand where the oil came from." (Emma, 02/02/10)
Nature study I	"While **observing** the different plants, I had to observe characteristics in order to differentiate between plant types." (Jake, 04/05/10)
	"We **gathered data** with the different probes and **made connections** between quantitative data (temp., UVB, salinity, etc.) and the environment's characteristics (canopy, surface, etc.)." (Sarah, W., 04/05/10)
	"We **collected qualitative and quantitative data**. We used **observation and inferences to make claims**." (Kortney, 04/05/10)
Nature study II	"We **identified plant species** based on physical characteristics and **used our previous knowledge** gained from other nature study activities." (Sydney, 04/07/10)
	"I was able to **organize the data** I had collected and **draw conclusions** about the site based on the trends in my graph." (Nick, 04/07/10)
	"We **gathered and analyzed empirical evidence** when we used our quantitative data to figure out the percent cover of each species and determine the averages to draw conclusions about the trends [in data]." (Kelsey, 04/10/10)

Inquiry process skills are highlighted in *bold*

Sharing Authority in Science Teaching and Learning

Although I had planned curricula prior to the start of the course, I allowed enough flexibility in class schedule to accommodate instructional changes. This was important to the goals of my self-study as I hoped to respond to students' personal interests and inquiry questions as a means for promoting authority in their science learning. To do this, I shaped day-to-day course activities based on students' feedback from formative reflections, their course assignments, and class discussions. Table 3.2 shows a few of the instructional decisions I made based on students' feedback. When I made instructional adjustments, I explicitly stated so in class to make them aware that their feedback mattered to me.

Another way in which I promoted students' authority was the way in which I actively sought to give students the space to speak freely without seeking my permission to do so first. At the beginning of the semester, I explained my goals for class discussion with students, elaborating that I preferred only to moderate in order

Table 3.2 Examples of instructional adjustments based on students' written feedback

Students' comments and questions	My reflection and adjustments to instruction
"Is there a correlation between a school's student population, childhood obesity, and the nutritional value of the school's food offerings?" (Laura, 03/10/10)	Students were completing data analysis on a personal nutrition log and had begun to ask questions about K-12 school nutrition. I presented an activity on school nutrition in which students compared the nutrition value of actual school lunches to the USDA's nutrition recommendations for children. I provided lunch menus from one affluent suburban and one poor urban school district
"How does the food served in elementary or high schools compare to the food we eat here on campus?" (Devyn, 03/10/10)	
"Do children in other countries have the same rates of obesity as children in the US?" (Danilsa, 03/08/10)	After completing the school nutrition assignment, students wanted to know how nutrition in the US compared to that of other countries. I presented an activity in which students compared one day's worth of their own food intake (data they had collected from a previous assignment) to that of an African girl
"How do Americans issues with food problems (i.e., obesity) compare to other countries?" (Josh, 03/08/10)	
"How do scientists collect data when they aren't doing experiments in a lab?" (Alison, 02/10/10)	Near the end of the nutrition unit (mid-term), students had completed several assignments on data analysis and interpretation. In addition, the weather had turned warm and many students were looking for opportunities to spend time outdoors. I presented two assignments on field data collection for students to experience science outside of a lab setting
"Now that the weather is nicer, it would be nice if we could go outside and collect data." (Jake, 03/10/10)	

for them to empower themselves to direct the discussion. I asked them not to raise their hands to speak, but instead voice their thoughts towards their peers and allow their peers to respond. Promoting equal roles during classroom discourse was one way in which I sought to disrupt students' prior experiences with and expectations of the imbalance of power in commonly assumed in science classrooms (Carlsen, 1992, 1997). By doing so, I hoped to help students implicitly question normative teacher-student roles and create a space for them to have more authority in their learning. In my time as a teacher, I found triadic classroom discourse between my students and I stifled their independence as learners and positioned me as the sole authority. When this power dynamic was established students learn to be helpless and were reticent to make decisions about how to approach class activities without first seeking my approval. This was manifested as aversion to risk-taking during inquiry and unwillingness to cognitively engage disciplinary concepts. Instead, superficial thinking about the connection between classroom activities and foundational science concepts often prevailed in the classroom. Giving students explicit permission to engage with one another without me acting as intermediary was one way I attempted to disrupt traditional teacher-student power relations in the classroom.

Early in the semester, I worked diligently, both implicitly and explicitly, to promote students' authority in the classroom. There was some evidence early on that I might have made some headway with students. For instance, one student wrote, "I really like the energy you bring to class and asking us about our weekend and talking to us on a more equal level rather than student/teacher" (Sarah W., formative reflection, 01/25/10). In another example, I wrote in my reflective journal about an experience where students questioned the way in which I explained how to plot data during a graphing activity:

> Although I am still getting to know my students, we seem to be making small steps toward sharing authority in the classroom. Today, as I was explaining how to plot data on a ternary diagram, one student said, "I think you marking the graph in the wrong place." When I looked up at the white screen, I realized she was correct. So I invited her to come to the front of the room and help me plot the data points. For a moment, she looked at me with some trepidation, as if to say, "Do you REALLY want me to come up there?" But I urged her to come up so we could work together to explain to other students how to plot the data. Samantha and I were able to talk it through in front of the rest of the students and we plotted the first data point on the diagram. Other students began to talk to us as we continued to plot subsequent points on the diagram. This activity went much smoother than it has in the past and I felt more comfortable with a student co-teaching (and co-learning) with me as we explained the process to others. (Reflective journal, 01/27/10)

Students, too, noted that during this activity we were engaged together in the learning process. As Samantha went back to her seat, she said, "I really like how we're allowed to question you or correct you during class" (reflective journal, 01/27/10). Another student noted in her formative reflection, "When we were graphing the ternary graph, when we worked out how to correctly graph points together as a class, it was almost like you were learning it with us" (Kortney, 01/27/10).

Not all of my early interactions with students were this positive, however. Two weeks later, when moderating a class discussion, the students and I assumed our normative speaking rights in the classroom. Despite my effort to disrupt this interaction, the students and I engaged in traditional triadic discourse (Candela, 1999) in which I posed a question, a student responded and I followed up with an evaluative comment. Below is an excerpt that displays this triadic discourse as the students and I discussed an empirical study on college nutrition:

ATN: Alright, what empirical evidence did she [the author] gather and how did she get it?
S1: Well, she got it by polling, surveying the students.
ATN: OK, she got data by polling college students about what they ate. OK. What exactly did she gather?
S2: Um, food choices, which were…did you want to know what kind of…
ATN: Yeah, the kind of data.
S2: Cold sandwiches, pizza, bread, potatoes, and fries, veggies and beans.
ATN: OK. So it sounds like the data…
S3: …were the top six food choices…
ATN: …were gathered on the top six foods eaten by students. OK. So she did it essentially through a poll or survey. And it seems like maybe she gave them a list and had them decide what were the top food that they ate, right? Would you all agree with that? [Only one student audibly says "yeah."] OK, somebody besides Andreanna or Mel, please, what conclusions were drawn from the study? Yes ma'am, Laura.
S3: College students don't conform all that well to the food pyramid.
ATN: Very good, Laura. Can somebody extend on that a little bit? Yes, Anastasia.
S4: Um, college students' diets only met two of the six recommendations from the pyramid.
ATN: And which two [recommendations] were they? Did we figure that out?

S4: Uh, grains and vegetables.
ATN: Right, grains and vegetables. (Class discussion, 02/15/10)

Clearly evident in this excerpt is the back-and-forth nature of discussion between individual students and me. Students raised their hands to wait for permission to speak, everyone in the classroom was silent except for the speaker, and students' gazes were directed towards me since I had placed myself at the front of the room in a traditional teacher-authority position. Furthermore, students were clearly concerned about my evaluation of their responses, which was evident when student 2 stopped in the middle of her response to ask me if I wanted to know the specifics of data collection in the study we were discussing. Rather than giving students the space to correct or extend upon one another's responses, I tightly controlled the direction of the conversation by giving evaluative comments and asking closed-ended questions. I was so concerned that they correctly understood the nature of the study and the data used by the author to make claims that I was unable to relinquish control over group discourse. Upon reflecting on my interaction with students that day, I wrote about frustration with myself and the conflict I felt between my goals for the course and my actions:

> I tell my students that I want them to feel like they have an equal voice in this class and I really do want them to construct their own knowledge of science, rather than me transmitting the knowledge to them. But I was an utter failure today in this regard. I acted just like some of my old science professors who would just keep calling on students until he got the "correct" answer. This isn't sharing the authority at all – it's me controlling their learning rather than trusting that they will construct their own understanding through discourse with their peers. How easy it is to fall back into that role of calling on students when they raise their hand! (Reflective journal, 02/16/10)

Despite my inability early in the semester to support students' authority in classroom discourse, I continued to offer opportunities for students' to talk about their science learning in small group and whole class discussions. Near the end of the semester, small groups (three to four students) were charged with researching an environmental problem on campus through photovoice (Wang & Burris, 1994). The purpose of photovoice aligned with my goal for promoting students' agency, as it a participatory action research method aimed at documenting community issues through photos and promoting group dialogue that stimulates social change (Strack, Magill, & McDonagh, 2004). In class, each group was required to write a report and present their project to the class. After each presentation, students in the audience were expected to ask questions and provide feedback to the presenters. Stephanie, Susan, Alex, and Kortney chose to investigate campus recycling programs. The excerpt provided below is a small portion of their presentation, followed by students' comments and questions.

Kortney: So this is a picture on a floor in Teter Hall and you can see that there's plastic bottles in the trash can. So it's not just happening in the dining halls. It's happening everywhere and we do have a recycle bin near our trash room, but it's never really full.
Alex: Why should we care? This is an issue because it's not just plastic. It's also styrofoam. When styrofoam is taken to landfills it dissolves into the ground and releases CFCs, which are damaging our ozone layer. And that's a huge issue because it causing us to

receive more sunlight and that's an issue for us and cancer. And then, plastics take thousands of years to deteriorate in landfills.

Susan: An alternative is that they [RPS] could get reusable dishes and a dishwasher. People are lazy because they don't want to take the time to separate their stuff in the trash. And maybe people just don't know how much it is affecting our environment and maybe if they did know they would take the time to recycle.

Kortney: Empowering facts, um, in 1980 we were sending 150 million tons of garbage to landfills and many time those landfills were not even in the United States. But today, we are sending about 100 million tons of garbage to landfills. So recycling obviously helps, 50 million tons less than thirty years ago. But still a lot of it can be recycled. I mean 100 million tons. I can't even really fathom that…. And the fact that it takes so long for plastic to disintegrate. It's affecting us, our children, our children's children and even their children. We're sending trash to India and it's ending up in people's backyards there. What if they were sending trash to our backyards? We would have a really big problem with that. We're not thinking about others.

Susan: What can we do about it? The biggest thing that we came up with is just make yourself and others aware. You need to be conscience of what you are throwing away, separate your trash in different bins.

ATN: OK group, the class is going to react to your presentation.

S3: This is a question to you guys. I know like in sororities and fraternities I don't think we have a recycling system. I was wondering did you guys look into how much waste fraternities have?

Kortney: We talked about like all the beer cans and liquor bottles, but didn't put it our presentation.

S4: It's really easy to setup something, though, because I live in the (inaudible) and we have like our own little room that's just for recycling and whenever we have to take out our trash, we just take it down there and we have someone once a month that come to pick up.

S5: There's also a program called "Greeks go Green" and they're trying to get them to…

Alex: Well, that would be a huge improvement if they could recycle all that stuff because we know they go through so much recyclables.

ATN: So you guys have made comments that you think RPS doesn't care about recycling. Do you think that if enough of you got together and voiced your displeasure about the way in which they handle trash that they would listen and respond?

Susan: Yeah, they would have to. Or maybe if we went to the Office of Sustainability, Bill Brown, the new guy, he seems to know all about this type of stuff.

ATN: Yeah. That's a great solution!

S4: I'm all about recycling and at the beginning of the year like I would go to eat with my friends and they wouldn't sort their trash. I kept saying recycle, recycle, recycle. So if you like say to three of your friends over and over, every time you eat, to put your plastic stuff in the plastic bin…I know my friends do it now without me even asking.

Susan: And if you think about how much recyclable stuff one person goes through in a day, especially if you eat at RPS, you know one person could make a huge difference.

Alex: I think some it would be good to make posters of some of those facts about trash and recycling and put them next to those recycling posters above the trash cans in the residence halls, because I don't think most people know how long it takes for plastic to breakdown in the landfill. I think people need to be more aware of those facts. (Class discussion, 04/14/10)

In the presentation given by these young women, I acted as a moderator instead of an authority who directed the focus and content of discussion. They presented facts about campus recycling, supported their claims with empirical data, and addressed comments and questions from their peers. During the presentations, I positioned myself at the back of the classroom, which forced students to address one another directly. Further, this excerpt indicates how students understood the role science played in their daily lives. As campus residents, they were bumping up against significant environmental problems and were willing to engage in dialogue about how to alleviate these problems by shaping or redirecting human action. Prompting them to think about solutions and to actively work towards those solutions was intended to encourage them to rise above their social paralysis and think about their capacity to affect positive change on campus.

Participation in Dialogical, Interactive Discourse

I thoughtfully considered how to foster students' relationship with science when designing course curricula and choosing particular instructional techniques. Though curricula was designed to help students better understand both content and processes of science, students related that three activities were particularly meaningful for helping them understand the process of scientific inquiry: a descriptive study on college nutrition, nature study, and photovoice (see Table 3.3). In the case of the study on college nutrition, it was many students' first attempt at conceptualizing and conducting inquiry centered on a meaningful problem or question.

Pairs of students were required to devise a descriptive inquiry project on college nutrition, plan a procedure for collecting data, and devise an instrument for data collection on campus. Once data were gathered, students were asked to analyze their data and draw conclusions. Nature study activities were field-based ecology activities designed to help students understand biotic and abiotic factors that influenced the campus environment. Students gathered and analyzed quantitative and qualitative data and drew conclusions about campus ecology. The photovoice activity is explained above.

Clearly these approaches to learning science were meaningful to students because they perceived themselves as active agents of science; they were not learning about abstract science concepts from a text or lab book, but rather purposefully investigating problems or questions directly related to their personal interests. Moreover, students indicated feelings of empowerment and/or competence in better understanding science-related problems that affected their lives. Last, these activities served as a source of inspiration when they chose topics for their self-selected inquiry projects. For instance, Jamie's group investigated pollution related to construction on campus in their photovoice project (see Table 3.3). Although she formulated several potential inquiry topics, Jamie chose to investigate the effects of air pollution due to construction on human health:

> This problem is significant because but it affects people's health. The construction industry accounts for over four percent of all air pollution. Air pollution is the introduction of chemicals, particulate matter, or biological matter that cause harm or discomfort to humans or other living organisms, or damages the environment and atmosphere… Construction activi-

Table 3.3 Student reflections on selected inquiry activities

Activity	Student reflections
Descriptive study on college nutrition	"The nutrition inquiry project has been a meaningful activity. I felt this activity put my acquired knowledge of scientific inquiry to use and I felt like a real scientist. In addition to using my inquiry skills, I also learned about something that I was always curious about…" (Emily, 02/18/10)
	"The descriptive project I did with Mel was interesting because it was a hands-on experience and actually allowed me to study something I'm interested in. I got to experience science the way it should be" (Brenna, 02/18/10)
	"I liked doing our own independent study with nutrition. I liked going around campus to gather data and then analyze it. This really made me feel like a scientist, which is what I think this course is about" (Sara E., 04/28/10)
Nature study	"We went outside to different streams and areas on campus and found details about each area. It taught me how to observe and come to conclusions by studying and comparing data we gathered" (Connie, 04/08/10)
	"The most meaningful activity for me was when we went outside to all of the different locations and discussed all of the things that were there. I am particularly interested in the outdoors and it helped me to realize how little I know about it and just how big science is. I had never realized how many different plant species were in one small area." (Jake, 04/48/10)
	"I enjoyed the nature activities where we went around campus and collected data from various locations around campus. I learned so much about the wildlife on campus that I didn't know about before." (Chelsea, 04/10/10)
Photovoice	"This activity was <u>so</u> meaningful to me. I do my best to go green and talking about recycling only made me more passionate about it! I loved this activity! We should do more projects related to recycling and helping the environment." (Sarah B., 04/14/10)
	"We were able to learn about different environmental problems on campus that we might not have known about. I was able to talk about my dad and do research about how pollution from construction sites effect [sic] our health and what can be done to fix/avoid the pollution." (Jamie, 04/14/10)
	"The photovoice project on recycling that my group and I did was important because we took pictures and learned how much recycling does help. I researched about recycling and found statistics related to recycling. Because of this project I am now recycling things I use." (Alex, 04/15/10)

> ties that contribute to air pollution include: land clearing, the operation of equipment, demolition, and working with toxic materials… (final inquiry report, 05/04/10)

For students like Jamie, prior inquiry activities had served as a means for asking relevant questions and for learning necessary inquiry process skills that aid students as they conducted their final inquiry projects. I considered final inquiry projects to be the capstone experience in the class and I carefully chose activities that would help them build competence and confidence in their science knowledge and inquiry skills while also leaving room in the curriculum for them to make choices and independently take direction over the focus of their learning.

Discussion

Taking a relational approach to teacher education means that educators support prospective teachers' growth through an epistemological stance of reciprocity and the construction of knowledge in relationship with others. In addition, relational teacher education is respectful of prospective teachers' personal practical knowledge and is sensitive to the milieu in which they live and work (Kitchen, 2005a). Through relational pedagogy, I endeavored to forge connections among students, science, the community, and myself. Further, I aimed to create a classroom environment in which students acted as agents in their own science learning, specifically to develop meaningful scientific knowledge and practical inquiry skills. This self-study clarifies the extent to which I was able to reach those goals.

For me, the most facile goal was supporting students as they constructed scientific inquiry knowledge and skills. I was able to draw on my own knowledge of science concepts as well as my prior professional experience as a science educator to scaffold activities and projects that would promote their development while also leaving openings in the curriculum for them to make choices in their learning. This is not to say that being responsive was always easy. I learned, as Berry (2007) did, that navigating tensions as a teacher educator is fraught with difficulty. In particular, Berry's tensions most salient to my experience as a teacher educator were telling and growth, confidence and uncertainty, and planning and being responsive. Learning to balance my desire to simply tell them what they needed to know was contradicted by my belief that students should be provided opportunities to learn about the process and content of science. To be sure, I was confident in my ability to teach science as I had learned it – through didactic methods – and uncertain I could drive forward their scientific knowledge and skills through relational pedagogical practices. As a result, my work was undergirded by my desire to ensure course goals were met, yet remain responsive to students' interests and needs through contingent planning.

To make effective decisions about the content and focus of lessons, I worked closely with Nicole, who had more experience with teaching this course than me. Together, we made a concerted effort to devise curricula that promoted the development of students' knowledge and skills as they engaged in science topics meaningful and relevant to them. I was able to reach this goal especially with nutrition and nature studies and the photovoice project. In all three cases, students investigated science through subjects proximal to their own experiences: a personal nutrition log, a descriptive study on college nutrition issues, collecting data on the campus ecosystem, and research on campus environmental problems. Similar to teachers in Luehmann's (2008) study, I found it both demanding and time consuming to drawing in students' interests as part of my relational practices. I often made daily (sometimes minute-by-minute!) instructional decisions that I believed would support students' science learning and effectively position them to teach through inquiry in their own future classrooms. My work benefitted at least some students, as evidenced by their comments in final course evaluations. One student wrote:

> I have always disliked science throughout school, but my instructor for this course presented topics to us in ways that were interesting. We always talked about topics that apply to my personal life and it wasn't some broad subject that I care nothing about. I was able to learn a lot about inquiry process skills and I'm sure I will be using them in the future (04/29/10).

In contrast, the findings above indicate that sharing authority for teaching and learning was a difficult and hard-won goal for me. Class discussions proved most difficult for me to share authority. Clearly, I had an agenda for helping students to learn particular science concepts and this made class discussion a high stakes endeavor. The dilemma I faced lied in the fact that I had devoted instructional time to discussing an activity, project, or empirical research article as a way to promote understanding. This was evidenced in my use of triadic discourse (Candela, 1999) during discussion of a research article on nutrition. I stifled active learning by forcing my students and myself to engage in the traditional, ritualized sequences of teacher-student question and answer (Carlsen, 1992, 1997). My fear of allowing students to direct the focus of discussion was grounded in the belief that efficiency or expediency for learning science might have been diminished. I sense sharing authority is difficult for many teachers; in other words, to allow students to fully elaborate upon and explore their ideas, especially in an educational climate dominated by achievement, learning standards, and proficiency testing. Even as a teacher educator not bound by standardized exams, I still felt acute pressure to "cover the curriculum." Acknowledging concerns while being attuned to the proximal needs of students requires teacher educators to continuously and systematically reflect on the goals for learning and the means for meeting those goals. My students did not learn faster or more efficiently just because I wanted them to do so.

Only through tenacity in achieving my goals was I able to share power with students in making instructional decisions and allow them greater venues for discursive participation so as to create an open and inclusive community of learning (Hanrahan, 2005). Similar to Darby (2005), my students and I collaboratively built a supportive learning environment whereby we were able to voice our thinking, contribute ideas, and engage in communal meaning making. Fostering students as agents of science was substantiated by numerous written and verbal comments made by students who indicated increased self-efficacy with regard to process skills for conducting scientific inquiry. Similar to teachers in Crawford, Kelly, and Brown's (2000) study, I attempted to valued student voice and allowed their queries and comments to direct the focus of teaching and learning. I also presented students with multiple opportunities to engage in scientific discourse and practice – lessons focused on planning and conducting inquiry; gathering, analyzing, and interpreting data; and connecting science to the community in which students lived. This approach allowed students to take ownership for their learning and act as scientists as they investigated authentic problems and questions (Crawford, 2000).

Ultimately, I learned that I can share authority with students, but cannot totally relinquish it. To be sure, this lesson learned through self-study challenged my initial belief that classrooms can be fully egalitarian. As the teacher, it is understood by my students that as the teacher I have set of knowledge and skills that they do not yet possess. It would be imprudent, even irresponsible, to allow students to completely dictate course goals, activities for learning, or the level of performance that constitutes exemplary achievement. Brubaker (2010, 2012) explored in detail the tensions in sharing authority with students. He asserted that democratically constructing course curricula provides students with a means for empowerment, yet many students are unprepared for such participatory ideals. The prevailing pattern of authoritarian teaching in P-16 education promotes lifelong dependence on teachers for dictating the patterns and pace of learning. Moreover, Brubaker (2010) noted, "… students were not sufficiently versed in principles of curriculum development and inquiry to fathom the complexity of designing and implementing their own learning experiences for the course – certainly not from scratch" (p. 174). In light of this, asking students to continuously dictate how to proceed in the course would have been unreasonable in light of their previous educational experiences. This realization has helped me to moderate my assumptions about the utility of relational pedagogy.

Finally, the extent to which I supported students to become active agents of science is in part indicated by my ability to scaffold their work in conceptualizing and conducting scientific inquiry centered on questions and problems they found meaningful. In this regard, the findings indicated that I was able to support students and their science learning. To do this, I used what Rodgers (2006) called *descriptive feedback*. Descriptive feedback is reflection on the experience of learning; it differs from self-assessment in that it offers students an opportunity to work in partnership with the teacher by granting students the authority to voice their own experiences and contribute to classroom decisions that affect them. Providing them with opportunity to reflect on learning through daily, written and verbal reflections gave students space to provide feedback about learning strategies, hands-on activities, and objectives for the course that I in turn used to shape the next steps we took in teaching and learning science – in other words, a form of relational pedagogy. While I began this self-study with the belief that all aspects of a course could be driven through descriptive feedback, in reality, this is a demanding and time-consuming practice. The feasibility of using descriptive feedback as a form of relational pedagogy must be balanced with the competing demands of teacher educators.

Implications

The tensions outlined by Berry (2007) and explored in this self-study and a self-study by Beeman-Cadwallader, Buck and Trauth-Nare (2014), collectively illustrate the work of teacher educators in engaging, emancipatory, and equitable methods of teacher preparation. These studies remind us that fostering agency through shared authority and multivoicedness is difficult work, yet remains a viable prospect for preparing future educators for teaching an increasingly diverse student population and navigating the demanding conditions of modern public school classrooms. Relational pedagogy can be a useful construct for guiding the work of teacher educators when it is practically manifested as dialogical, interactive discourse; shared authority in science teaching and learning; and active construction of scientific inquiry knowledge and skills. Berry (2007) described this as building on experience through deliberate pedagogical structures. We argue, as Brubaker (2010, 2012) did, that cultivating a collaborative community of inquiry involves constructing relations of mutual interdependence, deriving legitimacy from recognized (personal) sources of knowledge, and confronting teacher educators' and prospective teachers' deeply rooted familiarity with authoritarian teaching. These practices provide potential frameworks for negotiating the challenges of teaching relationally and democratically.

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Chapter 4
Using Self-Study to Learn to Teach Genetics to Pre-service Teachers for Understanding and for Teaching

Eunice Nyamupangedengu

Introduction

According to Loughran (2006) teacher education has two important foci: learning about teaching and teaching about teaching. The task of the pre-service teacher (PST) is to develop knowledge and skills for teaching and how to competently apply these in practice and that of the teacher educator is to teach about teaching that is the knowledge and skills of teaching. A survey of the Self-Study of Teacher Education (S-STEP) research literature shows that the focus of most of the research that has been done was on teaching about teaching in methodology courses (e.g. Berry, 2008; Bullock, 2011; Loughran, 2006). There is very little research on teaching about teaching when one is teaching content subjects like mathematics, science and geography in pre-service preparation programmes. Central to this chapter is the argument that teaching about teaching should also happen when teaching content subjects to pre-service teachers. Teaching about teaching when teaching content subjects is important for the improvement of practice in Higher Education Institutions where the model of teacher education is such that teacher educators are also responsible for teaching content courses.

When we look at teaching in teacher education contexts, teacher educators and the students of teaching should practice what Russell (1997) describes as the 'content turn' and the 'pedagogical turn'. The content turn focuses on knowledge of the discipline of teaching such as knowledge of classroom management, higher order questioning, constructivism and cooperative learning (Loughran, 2006). The pedagogical turn is when teacher educators consciously think about how they teach the content and the messages that are conveyed by their teaching (Russell, 1997).

E. Nyamupangedengu, PhD (✉)
School of Education, Division of Science, University of the Witwatersrand,
Johannesburg 2050, South Africa
e-mail: Eunice.nyamupangedengu@wits.ac.za

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According to Loughran (2006), teacher educators and the students of teaching have been seen to focus all their attention on the content turn without paying much attention to the manner in which that content is taught; the pedagogical turn. While this observation was made in the context of teaching about teaching, I see it as also happening in contexts where teacher educators are teaching content subjects. The purpose of teacher education is to educate teachers and therefore whether you are teaching about teaching or you are teaching content subjects, both the content and how that content is taught are important as both elements influence how the PSTs will teach when they become practicing teachers. How subjects in the school curriculum are taught is important to PSTs, as most of a teacher's time is spent teaching these subjects, especially in high schools. Loughran (2006, p. 4) argues that:

> At any given time in the teaching and learning environment, there is a need to be learning that which is being taught while at the same time questioning, examining and learning about the way in which it is actually being taught: asking questions about the nature of teaching, the influence of the practice on the subsequent learning (or lack thereof); the manner in which the teaching has been constructed and is being portrayed; how the teaching-learning environment has been created and so on.

From this argument, it follows that PSTs' learning agenda should always include both learning the subject content and learning about teaching that content and the agenda of teacher educators should also always include both teaching the subject content and how that content should be taught. However, according to Loughran (2006), focusing on both agendas is not easy. For the majority of the students, focusing on content is what they had been taught to do in the 12–13 years of formal schooling. In addition, the teaching that is done in universities sometimes reinforces a focus on content while ignoring pedagogy. It should therefore be the responsibility of the teacher educator to help PSTs to focus on both agendas in order to achieve the dual purposes of teacher education. The question however is: Are teacher educators aware of this responsibility and professionally equipped to undertake it?

Recent research indicates increasing awareness of the importance of focusing on both content and how that content is taught in the methodology courses (e.g. Berry, 2008; Bullock, 2009, 2011). Unfortunately, the same cannot be said about the teaching of content subjects. Research literature shows that when teaching content subjects, teaching content is all too often the only focus of attention for many teacher educators (e.g. Garbett, 2012; Tidwell & Fitzgerald, 2004) but good teaching when teaching content subjects to pre-service teachers requires a consideration of both agendas; teaching the subject content and how that content can be taught most effectively. The objectives of this chapter therefore are to report on a self-study in which I investigated my own teaching of a biology content course; genetics to pre-service teachers. The questions that guided my study were:

1. How can I teach a genetics content course to PSTs for understanding of content and for teaching it?
2. What are PSTs' experiences of my teaching and what do I learn from those experiences?

In attempting to address the two agendas of teacher education in my teaching of genetics to PSTs, I decided to use a modelling teaching approach (see LaBoskey, 2004; Loughran, 2006). According to Loughran, there are two forms of modelling teaching in pre-service teacher preparation. The first is the "traditional" form comprising of demonstration of teaching practices from which students are expected to learn by observing the teaching that is occurring. In the second, in addition to demonstrating the teaching practices, PSTs are offered access to the thinking and knowledge underlying a particular teaching approach, teaching and learning (T/L) aids or teaching procedure (Loughran, 2006). The unpacking of the teaching process is done so that PSTs access pedagogical reasoning, uncertainties and dilemmas of practice. Loughran considers the second type of modelling to be more effective when teaching about teaching. However, when teaching a content course, it is possible that the traditional form of modelling teaching can be equally effective especially if we consider the claim by Russell (1997) that HOW we teach is the message that students get from our teaching. In the self-study discussed in this chapter, I used both forms of modelling in my teaching of a genetics course. I aimed to teach in a manner that demonstrated aspects of 'good' teaching such as effective use of audiovisual aids and use of a variety of teaching styles without explicitly revealing to students the thinking and pedagogical reasoning behind the teaching that I was doing. In some cases however, I explicitly stated and explained the pedagogical reasoning behind my teaching practices. The term 'good' is placed between inverted commas because I agree with Fitzgerald, Dawson, and Hackling (2013) that good teaching is difficult to define as what is considered good depends on the experiences and opinions of stakeholders. In this study, I viewed good teaching in a pre-service teacher preparation programme as including features of teaching which could assist and enable pre-service teachers to acquire and understand the content knowledge of genetics and at the same time to acquire skills and competencies for teaching that content. In the next section, I outline the context in which the research was situated.

The Research Context

University of the Witwatersrand School of Education (WSoE)

The WSoE was the context of the self-study that is discussed in this chapter. The WSoE uses the concurrent (CC) model of Initial Teacher Education (ITE). In ITE, there is an academic component in which PSTs study content subjects (also referred to as subject matter knowledge) of one or more academic subjects and a professional component where students study educational theory and knowledge for teaching content. In the CC model, the academic component is studied alongside the professional component throughout the 4 years of the programme. PSTs who complete this programme successfully graduate with a Bachelor of Education degree. In the WSoE, teacher educators teach both the professional component and the general component. The aim of this CC model is to give PSTs deep knowledge and conceptual understanding of content knowledge and to teach them the professional component in close alignment with the teaching of the academic component. Courses in the professional component include general pedagogy and discipline specific methodology courses. Discipline-specific methodology courses aim to show pre-service teachers how to teach a specific academic discipline or subject. An example of such is Secondary Methodology Life Sciences, a course in which topics include planning for lessons, doing practical work and different forms of assessment are taught. Although the programme delineates the teaching of methodology courses in relation to PSTs' academic majors, the teaching about teaching that is done in the methodology courses is not in most cases linked to specific content that is taught in the academic course.

The Genetics Course

The genetics course which was the focus of my self-study is a third year course offered to PSTs who are taking Life Sciences as their major and fourth year pre-service teachers who are taking Life Sciences as their sub major. It is a 6 week course allocated seven 50 min periods per week. In this course, I use three periods (one single and one double) for teaching, one period for a tutorial and the last three periods for a practical session. The genetics topics that I teach include molecular level genetics (DNA, chromosomes, genes), meiosis, genetic inheritance, genetic diseases and genetic counselling and testing. In tutorial periods students answer questions based on content from the three teaching periods with guidance from a tutor and also engage in other activities such as role playing and presentations. In the practical session, students undertake microscopy or the modelling of biology phenomena.

South African School Contexts

The focus of this study was the teaching of genetics to PSTs who were training to be high school life sciences teachers in varied school contexts (I briefly describe these school contexts as knowledge of these contexts influenced the way I modelled my teaching of genetics to these PSTs). In South Africa, schools may be located in rural settings, township settings, suburban settings or informal settlement settings. Many rural schools are poorly resourced and lack even basic facilities such as furniture, electricity and running water. Township schools and those in informal settlements are often characterized by large overcrowded classes and many learners in these schools are from poor socio-economic backgrounds. Suburban schools can be public or private. Public schools are run by the government and some of them are well managed with adequate resources and others are poorly managed. Private schools vary from high fee paying schools with state of the art equipment and resources like smart boards, data projectors and computers with internet access to medium to low fee schools with correspondingly fewer resources. The PSTs that we train can find themselves teaching in any one of these school contexts after qualification.

Pedagogical Content Knowledge: Theoretical Framework

The theoretical framework that guided my study was the Pedagogical Content Knowledge (PCK) framework originally conceptualised by Shulman (1986). I chose and adapted the PCK model of Davidowitz and Rollnick (2011). The model is divided into two sections; the upper and the lower sections. The lower section consists of four domains of teacher knowledge: knowledge of subject matter, knowledge of students, general pedagogical knowledge and knowledge of context. This lower section also includes a teacher's beliefs as an underpinning factor that influences a teacher's knowledge domains and vice versa. The knowledge domains amalgamate to produce PCK which then manifests in different forms in the classroom during teaching. The upper section of the model consists of the manifestations of teacher knowledge. The self-study that is reported in this chapter was about my teaching and students' learning in pre-service teacher preparation. Therefore, I used the PCK model described above in my context as a teacher educator. The first aspect of the framework, which is the teacher's beliefs, represents what I believe as a teacher educator to be good teaching and to be important for good teaching to occur in pre-service teacher preparation. I viewed the four knowledge components in the model as aspects that could guide my planning for effective modelling of teaching to occur. However, I expanded the knowledge components so that they could inform my investigation by considering that as a teacher educator, in order to fulfil the two agendas of teacher education in my teaching of genetics to PSTs, I needed to have knowledge of:

1. My context which is teacher education and my students' future contexts which are the schools.
2. Students in my classroom (PSTs) and knowledge of PSTs future students.
3. The genetics that I needed to teach PSTs and PSTs will teach in schools
4. Pedagogy appropriate for teaching genetics to PSTs and for teaching it in schools.

I anticipated that knowledge at these dual levels would enable me to teach PSTs genetics for understanding as well as for teaching it after qualification.

Research Design

My concern was how to teach genetics to pre-service teachers in a way that would fulfil my dual responsibility as a teacher educator; teaching content and teaching about the teaching of that content effectively. I used both forms of modelling teaching in pre-service teacher preparation as a way of teaching content for understanding and for teaching.

Participants

With the methodology being a self-study, I was the main participant. Two colleagues and 13 PSTs from the 91 PSTs in the class were also participants. Purposeful sampling of the 13 PSTs was done so that I would have participants who were representative of the diversity of PSTs in the course in terms of gender, race and ability. PSTs' marks in the course were used to determine the ability levels. A total of 33 PSTs had consented to being interviewed. Of these 33 PSTs, 13 were eventually interviewed. The details of the participants are shown in Table 4.1 below.

Data Collection Methods

As is necessary in self-study, data came from multiple sources (Samaras, 2011). The data included detailed teaching plans; journal entries of my observations during teaching periods and reflections; audio transcripts of conversations and discussions with colleagues and critical friends, videotapes of the teaching periods and interviews with pre-service teachers about their experiences of my teaching. Journaling and discussions with critical friends were continuous processes throughout the research process. Below I describe and give examples of the forms of data collected.

Table 4.1 Details of participants

Participant category	Participant description
Self	Teacher educator responsible for teaching the genetics course to 3rd and fourth year pre-service teachers
Colleagues	Tondi and Belinda (pseudonyms), professors in the Department of Science and Technology Education responsible for teaching evolution and biotechnology courses. Tondi was also one of my critical friends
Pre-service teachers	7 females: 4 African, I Indian, 1 Coloured, 1 White 6 males: 1 Coloured, 4 Blacks and 1 Indian

Descriptions of My Teaching Plans

Below is an excerpt of my planning in which I described in detail how I was going to approach my teaching. The description is an extract from my plan book. For the purposes of this study I was describing in detail my planning including my reasoning.

> *I am going to incorporate in my teaching aspects from all the four domains of knowledge: knowledge of content, knowledge of students, pedagogical knowledge and knowledge of context. Examples of these aspects include the use of assessment activities and teaching and learning (T/L) aids that students can also use in their future contexts as teachers. Instead of only using a PowerPoint presentation, I will also prepare and use charts with pictures and diagrams, the same pictures that I would show in my PowerPoint presentation just to provide a different way of presenting content to students. I will also make use of the chalkboard in some of my lectures where I will come in early and draw some diagrams on the chalkboard and make reference to these during the teaching sessions. During feedback sessions, I will also write students' responses on the chalkboard.*

The use of charts and T/L aids and simple formative assessment methods were meant to be a way of modelling some good teaching practices to pre-service teachers in a way that would enable them to learn the content and at the same time to learn about the teaching and assessment of that content.

Journal Entries

I used journaling to document my thoughts and insights as I was planning, preparing and reflecting on my teaching. Below are examples of the journal entries. The first was written when planning to teach meiosis. It was a question that I intended to discuss with a colleague.

> *How does one teach in a way that goes beyond just describing the phases of meiosis?*

Next is a transcript of the dialogue I had with Tondi in response to the question above. To put Tondi at ease, I first described how I had taught meiosis then asked how he would teach it.

> *When I teach meiosis, I just describe the different phases. How would you teach it in a way that goes beyond just describing the phases?*
>
> *Tondi: If I had been teaching this ten years ago and I wasn't thinking in detail about it, I would have taught it in the way you have just described it but now because you are asking us about it and we know that you are doing this study, it's like we are meta-thinking about it. It's like metacognition. We are thinking deeply. I would suggest that you teach conceptually working out with them what would happen if for example ordinary cells of an organism with four chromosomes in each cell are used in sexual reproduction as sperms and ova.*

I also wrote journal entries about my observations, emotions and feelings before during and after the teaching periods. Below is an excerpt illustrating my emotions after a class in which I had invited a person with cystic fibrosis to share her experiences of living with the disease. On this day, towards the end of the lecture, one student walked out.

> *Today a student walked out of my lecture when a guest was making a presentation. That was very rude and inconsiderate. This person made a lot of effort to prepare for this class and you just decide to walk out on this particular day. Was it boring? Did he feel it was a waste of time? I am going to confront him to find out why he walked out.*

Entries like the one above would be presented to a critical friend for mediation of my thoughts and my reflections on the incident. I used the term trigger incident (TI) to describe observations like the one described above that triggered something in me such as thoughts, feelings and emotions that initiated a response and also prompted me to reflect on what was happening during my teaching of the genetics course.

Dialogue with Critical Friends (CFs)

Self-study requires constant dialogue with critical friends for purposes of mediating and critiquing one's work. By including critical friends in my study, I aimed to increase my awareness of what I could have been taking for granted in my teaching. At the same time, conversations with critical friends provided opportunities for support (Brookfield, 1995; Samaras & Freese, 2006). I however faced a challenge in regard to this important component of my self-study. It was difficult to find a colleague who understood the role of a critical friend and who was willing to commit to playing that role considering not only the demands of time for watching videos, listening and reading the work but also the challenges of critiquing a colleague's work. During the study, I worked with four critical friends. Having multiple critical friends increased the chances of getting my work critiqued in time for the next session. I present in Table 4.2 below how my four critical friends were involved in this study.

The use of a diverse group of critical friends contributed to a rich mediation and critiquing process. Below are two comments from California and Nico which are an

Table 4.2 Details of critical friends and their involvement in the study

Critical friend	Designation of CF	Description of CF's participation in the study
California	A professor in Science Education	She responded to journal entries, reflections, video tapes and interview transcripts
Tondi	Professor in Science Education	He critiqued my planning, reflections on my teaching and the analysis of my teaching and PSTs' interviews
Georgia	Colleague in the Department of Science and Technology	She critiqued my teaching
Nico	Professor in English at another institution	He critiqued my teaching and responded to the interview transcripts

example of the diversity of opinions of these critical friends. These comments were in response to comments made by PSTs about my teaching.

California: *Wow! I want to know what you did in your teaching that resulted in students giving such comments. You should articulate it as it positively impacted students' learning and will likely impact the teaching of others.*

Nico: *Why are there no tensions and contradictions in your teaching to make the whole thing credible? You would need to analyse your quotations in detail to bring about the hidden meaning behind all those nice words students say about your teaching.*

The critique from California and Nico shows two extremes. California was not concerned that comments from students were entirely positive and wanted me to articulate what I had done and share with a wider audience. Nico, however, was concerned about the possible superficiality of the comments and wanted me to dig deeper into possible hidden meanings.

Video-Recording of Lectures

I video-recorded all 18 teaching periods so that my teaching could be available to critical friends for critique. The video-recording focused only on myself as some students had not consented to being video-recorded. The video captured everything I did and said. Video recordings recreated the teaching situations which offered my critical friends and myself opportunities for post-event scrutiny. The audiotapes were transcribed by a professional transcriber. After transcription, I made the videotapes and audio transcripts available to Georgia and California who had agreed to critique my teaching. On one occasion, I sat with California and together we watched a whole 1 hour video of my teaching. The questions that guided the critiquing of my teaching were formulated around my first research question. The questions were:

1. What teaching practices are evident in my teaching?
2. To what extent are the teaching practices models of good teaching?

The answers to these questions formed part of the critical analysis of my teaching by my critical friends, the results of which are presented in the findings section.

Interviewing Pre-service Teachers

I used a semi-structured interview schedule which was adapted from a practice-based research project which was running in the institution at the time and piloted it to ensure its suitability for my study. The interview schedule allowed pre-service teachers to comment on: my teaching; the course content and skills; lessons learnt; usefulness; and enjoyment. Interviews were conducted with PSTs in small groups rather than with individuals. The pilot study showed that group interviewing created a relaxed atmosphere in which the PSTs could express their responses to the course freely. In addition, responses from group members acted as a stimulus that facilitated recall by others. 12 of the 13 PSTs were interviewed in four groups. One PST was interviewed alone as she was not available at the times that other students had indicated their availability.

The Interrelationship of the Data Collection Methods

Figure 4.1 below shows how the methods used were interrelated and added up to a rich data set that helped me to answer my research questions. The arrows in Fig. 4.1 indicate how I made use of the data. For example, the arrow labelled 1 shows that I collected data in the form of teaching ideas from my interaction with colleagues. I then presented my thinking about those ideas to my critical friends for their input. The arrow labelled 2 shows I collected data, again in the form of teaching ideas, from my discussion with critical friends and applied it to my teaching. Dotted arrows indicate that only some teaching ideas from colleagues were discussed with critical friends and implemented in my teaching. The thicknesses of the edges of boxes and of the arrows are representative of the quantity of data; the thicker the edge or arrow the bigger the contribution from a particular data source. All five data sources in Fig. 4.1 have been given alphabetical codes for ease of reference in the explanation below the diagram.

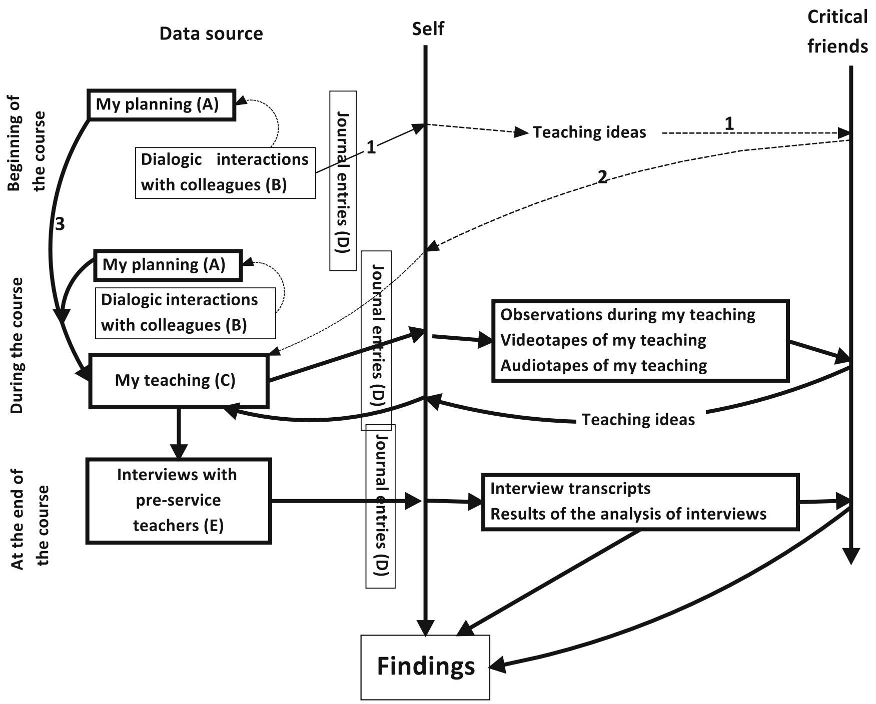

Fig. 4.1 The interrelationships between the various methods of data collection used in the study

A was my first data source and it guided my teaching. **B** was my second data source. From **B**, I developed teaching ideas some of which I discussed with critical friends and incorporated into my teaching. **C** was my third source of data from which I collected observations notes, videotapes and audio transcripts. These data sources enabled critical friends to mediate and critique my teaching. **D** was my fourth data source. I made entries in my journal of experiences, insights and reflections from data collection activities. **E** was my fifth data source. The interviews focused on my teaching which was guided by my planning and inputs from colleagues and critical friends. The different data sources contributed cumulatively to findings. For example, data from **A** and **B** fed into **C**; what happened in **C** in turn influenced what pre-service teachers said in the interviews. Being a self-study, my critical friends and I were involved from the beginning of the data collection process to the findings; hence, the two downward arrows from self and from critical friends. Although, I was at the centre of the whole study, my critical friends were also involved throughout the study supporting and critiquing my work.

Data Analysis

Analysis of Trigger Incidents

As described earlier, the events that I described as TIs were events that activated my thoughts, feelings or emotions, what Mason (2002), referred to as sensitivities and prompted me to reflect on what was happening in my teaching. I recorded seven TIs during my teaching of the genetics course. The first TI was about the responses to a teaching activity that I got from PSTs in my introductory lecture that I had not anticipated. The second was the non-participation in discussions of two PSTs Regina and Dylan. The third was the refusal by two PSTs Simba and Kuda to participate in whole class feedback sessions for fear that they would be ridiculed by fellow PSTs if their answers were wrong. The fourth was my failure to understand Fadzi's question (one of the PSTs). The fifth was when a PST (Walter) walked out during a presentation by a guest lecturer which I then perceived as rudeness. The sixth was a comment by a PST which showed his thinking that as a lecturer I no longer needed to read in preparation for lectures as I now know the content. The last was about the two PSTs Simba and Kuda who earlier in the course had refused to participate in whole class feedback sessions for fear that they will be ridiculed by fellow PSTs but later in the course participated in the role-playing activities without a problem. These are some of the events that made an impression on me and prompted me to reflect. Analysis of these TIs involved both California my CF and myself and was done as close as possible to the time when they happened. We would meet and immerse ourselves in the data (descriptions of the TIs). To guide the analysis of the TIs, we used the same questions that I used for the analysis of videotapes:

3. What teaching practices are evident in the TIs?
4. To what extent are these teaching practices models of good teaching?

During the discussion, we would identify the teaching practices and discuss them. We would also discuss my thinking and my experiences of the incidents and my CF's own thinking about the incident. After each discussion, I would record in my journal the teaching aspects identified and how they model good teaching practices. Below I use the first TI to illustrate how we analysed the TIs.

The Description of the First TI: Unanticipated Answers from Students

I used an image to introduce the genetics course. In the image were a population of people, a man and a woman coming out from the population to become a couple. From the man and the woman the image showed illustrations of meiosis, sperm and egg, and what happens from the time a sperm fertilizes the egg to form a zygote until a child is born. When I asked students to tell me what they could see in the image, I had expected straight forward answers from the PSTs; that they could see a group of people, a couple/a man and a woman, a cell, a group of cells, a child. However, the answers that PSTs gave were different to the ones I had expected. One PST said she could see reproduction taking place. Another PST said she could see that the child was different to the parents. When I got the second answer, I felt the urge to say to the PST "but you can't see that on the picture" but I decided to wait and hear all the answers from the PST. To my surprise, all the answers that the PST gave were different to the answers I had expected. These unexpected answers marked a moment for reflection.

When I presented this incident to California, the first thing she said was:

> *Before we look at what happened in this incident, what I see is that you care about the students. This is because by looking for a visual aid in the form of a picture to help students to understand the content that you were going to teach is an act of caring for the students. Therefore caring is the first aspect that I can identify from this incident. It is not a teaching practice but a human characteristic that I think all teachers should embody.*

As can be seen in California's response, the analysis was not confined to the two questions above but was open to all possibilities. After California's first input above, we went on to discuss other teaching practices that were reflected in the incident description. One such practice was that I had used a visual aid, the picture to support my teaching and PSTs' learning. The other teaching practice that I was able to identify with the help of my CF was the application of the tenets of constructivism as explained by Ausubel (1977) from the way I had used the picture. The use of the picture had helped me to identify prior knowledge that PSTs had that is linked to genetics such as reproduction and variation. The picture had also acted as an advance organiser which helped PSTs to identify important genetics concepts and the relationships between them.

The account above illustrates how the analysis of TIs was carried out. The TIs were analysed as close as possible to the time they had happened.

Analysis of My Teaching

Analysis of my teaching involved coding video transcripts. Although I was open to any interesting aspects that I could find about my teaching during the analysis process, my main focus was to find out if I had modelled teaching to PSTs that covered the four domains of a teacher's knowledge namely knowledge of context, knowledge of students, PK and knowledge of content. Therefore, I commenced my analysis with what Berry and van Driel (2013) called a priori system of codes and categories. I developed the codes from my theoretical framework and literature. Below are a few examples of the codes I developed and their definitions.

TP: **Teaching procedure**. Method of teaching that I used to bring about a teaching and or a learning activity e.g. group work in which each group member is allocated a specific role and feedback session.

TA: **Teaching activity**. What I did as part of my teaching e.g. explaining a concept, describing a process

TS: **Teaching strategy**: Describes the development of an overall approach aimed at achieving a specific behaviour, attitude or lesson in students

T/L aid: **Teaching and learning aid**: device, object, material that I used to present information to students with the aim of promoting students' understanding of the content e.g. pictures, diagrams, models and charts

Below is an example of a coded video transcript of my teaching

1. Lecturer put up some questions on the screen at the beginning of the lecture. (**Teaching Procedure**-**TP/TS**)
2. Lecturer gives instructions to students to discuss the questions in pairs (**TP**)
3. Lecturer puts up a picture on the screen- (**T/L aid**)
4. Lecturer invites students to look at the picture and asks them to say what they can see-**Lecturer Student Interaction** (**LSI**)
5. Lecturer takes responses from students and writes them on the chalk board-(**LSI**)
6. Lecturer repeats the question and waits for more responses-(**LSI**)
7. Lecturer moves on when no more responses are forthcoming-she **describes** in detail what the picture is showing-reproduction, meiosis, mitosis etc. (**TA**)

After coding the video transcripts, I assigned codes to the four categories of knowledge about teaching that I had derived from my theoretical framework namely knowledge of context, students, PK and content.

Analysis of Interviews

Analysis of interviews involved coding the transcripts. The coding was both deductive and inductive. I began the coding with the same codes that I had developed for analyzing my teaching and developed more codes as the coding progressed.

After the coding process, I created categories and subcategories. Below is an illustration of the coding process. The codes are underlined.

Servie Well after Mrs Nyamupa's lectures I think I now understand what genetics is, (outcome of my teaching practices) I understand better than high school (outcome of my teaching practices) because you know in high school I had a very very bad Life Sciences teacher (evaluation of high school teacher). The genetics course was something else. Especially when it comes to the hybrids, the crossings and stuff (description of content), the teacher used the textbook and then he would read everything from word to word (description of the high school teacher's teaching procedure) and then couldn't even interpret some of the things, (evaluation of high school teacher's teaching) so I think Mrs Nyamupa was the best ever, I understood the topic better (evaluation of the lecturer)

Agnes We were able to visually see ourselves, (outcome from practical work done) we were able to create things ourselves, to give everybody an example of what… like with the Reebop· that of just mixing it up and making something out of something, (outcome from practicals) it just made it easier to understand maybe how it works in the body and so forth (outcome from practicals)

Agnes As a teacher (identity) it's of being prepared, (outcome lesson about teaching-preparation), of not having just one example or one way of explaining something; (outcome lesson about teaching –teaching technique) there was multiple She used multiple ways of teaching the same concepts, (description of teaching technique) so she didn't just rely on a definition, she elaborated on it, (description of teaching technique-scaffolding) she showed us visual examples, (description of teaching technique) and as a teacher (identity) it shows me how I should teach as a Science teacher or a Biology teacher (lesson about teaching/awareness of future context)

I had 47 codes from the analysis of the five group interview transcripts. From the 47 codes, I generated four categories of PSTs' experiences of my teaching. The first category was PSTs descriptions of my teaching practices. The second category was PSTs' responses to my teaching practices. The third category was PSTs' descriptions of their identities and the fourth category was PSTs' descriptions of the knowledge they gained. All four categories had subcategories. The categories and sub-categories are all shown in Fig. 4.2 below.

Presentation of Findings

Below I present the findings from the analysis of TIs, my teaching and from PSTs experiences of my teaching.

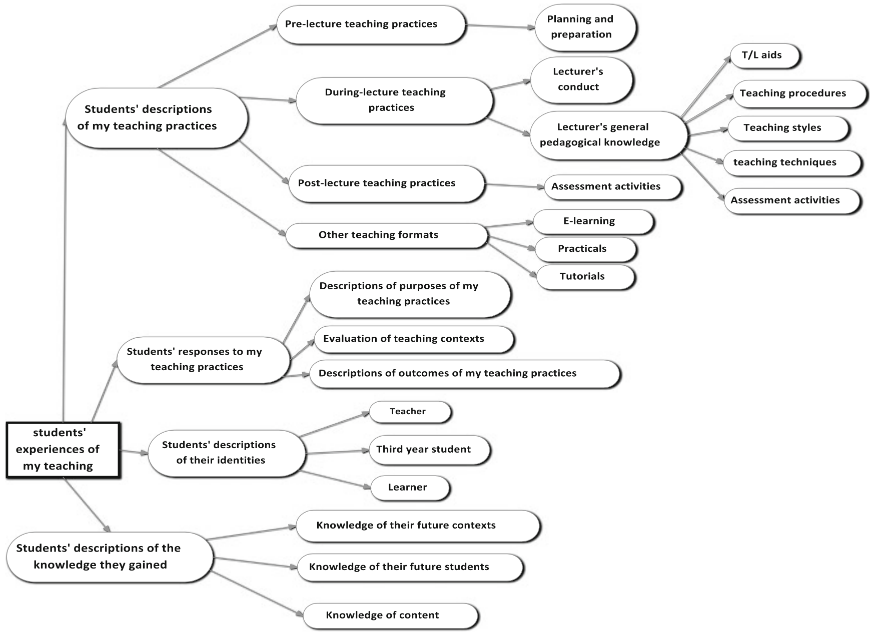

Fig. 4.2 The results from the coding of PSTs' interview transcripts

Findings from the Analysis of Trigger Incidents

California and I identified many aspects of my teaching from the TIs that could be considered cases of modelling good teaching to PSTs. Some of these aspects were easy to identify and others were subtle and not easy to see. The aspects that were easy to identify were the general pedagogical practices such as the use of T/L aids, discussions, explanations and question and answer sessions. The subtle aspects of my teaching were those that I had never thought about when I was planning and when I was teaching. These aspects were: the use of tenets of constructivism, practices that show that I care about students that I teach and that my teaching is student centred. In the illustration of the analysis process earlier on, I described the evidence that indicated that I was applying constructivism in my teaching and that I care for students. The tenets of constructivism showed in the way I had used a visual aid to find out the prior knowledge PSTs had about genetics. An attitude of caring showed in looking for an image to use in my teaching to help PSTs to understand what genetics is about. California pointed out more aspects of caring in the other TIs. For example, in the third trigger incident in which I went to listen to Simba and Kuda and gave them feedback (Simba and Kuda had refused to participate in a whole class feedback session for fear that their fellow PSTs would laugh at them if they use incorrect English or ridicule them if they happen to give incorrect responses), California pointed out that what I did showed that I cared about students:

> *You are empathetic. The fact that you went to the students despite the structure of the lecture theatre and listened to them and were able to understand their position is empathy. I again see student centeredness. Most of the times we think of student centredness in terms of getting students to be actively involved but there are other levels of student centredness … caring for students is one of them.*

In TI two, Regina and Dylan were not participating in a discussion. Therefore, I went up to them to investigate why. California pointed out that going to the students to investigate why they were not participating in the discussions, was student centredness and student centredness is an aspect of caring:

> *You were able to discover these things because you reached out to students. You wouldn't have known these things if you had not reached out to them. You do not see your position in front of the lecture room as your fixed position. You go to your students to find out, to try to know individual students at a much deeper level. This is student centredness.*

As we were going through all the TIs, we noted that the aspect of caring was featuring in all seven TIs. During the analysis of interview transcripts we noted that PSTs had also picked this aspect of caring in the way I had taught them. The utterance by Tendai shows that PSTs experienced the caring aspect that my CF had picked in the TIs:

> Tendai: *I personally really enjoyed the fact that she was always prepared. It makes a big difference, and that she put so much effort into making us understand, because she didn't have to get flowers and she didn't have to do any of those things because, I mean, she's a lecturer, and she said that this is the textbook, do it, that she could have quite easily have done that. But the fact that she always tried to get us to learn and that she was showing us more than just learning genetics…. I think that was very helpful*

The other teaching practice that my CF picked from one of the TIs was the tendency to tell students answers when they ask questions instead of prompting them so that they can get to the correct answers themselves. In TI number 4, I rushed to give an answer to Fadzi's question and later as I was reviewing the teaching with California realized that by rushing to answer the question, I had missed an opportunity to understand better the source of the difficulty the PST was facing and in the process gave an answer which, though correct was not addressing the PST's problem.

In addition to identifying teaching practices, recording the TIs and reflecting on them also helped me to understand my teaching. I became aware that the use of representations such as models, analogies and examples are tenets of constructivism which according to Cimer (2007), facilitate the development of a better understanding of abstract concepts. Furthermore, the TIs helped to clear some assumptions that I had about PSTs. For example, when Regina and Dylan did not participate in the discussions, my first thought was that they wanted to undermine my authority, only to find out that Dylan was trying to understand the content in a way that would work for him which was to go over the explanation in silence instead of discussing it with someone else. When Walter walked out of the lecture theatre during a presentation by a guest lecturer, my thinking was that he was being inconsiderate and rude only to find out that he had been emotionally affected by what was being presented. Reflecting on these TIs therefore helped me to develop a better understanding of how to best respond to PSTs' behavior during teaching sessions.

Findings from the Analysis of My Teaching

In this section, I present aspects of modelling teaching to PSTs that showed in the videotapes of my teaching. My main focus was to find out if I had modelled teaching to PSTs that covered the four domains of a teacher's knowledge namely knowledge of context, knowledge of students, PK and knowledge of content. I present my findings in Table 4.3 below using the four domains of knowledge as sub-headings.

Table 4.3 Findings from the analysis of my teaching

<table>
<tr><th>Knowledge of context</th><th>Knowledge of students</th><th>Pedagogical knowledge (PK)</th><th>Knowledge of content</th></tr>
<tr><td>Knowledge of my context-the diversity in my classrooms--e.g. knowledge of students' different linguistic abilities and schooling backgrounds</td><td>Knowledge of misunderstandings that students bring to class e.g. that interphase is part of meiosis</td><td>Use of a variety of T/L aids (pictures on the screen, charts, models, concrete materials)</td><td>Specialised content knowledge--e.g. highlighting aspects of genetics content that makes it difficult to teach and learn</td></tr>
<tr><td rowspan="6">Knowledge of my students' context- e.g. description of T/L aids appropriate for use in rural contexts and for urban contexts</td><td>Knowledge of misconceptions that students bring to class e.g. that genes are directly responsible for our features</td><td>Teaching styles (visual/auditory/active/passive etc.</td><td rowspan="6">Common content knowledge--e.g. description of the structure of DNA</td></tr>
<tr><td rowspan="5">Knowledge of genetics concepts that students find difficult to learn about</td><td>Teaching activities e.g. explaining and describing</td></tr>
<tr><td>Individual work e.g. draw, quiz</td></tr>
<tr><td>Formative assessment activities e.g. quiz</td></tr>
<tr><td>Teaching and learning activities e.g. whole class discussion, worked examples</td></tr>
<tr><td>Role-playing student to student interaction through small group discussions or discussions in pairs</td></tr>
</table>

The results presented in Table 4.3 above show that I managed to expose PSTs to knowledge of the four domains of a teacher's knowledge in my teaching of genetics.

Findings from the Analysis of PSTs Experiences of My Teaching

PSTs' experiences of my teaching fell into four categories that I could identify from the analysis: PSTs descriptions of my teaching practices, PSTs' responses to my teaching practices, PSTs descriptions of their identities and PSTs descriptions of the knowledge they gained. Examples from these categories are presented below. It was however difficult to present each category separately from other categories as they were all inextricably intertwined within students' utterances. I therefore used an integrated approach in my presentation whereby as I presented examples of PSTs' descriptions of my teaching practices, I at the same time was highlighting aspects from the other three categories.

The PSTs' descriptions of my teaching practices included pre-lecture pedagogical practices such as planning, good organization and punctuality, during-lecture practices such as the use of T/L aids and post-lecture practices such as being available for consultation and assessment activities. Munya for example mentioned planning as one of the good teaching practices that he had observed from my teaching and went on to point out what he had learnt from that practice as a future teacher:

> Munya: *I think also the key aspect that she displayed was planning. I learned that if you're going to teach learners, and make sure that they understand, you first as a teacher must first be prepared – fully prepared – and organise each and every thing that you are going to use, so that when you implement whatever plan you had, you have, you cannot be confused and will be able to clarify any misconception and challenges that you're going to encounter.*

Munya's utterance showed that first; he was looking at himself as a future teacher (identity) and second was able to focus beyond the content that I was teaching them to the pedagogical practices that I was modelling. As a result, he was able to derive meaningful lessons about teaching from my teaching. Munya went further to describe the motivation to attend lectures and the enjoyment of the genetics course that he experienced as a result of coming to know that my teaching was thoroughly planned.

> *… there's nothing that motivates me more to go to a class where you know that you're going to do something constructive. So basically, as I have mentioned that she was always prepared, that motivated me to keep on going to class each and every day, so it helped me to enjoy and love the genetics course as a whole. And also based on the practicals, like in genetics, I never thought of any practicals that are possible to be carried out within the context of genetics, so to me it was challenging to see the new strategies she came up with to try and outline the concepts within meiosis.*

The during-lecture teaching practices that PSTs described include the use of T/L aids, teaching techniques, teaching procedures and teaching styles. PSTs made reference many times to my use of T/L aids. The T/L aids included visuals like charts, diagrams on the chalk board, models and real objects like flowers and string. The PSTs did not only mention the T/L aids, they also made comments on what they thought were the purposes of using the T/L aids. Agnes for examples saw provision of concrete examples as the purpose of my use of the T/L aids.

> Agnes: … *she always had either the posters or something to refer to or hands-on materials like the strings and so forth, always just to give us concrete examples or something that we could see.*

Plackie saw my use of visual aids as bringing life to the abstract concepts and judged the use of visuals as 'good teaching strategies'.

> Placki: *Ja, when she was explaining the chromatin network and how it shortens and thickens with the different ropes like a good visual, like you could actually see it happening and picture it in yourself. And then also getting us to view the slides and identify what cells were going under what. Those were good teaching strategies and tools.*

The words 'good visual' and 'good teaching strategies and tools' show that Plackie did not only learn about the chromatin network but also examined how I had taught it and concluded that it was good. Therefore, the use of visual aids not only promoted her learning of content but also developed in her an understanding of the usefulness of T/L aids in teaching. Percy showed that he had gained pedagogical knowledge for teaching genetics from the way I had taught the course:

> Percy: *Look, I have to admit, before this course if I had to teach genetics, it would have probably been diagrams on the board, a couple of worksheets, chalk-and-talk, I might have shown them a video or two, but I wouldn't have really had that tangible aspect. From the course itself in terms of the practical activities and even from the group works and presentations I have learned techniques which I am going to use as well, and you know that's something that I think is very valuable … and for the course to then have permitted that, was good in itself.*

Percy's utterance above shows that just like Munya, he also took on the identity of a future teacher and as a result was able to learn from the pedagogical activities that they were doing in the course. Agnes showed that she disliked one practical activity that they did that was called the Reebop activity. For her, the activity was not suitable for a third year student (identity):

> Agnes: *Okay some of the activities, you'd do it and you'd be like, "okay, we could have just left that little part out", like with the Reebops, with the building of the marshmallows and everything, that for me was just a little bit maybe not for the level of the third year student. It was a good activity, just the concept, but just maybe don't take it as far as having to build the little creature.*

Percy on the other hand liked the activity.

> Percy: *Looking at the practical aspects especially the practical with the Reebop, it gives a different dimension to what can be done in terms of Biology. It makes it more fun and entertaining for if you're looking at kids – Grade Nine, Grade Ten, it sort of almost personalises*

the content to a certain extent where they can actually interact with what's happening and with Biology it's not always the easiest things because you can't give them a live animal and watch this thing mate to a certain extent, so it's a good representation, it brings the knowledge onto the learners' level.

The utterances by both Agnes and Percy showed that PSTs were taking on different identities during the course and these identities they were taking on at any given time influenced the learning they were getting from the activities they were doing.

PSTs descriptions of my teaching practices also showed that they not only gained knowledge about the different kinds of T/L aids but also knowledge about the T/L aids that they can possibly use in their future contexts which maybe poorly resourced schools.

Chipo: *I think another thing is we as teachers we are going to teach at schools which are not equipped with the resources, the resources she used, any teacher can use, anywhere. So I think it kind of teaches us to kind of use different variety of resources. For example, she used pictures, a normal picture. Any teacher can get a picture of the different varieties of cow skin. Another thing she used was the flowers, the roses, she brought red roses, yellow roses, white roses, to show us the different variations of roses, colour in roses.*

The utterance by Chipo above shows that she gained knowledge of the kind of T/L aids she can use when teaching certain genetics concepts in poorly resourced contexts. We see here evidence that the use of T/L aids was not only useful in terms of helping students to understand content but was of personal relevance to students as future teachers. Agnes gained knowledge about possible future students in the course. She felt that the course had prepared her to handle children with albinism and showed that she was aware that this is something she may encounter in her future contexts.

Agnes: *As a teacher like for example, with the albinism, we were made aware of if we have a student like that in our classroom, let them sit a little bit more in front, try and keep it a spot in the classroom where's there's not much light or whatever that's going to distract the learner or whatever and their ability to see, so as a teacher it made me it will prepare me for maybe students that may have some of the genetic mutations and so forth. So it will help me to understand my learners a bit better.*

In terms of content, because genetics is a content course and the main aim of the course is to teach students about genetics, it was expected that PSTs would gain content knowledge. However, not all PSTs experienced the content that I taught in similar ways. Margie encountered new content which she had not encountered in high school.

Margie: *I'd say the crossing part of monohybrid and dihybrid… all of that. In high school my teacher never did that, so it was new to me…She never explained anything so, ja. That's what I learned as something completely new.*

Tendai gained a new understanding of the content she had learnt in high school.

Tendai: *Well we did the structure of DNA and chromosomes, and it was actually the first time that I really understood chromosomes, I realised at school I never understood them* [*laughs*].

Ephy encountered content that was likely to confuse them as future teachers.

Ephy: *I think what I came to understand is she focussed on stuff that we would get confused, so we as future teachers know how to, if we are faced with the same confusion, we know how to engage with that information and put it to our learners in a simpler way. So she's creating understanding, making sure we understand whatever concept that she's teaching well, so when we go back to the classroom, we can teach that concept well.*

Therefore, some PSTs gained new content. Others gained a new understanding of the content that they had done in high school. Others, experienced depth to the content that they had learnt and content that prepared them to deal with confusing genetics concepts in their future teaching of genetics. The content was taught in completely new ways that helped them to understand it better. The PSTs also gained knowledge about misconceptions associated with the content they were learning and content that was useful and sufficient enough to make them feel comfortable and confident when they thought about teaching the same content in future.

Discussion

In the self-study that is reported in this chapter, I investigated the effectiveness of modelling teaching in PSTs in an attempt to address the dual responsibility of a teacher educator; teaching PSTs for understanding of content and for teaching that content. The findings from this study show that I used a number of teaching practices in my teaching as part of modelling teaching practices to PSTs. The findings also show that PSTs learnt content and ways and skills of teaching that content from the way I taught the course. The teaching practices that I used in my teaching include the use of a variety of T/L aids (such as models, charts and pictures), teaching techniques (such as questioning and the use of analogies) and discussions and feedback sessions. I deliberately used these practices as part of modelling good teaching to PSTs. The other aspects of my teaching which I identified with the help of a CF were tenets of constructivism and caring for students. I did not plan these aspects of my teaching. They played out as a result of the modelling of good teaching that I had undertaken.

The analysis of interview transcripts helped me to identify the learning PSTs had gained from my teaching. PSTs gained more than content knowledge from the genetics course. They gained some knowledge of their future contexts and their future students as well as PK. Knowledge of content, one's context, students and PK is knowledge that a teacher should have for effective teaching to occur (Rollnick et al., 2008). PSTs gained pedagogical knowledge through observing and participating in the activities that were done in the genetics course. This way of learning about teaching shows that modelling teaching when teaching content courses can be an effective way of teaching PSTs content and how to teach that content. Modelling teaching in content courses can support and develop the pedagogical knowledge that PSTs need for their future teaching of that content. According to Maduna (2002), many teacher-training institutions are failing to provide training to PSTs on how to select and use T/L aids in one's teaching. The use of T/L aids in my teaching as a way of modelling good teaching showed that it indirectly provided that training.

In this study, PSTs took on different identities during the course. They sometimes viewed themselves as learners, sometimes as third or fourth year students and sometimes as future teachers. The identities that some PSTs took on during the teaching and learning activities caused them to view the teaching and practical activities as inappropriate. The ability to recognize multiple identities enabled other PSTs to overcome similar problems. The case of Agnes showed that not all PSTs were able to see the teaching intentions behind the teaching activities that I engaged them in during my teaching of the course. This observation brings out the need for us as teacher educators to practice the form of modelling that was described by Loughran (2006) whereby in addition to demonstrating good teaching practices, PSTs are also offered access to the pedagogical reasoning underlying a particular teaching approach if they are to benefit from our teaching practices as future teachers. There is also a need for us as teacher educators to constantly remind PSTs to take on all three identities of learner, university student and future teacher in our teaching of content courses if our modelling of teaching is to achieve the twofold agenda of teacher education of enabling them to learn content as well as the skills and competencies of teaching that content.

The various aspects about content that students talked about reflect the diversity in academic background that was characteristic of my genetics class which was necessary to consider when I was choosing content for my course. I needed to consider that some PSTs' had not done biology in high school and others had not done the topic of genetics. Other considerations were in terms of PSTs' future teaching contexts. I am therefore of the idea that the choosing of content for a course should be a collective endeavour where all members of a subject in the faculty get involved. Inputs from colleagues based on their own knowledge of contexts, knowledge of students and knowledge of content is likely to build a course that will cover most of the aspects about content that PSTs made reference to during interviews.

Discussing the TIs with a friend helped me to not only confront some wrong assumptions that I had about students, for example, the cases of Regina and Dylan and of Walter but to also understand the salient aspects of my teaching. Before discussing the TIs with my CF, I was completely oblivious of the fact that my behavior in the seven TIs reflected an attitude of caring which California picked up and PSTs made reference to in their interviews. It took a CF's input for me to become aware that by doing what was described in the TIs, I was actually sending a message to students that I care about them. This finding confirms an assertion by Loughran (2006, p. 77) which says: *A shared experience with a valued other provides greater opportunity to reframe situations and confront one's assumptions about practice*. As the course progressed, I was now deliberately enacting those pedagogical practices that show that I care as part of modelling good teaching practices. Discussing the TIs with a CF also helped me to understand the importance of what Mason (2002) called noticing. To notice is to perceive or to become aware of a change in one's environment or situation (which in my case was a teaching situation) that is captured by one's sensitivities which may be emotional, physical or cognitive.

Noticing helps a teacher or teacher educator to recognize and to build on that which is problematic in practice. The ability to notice helped me to act on what I was noticing by checking with the students. In the process I got to learn that there was more to students' behavior than what I had assumed. Therefore, by checking what I was noticing or by taking some action and/or reflecting, I increased the range of meanings of what I was noticing. According to Mason (2002), a range of meanings of what one notices helps one to make informed decisions on how to act in a moment or to respond to situations as they emerge. Acting on what I was noticing also helped me to develop a better understanding of what was happening in my teaching which in turn helped me to think of teaching and assessment strategies that were suitable for my classroom context. Therefore, noticing is an important attribute that we need to develop as teacher educators as being able to notice and to act on teaching situations is a source of valuable information that can promote modelling of good teaching practices. However, noticing requires a sensitization which only develops with experience (Mason, 2002).

Conclusion and Implications

The aim of this self-study was to find out how to teach genetics in a way that helps PSTs to learn content as well as how to teach that content. This study has shown that it is possible to teach content for understanding and for teaching to PSTs and modelling good teaching is one approach that has the potential to successfully achieve this twofold agenda of teacher education. The study confirmed the assertion by Russell (1997) that how we teach is the message that students get from our teaching. The study also confirmed the suggestion by Loughran (2006) that we can teach preservice teachers about teaching by modelling teaching practices. Although Loughran made this suggestion in the context of teaching methodology courses, this study has shown that the same can be achieved in the teaching of content courses. In conclusion therefore, I argue that as teacher educators we can teach a content course for understanding and for teaching by modelling good teaching practices.

Reflections

After the analysis of my teaching and students' interviews, I presented my findings to Nico for critical feedback and validation of my findings. Below I present the comments that I got from Nico which became a catalyst for reflection. I also present my reflections on this self-study.

Comments from Nico on my teaching: *What you did is not your "normal" teaching, but something that came with a lot of effort on your part; some kind of rehearsal, you may want to say. Yes, I know, in the process you developed yourself into a good teacher. But is this sustainable; or it is just for display? Would someone not do nearly the same with the same effort?*

Comments from Nico on what PSTs said in the interviews: *Why are there no tensions and contradictions in your teaching to make the whole thing credible*? *You would need to analyse your quotations in detail to bring about the hidden meaning behind all those nice words students say about your teaching*.

There are two issues that Nico's comments bring out that are important for our practice as teacher educators. The first one is that good teaching certainly does not come easy. It requires time. As a result and as Nico said, the effort that I put into my teaching in this study may be difficult to sustain. However, what I think would be important to focus on is the evidence of classroom practice that I gathered that has equipped me with the knowledge and expertise that I can use to continuously improve my own teaching of content courses and that of others to PSTs. Therefore, while it will be difficult to sustain the effort that I put in my teaching in this study, the initiatives for continuous improvement of practice and professional development are sustainable. The second issue that Nico's critique brings out has to do with some common difficult associated with self-study research; that of academics seeing self-study research as self-indulgence. Collaboration with colleagues and literature which is a characteristic of self-study can therefore not be over-emphasized when doing self-study research. Nico's acknowledgement that in the process of doing this self-study, I developed into a good teacher also shows that there is value in self-study; that of enhancement of teaching.

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Chapter 5
Using Self-Study to Evaluate a Pedagogical Approach for Navigating Conflict in a Science Content Course for Preservice Teachers

Sarah Quebec Fuentes and Mark Bloom

Introduction

Teachers face conflicts in their classrooms and take on the role of problem solver. When issues are encountered, teachers often act in the moment: diagnosing a problem, determining a course of action, and enacting this response. Without devoting time to ascertain the nature of a conflict, however, these immediate reactions may not address the actual problem. Teachers need to reframe a problem prior to taking a particular course of action (Cuban, 2001). Through this process, teachers assess and appropriately modify their practice, thus enhancing their professional knowledge.

This self-study describes a conflict, which arose in my (second author) science content course for preservice elementary teachers, and my use of self-study in response to the situation. The conflict centered on the drastically different views held by me, the teacher educator (TE), and the preservice teachers (PSTs) regarding the quality of work completed by the PSTs on a course assignment. Rather than overlooking the conflict and continuing with the curriculum schedule, I chose to critically examine my practice by exposing my assumptions, identifying the underlying sources of the conflict, and evaluating the effectiveness of the pedagogical approach used to navigate the conflict.

The present chapter provides a theoretical framework which grounds the research in teacher identity development, describes the methodology employed to examine my practice, and shares findings, which contribute to the pedagogy of science

S.Q. Fuentes (✉)
College of Education, Texas Christian University, Fort Worth, TX, USA
e-mail: s.quebec.fuentes@tcu.edu

M. Bloom
College of Natural Sciences and Mathematics, Dallas Baptist University, Dallas, TX 75211, USA
e-mail: markb@dbu.edu

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teacher education. Specifically, the chapter describes my use of reflection activities as a mode of inquiry to understand the problem from multiple perspectives, to assist in navigating the classroom conflict, and to identify and manage the tensions in my practice.

Theoretical Framework

Identity can serve as a theoretical framework to understand the developmental stages through which PSTs progress for the purpose of guiding TEs' course design and instructional decisions. In other words, the TE can make informed decisions of when and how to adjust his practice to accommodate the PSTs' current positions in the progression of their professional identity development. There is a significant body of research with respect to identity generally falling into two different camps: the psychological development of self and the social development of identity (Roeser, Peck, & Nasir, 2006). For the present self-study, as recommended by Hamman, Gosselin, Romano, and Bunuan (2010), the TE examined his practice while considering his PSTs' development in the context of the social construction of identity. In particular, two constructs are integrated: possible selves (Markus & Nurius, 1986) and figured worlds (Holland, Lachicotte, Skinner, & Cain, 1998). In conjunction, they guided the structure of the aforementioned course, which focused on developing teacher knowledge, a critical component of teacher identity. Further, throughout teacher identity development, PSTs encounter various obstacles. The nature of such obstacles offer insight into how TEs can modify their practice to help PSTs continue in their professional identity development.

Identity is the way in which someone perceives oneself (Horn, Nolen, Ward, & Campbell, 2008). Therefore, a teacher's identity reflects the views of oneself as a teacher (Lasky, 2005). These images are evolving and are influenced by PSTs' experiences as a student and their coursework, fieldwork, and student teaching during their teacher education program (TEP). PSTs negotiate their teacher identity as they integrate these experiences. This negotiation involves the development of a collection of potential teacher identities or possible selves. Possible selves stem from a person's past and reflect views of oneself in the future incorporating one's purposes, hopes, and concerns (Markus & Nurius, 1986). Although there have only been a few efforts to use the theory of possible selves in the context of the identity development of teachers, Hamman et al. (2010) argue that the theory is particularly applicable to individuals new to the field as they transition from student to teacher.

In TEPs, PSTs are in the process of developing a professional identity, which, in contrast to possible selves, is a more consistent view of oneself as a teacher (Ibarra, 1999). To transition to this more established professional identity, PSTs experiment with provisional selves (possible selves that are actually explored) (Ibarra, 1999). At first, the provisional selves are responses to new experiences and expectations as PSTs progress through their TEP; some of the provisional selves are incorporated into PSTs' professional teacher identity (Ronfeldt & Grossman, 2008). Ronfeldt

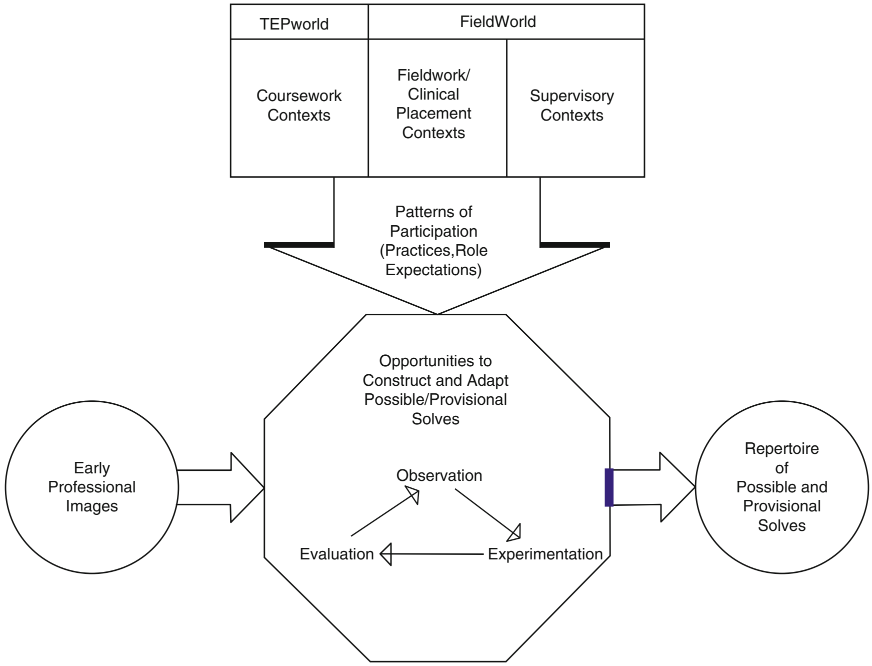

Fig. 5.1 Modification of model of the identity adaptation process for preservice teachers (Ronfeldt & Grossman, 2008, p. 43). [Used with permission of Caddo Gap Press.]

and Grossman (2008) adjusted Ibarra's (1999) model of the identity adaptation process for business professionals to show this transition for PSTs (Fig. 5.1).

The model reflects the process of PST identity development during a TEP. The circle on the left represents the early professional images that PSTs bring with them to their TEP and have been developed through their years of experiences as students, which Lortie (1975) calls the *apprenticeship of observation*. The top three rectangular regions represent the different components of TEPs (e.g., coursework, fieldwork, and student teaching). These three components along with the early professional images result in the development of possible selves through observation. The possible selves are tested through *approximations of practice* such as role playing in course work, working with a small group of students in a field experience, or taking over instruction during student teaching (Grossman et al., 2009). The PSTs then evaluate these provisional selves through self-assessment and feedback from others. As PSTs complete their TEPs, they enter the teaching field with a set of possible and provisional selves that they have gained via the repeated, cyclic process of observation, experimentation, and evaluation.

One of the challenges that PSTs face during this identity development process is the contradictions that exist between coursework and field placements (e.g., Feiman-Nemser & Buchmann, 1985; Horn et al., 2008; Smagorinsky, Cook, Moore, Jackson, & Fry, 2004; Walshaw, 2004; Wideen, Mayer-Smith, & Moon, 1998). For example, a methods course in science may promote inquiry-based learning; however, in the field, students observe teachers using a direct-teach model. The two settings represent different *figured worlds*; that is, each is a sociocultural space with its own distinct set of norms, goals, and values connected to the role of the teacher and the act of teaching (Holland et al., 1998; Roeser et al., 2006).

Horn et al. (2008) label these two worlds as the teacher education program world, or TEPworld, which represents the coursework component, and the FieldWorld, which represents the field experiences of a TEP. As demonstrated in the previous example, Horn et al. found that the methods to which the PSTs are exposed in the TEPworld were not necessarily in alignment with, or a feasible practice in, the FieldWorld. However, navigating the contradictions between the two worlds had the potential of resulting in learning. The PSTs who successfully negotiated the contradictions between the two worlds, or experimented with possible selves, built a collection of provisional selves in the development of their professional identity. On the other hand, PSTs, who did not experience challenges or encountered too much frustration and gave up on the practices promoted in the TEPworld did not have the opportunity to try out possible selves and reduced their opportunity to reflect upon and revise their practice. The underlying message is that challenges, monitored by TEs, are a critical part of learning, or professional identity development.

The focus of research with respect to identity development changes, and is influenced by, the career stage of a population of teachers (i.e., PSTs, student teachers, novice teachers, etc.) (Beijaard, Meijer, & Verloop, 2004; Rodgers & Scott, 2008). The aforementioned research concentrates on the obstacles to identity development of PSTs who were well into their TEP and were already experiencing the FieldWorld; that is, they were simultaneously residing in both regions at the top of Fig. 5.1. The challenges that these PSTs face are distinct from those they experience at the outset of a TEP as they only reside in the top left region of Fig. 5.1. Since the PSTs are just entering the TEPworld, their repertoire of provisional selves is minimal and most of them stem from one source, their experience as K-12 students. By contrast, later in the TEP, their provisional selves derive from multiple sources including experiences as a student, TEP course work, and field experiences. In addition, the PSTs have not yet entered the repeated cycles of constructing, experimenting, and evaluating provisional selves. Little research in the area of identity development has been conducted with PSTs at this early stage of their TEP.

Ma and Singer-Gabella (2011) acknowledged this need to examine how PSTs with minimal exposure to teacher professionals start to build a collection of provisional selves. Specifically, they used the framework of figured worlds to explore PSTs' identity development while they were enrolled in a mathematics course for elementary teachers. Unlike the participants in the Horn et al. (2008) study, these PSTs had limited access to the FieldWorld. The PSTs were exposed to the figured world of reform mathematics pedagogy exemplified by high-level tasks, which require active engagement of students in problem solving and communicating their reasoning. In this context, the instructors positioned the PSTs, through approximations of practice, sometimes as learners and other times as teachers of mathematics. Ma and Singer-Gabella (2011) found that while some PSTs willingly assumed the different roles, others resisted and maintained the identity of a student in a college course.

The struggles in helping the PSTs start to take on a teacher identity described in the Ma and Singer-Gabella (2011) study reveal the induction into the TEPworld from the StudentWorld (Quebec Fuentes & Bloom, 2011). The StudentWorld has two components; it consists of the PSTs' past educational experiences, termed the RealWorld (Horn et al., 2008), and the PSTs' role as student in a course. The PSTs' StudentWorld experiences influence their identity development in two ways. First, the initial repertoire of provisional selves brought to a TEP by the PSTs is limited to their experiences as students. Second, many PSTs new to a TEP have not been expected to simultaneously participate in a course as a university student and to consider the classroom activities from the perspective of a teacher.

Expecting the PSTs to take on dual-roles in such a class, as they work towards developing their professional identities, presents challenges that can result in various tensions in the TE's practice. Berry (2007a, 2007b) proposes a conceptual framework, centered on tensions, for the practice of TEs. In the context of teacher education, Berry (2007a) describes tension as the "internal turmoil experienced by teacher educators as they found themselves pulled in different directions by competing pedagogical demands in their work and the difficulty they experienced as they learnt to recognize and manage these demands" (p. 119). Through self-study of her practice as a biology TE, Berry identified six tensions. Although articulated as six unique tensions, multiple tensions may be evident in an incident. For instance, the present self-study exemplifies the confluence of three tensions: *safety and challenge*, *telling and growth*, *confidence and uncertainty*.

Telling and growth refers to the tension that exists as a TE struggles with the desire to tell the PSTs what they need to know about teaching, and alternatively providing opportunities for the PSTs through which they can personally build an understanding of the complex nature of teaching and learning. Further, early in TEPs, PSTs can possess a limited repertoire of possible selves, which is primarily informed by their experiences as a student. As such, TEs can experience tension regarding how to adopt a pedagogy that is contrary to what PSTs might expect and may seem unfamiliar and challenging to them. Utilizing a new and unfamiliar pedagogy can result in another tension: *safety and challenge*.

Safety and challenge refers to the tension that a TE must manage when challenging PSTs with learning activities that confront their preconceived perceptions of teaching and learning. The TE must simultaneously balance challenging experiences with a safe environment so that the PSTs can successfully navigate through and learn from the discomfort. If the TE provides too safe an environment, PSTs are denied experiences through which they can demonstrate learning. Alternatively, if the environment is made too confrontational, PSTs can shut down and learning will cease. However, if the TE successfully manages this tension, the challenges can be valuable learning experiences (Daloz, 1999; Horn et al., 2008; Kegan, 1994).

Confidence and uncertainty refers to the tension TEs experience when exposing their vulnerability, while dealing with the messiness of teaching, and also maintaining the PSTs' confidence in them. Uncertainty is inherent in trying novel pedagogical approaches, and should be exposed to PSTs. However, TEs must demonstrate confidence in light of such uncertainty to maintain the trust of the PSTs during the experiences. In this way, TEs model to the PSTs how to maintain confidence in their own ability in light of the messy and complex nature of teaching.

These three tensions were revealed through the conflict that occurred in my science content course for preservice elementary teachers, early in their TEP. The purpose of the present self-study is to examine how I changed my practice in response to the conflict. The overarching question addressed was: How can I use reflection activities to navigate the conflict? In order to address the conflict and assess my practice, I also needed to answer the following subquestions: (1) What were the underlying sources of the conflict? and (2) In what ways did my change in pedagogical approach help resolve the conflict?

Methods

Self-study has developed in response to the need for teacher educators to examine their own practice of teaching about teaching (Loughran, 2005). It is influenced by and has emerged from other domains including practitioner research, action research, and reflective practice (Russell, 2004) and examines "the learning from experience that is embedded within teachers' creating new experiences for themselves and those whom they teach" (Russell, 1998, p. 6). Self-study is considered a methodology, and, although there are no specific guidelines to follow (Loughran, 2005), self-study has various defining characteristics. The impetus for action in self-study is the contradictions sometimes found between what one intends and the reality of one's experiences (Loughran & Northfield, 1998). Self-study methodology focuses on improving/transforming practice through reflection substantiated through the analysis of data. It is personally situated in one's own classroom teaching and involves interaction with past experiences and literature as well as collaboration with peers and PSTs. Further, self-study utilizes rigorous and transparent qualitative methods establishing the trustworthiness of the findings. Last, self-study research should be made public so as to contribute to the pedagogy of teacher education (LaBoskey, 2004; Samaras, 2011). The present study meets these criteria.

Context and Participants

The self-study was focused on my practice in a science content course for preservice elementary teachers. My course objectives were to increase PSTs' science content knowledge for teaching; to develop PSTs' ability in accessing, interpreting, and assembling science content knowledge from various sources for use in instruction; and to allow the PSTs to engage in approximations of practice through peer-teaching. In repeated cycles, I engaged the PSTs in specific scientific topics (e.g., tsunamis/earthquakes and ecological food webs) via film clips, Youtube videos, children's books, or other media. After each engagement, I challenged the PSTs to investigate the topics further by responding to guiding, open-ended prompts and questions. The PSTs used Internet searches, textbooks, and other academic resources to inform their investigations. Working in groups, the PSTs explored the topics and prepared presentations of what they learned. For each investigation cycle, one group was selected to present their findings to the class and answer questions that arose from the other groups and me.

Science for Elementary Teachers was a required course for preservice elementary teachers prior to their official entry into the College of Education. Traditionally, PSTs enter the College in their junior year and, therefore, most of the PSTs in this study were enrolled in their freshman or sophomore year. This course often marked the PSTs' first interaction with the College of Education, as it was one of their first education courses.

At the time of the current study, there were 24 female PSTs enrolled in the course. I was in my third year of teaching within the TEP. Prior to this position, I had over 9 years experience teaching in colleges of science and engineering. Along with Science for Elementary Teachers, I also taught methods courses for elementary, middle, and secondary science and graduate level education courses. In addition, I had over 7 years experience conducting professional development for elementary, middle, and secondary science teachers. I personally designed and developed the course, Science for Elementary Teachers, and, during the current self-study, was teaching it for the fourth time.

Data Sources and Analysis

I used multiple data sources to evaluate my practice; seek out my assumptions, which were contributing to the conflict; and allow me to make improvements to my practice in order to manage the conflict. In this section, I briefly summarize each of the data sources and provide the general storyline of the study. In the subsequent sections of the chapter, I elaborate on the events that occurred and include more details about the various data sources.

- PST Coursework: PSTs completed group reports on specific science content areas stemming from prompts that I provided. One of the investigations, the center of the conflict, is presented in detail later in this chapter. For each investigation, the members of one group presented their understanding of the content to the class. Throughout the semester, I assigned six investigations.

- PST Journal Responses: PSTs responded to two sets of reflective prompts. I assigned the first set of prompts immediately after the conflict surfaced to elicit the PSTs' perspectives about the conflict. I assigned the second set of prompts later in the semester to assess any change in perspectives. Both sets of prompts appear later in the chapter.
- Class Discussions/Activities: I modified my course plan to navigate the conflict. Specifically, I conducted two whole-class discussions to debrief on the PSTs' responses to each set of reflective journal prompts. Between the two journaling assignments, I designed and implemented three activities to address some of the core issues surrounding the conflict.
- Class Sessions: All class sessions, including the investigation presentations, whole-class discussions, and course activities, were documented through field-notes and video recordings. I used the transcripts of the video recordings as evidentiary documentation of the events that occurred throughout the course.
- TE Journal: After examining the PSTs' responses to the first set of journal prompts, I documented my thoughts via journal writing. In particular, I responded to the PSTs' perspectives about the conflict by considering my views, assumptions, and practices.
- Peer Consultation: My colleague (first author) served as a critical friend. She taught the corresponding mathematics education courses for the same population of PSTs and was, therefore, familiar with the PSTs' development throughout the TEP, my course, and its underlying philosophy. She brought a unique perspective to examining the conflict since her background was in a different content area. I engaged in frequent conversations with my critical friend about the conflict, the PSTs' perspectives, the tensions that emerged in my practice, and my pedagogical decisions and the outcomes of those decisions.

The self-study progressed in an iterative fashion using data analysis to continually identify the conflict between my PSTs and me and inform and evaluate the changes in my practice namely the subsequent reflection activities that I employed to mediate the conflict. The self-study initiated after a conflict arose between the PSTs and me, in response to one content investigation. I asked the PSTs to reflect upon their work and respond to a set of journal prompts. In collaboration with my critical friend, I evaluated the PSTs' journal responses in order to identify the nature of the conflict. At the encouragement of my critical friend, I reflected upon my part in the conflict, examining my own perceptions. I used reflective journaling to scrutinize my teaching practices, my assumptions, and my approaches to dealing with the conflict. A deeper understanding of my perspectives, and those of the PSTs, informed my instructional decisions about class discussions and activities. After implementation of these modified practices and subsequent content investigations, I asked the PSTs to complete another journal response, which was analyzed to identify and document the implications of the changes in my practice.

My critical friend and I utilized the constant comparative method (Glaser & Strauss, 1967) to analyze the PSTs journal responses. To initiate the analysis, we, along with three graduate students, each read a subset of the first set of journal responses in order to identify preliminary codes. Two analysts coded each of the 24 journal responses. After coding, we all discussed and refined the codes, identifying three salient themes: grades, components of a quality response, and need for guidance. My critical friend and I then re-analyzed all 24 sets of journal responses using the identified codes. I then utilized the identified codes and themes to frame my own journaling about the conflict and my pedagogical choices for the course. In addition to the codes that stemmed from the analysis of the first set of journal responses, my critical friend and I identified new codes in the process of analyzing the second set. The codes fell within two different continuums: understanding instructor expectations and developing teacher identities.

Since self-study has roots in action research, I utilized Anderson, Herr, and Nihlen's (2007) validity/trustworthiness criteria. For example, I established *dialogic validity/trustworthiness* through consultation with my critical friend. By soliciting the PSTs' perspectives and considering them in light of my own, I met the criteria for *democratic validity/trustworthiness*. Instead of merely identifying the problem, I adjusted my practice and evaluated the changes I made to ensure that I addressed the conflict; these actions achieved *outcome validity/trustworthiness*.

Learning Through the Self-Study Process

Prior to the Conflict

As discussed, the major assignments of the course were cyclical content investigations that were assigned to small groups of PSTs. My journal about the course describes my expectations for the PSTs' improvement on these assignments over the semester:

> When it comes to measuring student learning, I do not focus on individual assignment grades, but rather pay attention to the quality of the student work over time as indicative of how the students are growing in their ability to meet course objectives … In addition to the grades, written comments throughout the reports indicate when and how expectations are met or exceeded. Conversely, when expectations are not met, comments indicate how responses are deficient, and suggestions for improvement are offered. … my ultimate goal was for them to exceed expectations and produce elegant knowledge packets that reflected the knowledge needs of teachers.

The initial investigation focused on hurricanes, and I used it to introduce the PSTs to the investigation cycle. To engage the PSTs in this investigation, I drew upon a local newscast weather report that was describing the ongoing storms resulting from a current hurricane forming in the Gulf of Mexico. I then gave the PSTs a series of questions about hurricanes for them to investigate (e.g., How do hurricanes form? Where, globally, are hurricanes most common? What causes "hurricane season?").

For the second investigation, I showed the PSTs a clip from *Finding Nemo* (Stanton & Unkrich, L. (Directors), 2003) that depicted a variety of ocean animals living in a community. I assigned each group of PSTs a different organism and provided prompts to guide their research (e.g., Describe the life cycle of your animal. What characteristics help your animal survive in its environment?). For each investigation, the PSTs submitted a group report. On these reports, I provided feedback in the form of questions and comments to encourage the PSTs to go into greater depth (or breadth) when their answers were too simplistic (or narrow in focus). For example, in response to a group's description of ocean life, I probed the PSTs' thinking with questions such as "What makes anemones 'plant-like'?" and "What are the different stages of a shark's life cycle?" and criticized their work with comments such as "This doesn't give me a greater understanding." My goal was for the PSTs to read these comments and allow them to guide their preparation of subsequent investigations.

The Conflict

For the third investigation cycle, I engaged the class with a video and reading of *The Very Hungry Caterpillar* (Carle, 1969). Similar to the second investigation, I asked the PSTs to describe general life cycles and characteristics of a species. In contrast, the third investigation focused on a single species: the monarch butterfly. Additionally, PSTs needed to explore a new concept: metamorphosis. Specifically, the prompts for the Monarch Investigation were:

1. Describe the life cycle of the monarch butterfly.
2. Where do monarchs live?
3. How long does a monarch butterfly live?
4. Describe the migration of the monarchs.
5. Why do monarchs migrate to their winter location?
6. What specific foods do monarchs eat?
7. How does a monarch caterpillar turn into a monarch butterfly?
8. Is there anything special you would like to share about monarchs?

The results of this investigation did not reflect growth in the PSTs' ability to develop content knowledge for teaching that I expected at this point in the course. Their answers lacked content depth and included clear misconceptions. For instance, the following Monarch Investigation response demonstrates a lack of content depth:

> The change from a caterpillar to a butterfly takes place through the process of metamorphosis. The caterpillar will attach itself to a stem or leaf using silk and transform into a chrysalis. The chrysalis state of the life cycle, which is ten days long, is where a lot of change takes place, even though it is not apparent from the outside. During this stage, metamorphosis takes place, which is the transformation from a caterpillar to a butterfly. They build a cocoon, or chrysalis, where they hang upside down as they change into a butterfly. The chrysalis' color changes, as the caterpillar inside becomes a monarch. It goes from green to

> brownish, reddish, and lastly an orange color. Dramatic changes occur inside the chrysalis. The mouth parts must go from being those required for chewing, to what a butterfly will need: a straw-like tongue used for sipping nectar from flowers. And a crawling insect will become a flying insect during this stage. Butterflies are one of the most beautiful insects on earth and it is amazing that they make this transformation within days. (PSTs 2, 7, 13, 16, and 24)

The PSTs clearly attempted to construct a quality response to the prompt. They identified the process of metamorphosis, named a critical stage of metamorphosis (the chrysalis), emphasized two structural changes that occurred during metamorphosis (regarding feeding and locomotion), and described observable color changes that occurred during the process of metamorphosis. However, the PSTs did not adequately address the seventh prompt: to explain the process of metamorphosis. Had I failed to communicate the overarching purpose of the investigations?

In addition to lacking content depth, other responses demonstrated misconceptions. One group's response to the fifth prompt exemplifies one such misconception:

> The nectar supply shrinks as the air gets colder, and as this is the butterflies' main source of food, they need to leave. They are cold, and hungry, so they make the journey to where their food sources and climate will benefit themselves. Eggs will not hatch unless the weather is warm enough, because they are cold-blooded. (PSTs 8, 15, and 21)

The PSTs indicated that monarchs could not survive cold winter temperatures, when in actuality, they spend the winter months hibernating in high altitude forests where temperatures often drop to freezing or below. While the PSTs' response did explain the initial cause behind migration (following food sources), the response did not to accurately describe the final migratory location.

The group presentation of the Monarch Investigation was the flash point of the conflict. I was dissatisfied with a lack of content depth and the presence of many of the aforementioned misconceptions. Throughout the entire presentation, I repeatedly interrupted the presenters with questions. As the presenters described the stages of the life cycle of the Monarch butterfly, I interjected: "Can I stop you? … I think there could be misconceptions fostered by what you are saying." A lengthy conversation ensued during which I pushed the PSTs to explain what is occurring in the chrysalis: "So, I'm the caterpillar … I am wrapped up in this chrysalis … So, I dissolve? …I turned into liquid? … So, my arms just fall apart? … My appendage just disintegrates?" After peppering the PSTs with questions, I allowed the presenters to continue, and they turned the focus to the migratory pattern of the Monarchs exposing a misconception:

> PST11: Like other animals and insects, they avoid cold weather, so that's why they migrate, to go to warmer weather.
>
> TE: Tell me again, about warm weather; what about warm weather?

The remainder of the presentation proceeded in a similar fashion. At the close of the presentation, I inquired: "First off, what's going on today? What happened to you all today?" I expressed my perspective on the quality of the PSTs' responses: "I thought the answers were really weak compared to what we've had on the previous investigations." I also acknowledged the feeling of frustration on the part of the PSTs: "You're resistant, you won't talk." In response to these questions, PST 22 explained: "I think maybe the group who was presenting might have been a little intimidated because of you. … Because you asked so many questions and jumped on them so fast." Near the close of the conversation, I shared: "I want to go back and reflect upon what we have presented … what your tasks are … so, what I've decided to do is turn this into a reflection on my teaching. … So, with that being said … I've got to totally regroup and figure out what we do for [the next class]."

Examining the Conflict

Instead of proceeding with another investigation cycle, I decided to examine my practice to see how it contributed to the conflict beyond the surface features that manifested during the Monarch Investigation presentation. Moon (1999) suggests the use of reflection to clarify the source and examine the nature of a conflict. The PSTs, in collaboration with me, engaged in critical reflection through journal writing and class discussion. Utilizing a structured approach to journal writing (Moon, 1999), I constructed an initial reflection activity, in lieu of an investigation, consisting of five prompts to which the PSTs responded:

1. How did you feel about the way we graded the first two investigations?
2. What do you think went awry with the Monarch investigation?
3. How did my reaction (and the subsequent conversation) make you feel? More anxious or more at ease? More comfortable or less comfortable? Other?
4. How confident are you now that you know *how much* needs to be in the answers to your future investigation questions? Explain your answer.
5. What do you think about rubrics in relation to our investigations? Could they be used? If so, how? What would they look like? Explain your answer.

The PSTs' responses provided material for me to reflect upon while documenting my perspectives in my journal.

In some of their responses, the PSTs confirmed their frustration and lack of security stemming from Monarch Investigation presentation.

- I definitely feel like you and [the teaching assistant] are disappointed in us. (PST 2)
- At first I was really uncomfortable and nervous that my investigation wasn't up to the standards that you wanted. (PST 5)
- I felt extremely frustrated just because I had worked hard on the monarchs and just felt as if I was not working hard in the way you wanted. (PST 12)
- If I was up there I would have been feeling uncomfortable because my answers were being questioned. (PST 13)
- I feel that the question asked by [the TE] makes students feel stressed, like they are doing something wrong. (PST 14)

- Your immediate reaction made me feel very inadequate and sort of awkward. (PST 22)

While the PSTs' comments indicated that my immediate reaction was causing feelings of insecurity, the overarching positive and informative outcome from the initial reflection activity was my recognition that my view of the PSTs' role in the class was clearly distinct from their own. Identifying these divergent perspectives regarding the PSTs' and my expectations of the course and the course assignments allowed me to recognize sources of the conflict.

Grades

I perceived the role of the investigations as iterative opportunities for the PSTs to develop their skills at building knowledge packets for teaching elementary students. As such, feedback on PSTs' reports was intended as constructive and helpful. As I wrote in my journal: "I value the academic exchange between student (via classroom deliverables) and teacher (evaluation of them) as integral components to teaching, not as a punitive measure to devalue students who do not fully achieve my expectations." However, my objective for providing feedback was confounded by the fact that the PSTs also earned a grade on the investigations.

The PSTs' responses indicated that, despite my intentions, they were focused on their grades instead of the quality of their work that led to the grades; the latter of which would have helped them demonstrate growth in their future work and develop toward the course goal. Being graded on what was intended as a learning opportunity, the PSTs were naturally concerned about not receiving higher scores on their reports: "On the second investigation we also received a B even though in my opinion we had more than enough information and I consider our investigation #2 to be at least an A-" (PST 10). The PSTs knew they were going to be evaluated based on their performance on the investigations; one PST conveyed her concern:

> [I am] feeling really anxious about this class in general right now because I don't know what to expect as far as grading and in-class activities. I was surprised when you said that we did so much worse investigating monarchs, and I am very nervous about my grade in the class because I really want a good grade but don't really understand how to get one. (PST 24)

Based on this and similar comments, I realized that I had made the faulty assumption that the feedback given on previous assignments was providing the guidance that the PSTs needed to develop their understanding of how to adequately prepare an investigation report.

Components of a Quality Response

In my journal, I explained my expectations with respect to aspects of a quality response:

> When I evaluate the investigation reports, I look for evidence that students have developed a sophisticated understanding of the content sufficient to teach it to young learners. This, of course, entails much more knowledge than is included in student learning materials (e.g., textbooks) or what they will expect the elementary students to learn. Additionally, their answers must demonstrate an ability to critically evaluate sources of information (for accuracy and reliability) and to determine the appropriateness of the content for their teacher knowledge. To do this, they must be able to take highly varied sources of information, find the content that is pertinent and useful for conveying the overarching ideas, and construct a response that logically, cohesively, and concisely demonstrates their conceptual understanding. For example, a textbook may depict the annual migration of monarch butterflies from Canada to Mexico, but fail to explain what drives the movement … A teacher should understand the annual migration of monarchs sufficiently to link this phenomenon with changing seasons, weather patterns, and geology (all determinants of milkweed growth).

From my perspective, I deemed elegance and relevance as critical components of a quality response. However, the PSTs' Monarch Investigation and journal responses revealed a lack of understanding of the components of a quality response. Because they could not discern the requirements of a quality response, the PSTs constructed a standard for themselves: equating the quality of their answer with its quantity of information and/or their effort put into its creation. One PST articulated this approach to completing the investigations: "If you don't know what you have to do to get an A, you are just going to do the best you can and get as much information as possible because you don't know what exactly is needed" (PST 5). Another described her perception that the quantity of information in her answer was indicative of its quality: "I now know the importance of adding extra information … the extra information shows that [we] worked extra hard" (PST 14). Clearly, I had not adequately guided the PSTs to an understanding of what components were needed to construct a quality response to the investigation questions.

Need for Guidance

The PSTs desired more direct explanation of what components they needed to incorporate into their answers to investigation questions:

> I am still confused about what exactly is wrong. I question what exactly you expect out of us with these investigations … We knew we were supposed to research the questions asked, but we had to idea to what extent … We have been handed rubrics describing what the teacher expects of us all through our school years, and tend to have trouble when the guidelines are not set out for us. (PST 9)

Conversely, I wanted the PSTs to gain an understanding of what constituted a quality response over the span of the course. In my journal, I summarized my perspective on how much guidance I should provide to the PSTs when they construct responses to the investigation prompts:

> When I assign investigations, I deliberately choose not to provide a rubric on how the assignment will be graded. Instead, I want to use the iterative attempts as formative assessment of what the PSTs believe constitutes sufficient teacher knowledge. While the PSTs may perceive the first assignment as lacking direction, they quickly receive my feedback on

> ways to improve so that their subsequent attempts can demonstrate growth. When PSTs officially enter the field, they must be able to research the subjects they will be teaching, identify credible sources of information, and find ways to communicate the knowledge in meaningful and appropriate ways. …They need to be able to connect the underlying concepts of the content they teach to other broader areas of science. They are expected to do all of these things without the guidance or structure of a rubric. Indeed, they must have an *internal rubric* to determine the teacher knowledge for each topic they teach. The goal of my class is to help the PSTs develop these skills; providing a rubric to guide them would impede this goal.

Contrary to my perspective on using rubrics, the PSTs felt like a rubric was necessary to adequately complete course assignments: "I think rubrics would be very helpful. It would be easier to try to figure out what you are looking for instead of just trying to guess" (PST 23). PST 13 described the potential structure for such a rubric: "[The rubric] needs to be structured so that we know what to answer … putting a broad question and having a few key points that we must have in the answer is the best idea." I had not provided enough direction for the PSTs, and, instead of feeling supported and empowered to navigate the challenges of developing teacher knowledge on their own, their comments revealed a sense of helplessness.

Response to the Conflict

After evaluating the PSTs' and my responses to the reflection prompts, I recognized areas in which I could improve my practice and purposefully designed several activities to respond to the conflict. In the subsequent class session, I incorporated three activities to address the PSTs' perspectives: descriptive exercise, exploration of rubrics, and identification of course objectives. After these activities, the PSTs completed two more investigation cycles and a final reflection activity before their last investigation: a second attempt at the Monarch Investigation.

Descriptive Exercise

I opened the next class by guiding the PSTs in an exercise to explore the qualities of a sufficient description of a natural phenomenon. I began by stating:

> What we're doing today, we're stalling. We've stopped. We've taken a road trip, a side trip. We have diverted from our path. … it allows us to stop and rethink where we're going. … You need to figure out how to know what we [TE and teaching assistant] want. … And we need to figure out how to communicate to you what we want.

Specifically, I asked the PSTs to describe a golden retriever. After working for several minutes, the PSTs shared their descriptions. I opened a critique of the descriptions by stating: "So, let's think about those answers, and look at yours. I'm not attacking your answer. Don't think that, but I'm wanting to analyze your answer, so that we can think about what you need to put in future answers." For example, several PSTs shared their descriptions:

PST16: I put, a four-legged mammal. It has eyes, a nose or snout, a tail, paws and mouth.
…
TE: But you're just saying cat. You're right. It could be a large tabby cat, right?
PST12: Yes, you don't usually describe cats as having snouts.
TE: How would you differentiate that from a … fox?

In addition, I modeled the same exercise by sharing my own description of a Boston Terrier. After completing my description, I opened it up for critique from the PSTs. Several of the PSTs made suggestions for clarifying and enhancing my description such as defining terms (e.g., mammal and snout) and providing the origin of the name "Boston Terrier" and the breed's utilitarian purposes. My goals of the descriptive activity were to help PSTs develop an understanding of the appropriate depth and breadth of their investigation responses as well as the ability to evaluate whether their responses met these standards.

Exploration of Rubrics

In response to the PSTs' desire for specific guidelines in the form of a rubric, I asked the PSTs (in groups) to create a rubric for one of the Monarch Investigation prompts: Describe the migration of the monarchs. When I reconvened the class, several of the groups shared their ideas. One group suggested the rubric consist of subquestions that need to be addressed (Why do they migrate? Where do they go? What is the distance travelled? What is the route?). When PST 15 suggested incorporating the number of generations over which the migration occurs, PST 24 responded: "No, we didn't want to be giving the answer." Another group proposed using who, what, when, where, why, and how as a guideline. A third group recommended that the rubric include the key information I expected. PST 17 noted a potential issue with this approach: "But then … I'm just going to do the bare minimum." I mentioned that my investigation prompts had some focus (e.g., *Describe the life cycle of the monarch butterfly* rather than *Teach me about Monarchs*) but were not "too detailed, or I'm squelching the investigation." By creating and discussing potential ideas for rubrics, I guided the PSTs toward an understanding of some of the drawbacks of using a rubric. They interestingly started to think about the components of a quality response without explicit guidelines.

Identification of Course Objectives

I also initiated a discussion about the purpose of the course: "What is the learning objective of this course?" After the PSTs discussed the question in their groups, several PSTs shared their responses:

- For us to learn the information, but to learn how to teach it. … But just not the plain, basic information about something. (PST 13)
- How to provide or how to … [re]search [content] to teach science to the kids. (PST 21)
- I think it's also become familiar with the concepts that you're going to teach to an [elementary student]. (PST 19)

Building upon the last PST's response, I closed the conversation by discussing the importance of identifying the big ideas and concepts when completing their investigation responses and, in the future, when they are a classroom teacher.

Interim Investigations

After the Monarch Investigation, I initiated another that focused on tornados. I asked the PSTs questions regarding how tornados form, where they are most common, and how weather forecasters predict their occurrences. I also assigned a second interim investigation, similar to the Monarch Investigation; I asked the PSTs to describe hibernation in bears as well as the behaviors of other forest animals.

Final Reflection Activity

In the subsequent investigations, I observed improvement in the quality of the PSTs' responses. To further assess the implications of the changes that I made to my practice, I assigned a follow-up reflection journal, which consisted of the following six prompts:

1. What was missing from your report on monarchs that made me think you weren't trying very hard?
2. What was included in your most recent report that made me think you really put effort into your answer?
3. If you had to tell next semester's students what kind of answer I would be looking for, how would you characterize a "good answer"?
4. Do you feel you now know how to earn high grades on your reports? If so, what was the "turning point" for you? If not, what can I do to help?
5. What have you learned from this experience?
6. Is there anything else you would like to share with me at this point in the semester?

Analyzing the PSTs' responses to these journal responses allowed me to gain a better understanding of my role as a teacher educator. I realized that my initial evaluation of the conflict was highly focused on the students and that I was considering their performance on the assignments and engagement with the class as deficient. In other words, I was only attentive to the students' contribution to the conflict. My perception of the students' performance shifted from criticizing them to recognizing areas in which I needed to better support their development. Specifically, the PSTs' responses to the second set of journal prompts demonstrated the intricacies of student growth (or lack thereof) on two continuums (understanding instructor expectations and developing teacher identities). The PSTs are on various locations along these continuums. Part of my role as a TE is to identify the PSTs' placement on the continuums and help them progress along them. In the case of this self-study, the modification of my practice resulted in student progress, which focused my attention on my responsibility for their development. The first continuum is a critical aspect of my instructional goals for this particular course; the second continuum is applicable to all teacher education courses.

Understanding Instructor Expectations

As described, many of the PSTs did not initially understand my expectations with respect to the investigation assignments and/or the objectives of the course. Although some PSTs still had a *lack of understanding* of my expectations after my instructional interventions, others moved to having an emerging or full understanding. Some of the same misconceptions previously discussed persisted among the PSTs. In particular, some of the PSTs continued to equate quality with quantity. For instance, PST 9 wrote: "I have learned that you have to give more to everything than what is expected." In contrast, others expressed an *emerging understanding* of a quality answer, characterized by perceptive views mixed with lingering misconceptions. For example, one PST wrote:

> What was missing on our 'Monarch Report,' were answers that went beyond the questions. What I think that we finally learned, in our project specifically, was that you answer the question, but you also *add answers to your answer* … We put basic answers, but then defined words that might be difficult for little ones to understand, and we also added in some other interesting facts on top of all that … Instead of just copying and pasting everything off the internet, we actually put thought into each answer and added in information that we each found. (emphasis added) (PST 15)

This PST aptly described aspects of a quality response considering the knowledge relevant for teaching the content; however, she also had a misconception expressed in the idea of adding *interesting facts*. Several of the PSTs demonstrated a *full understanding* of my expectations for the investigations. Unlike the PSTs, who had an emerging understanding, these PSTs did not maintain any previously discussed misconceptions. For instance, one PST described her process:

> I think the most important thing to do when researching a topic is going to as many websites as possible, not just looking at one and getting all of your information from there. Also, read as much as you can about the topic before you write down an answer so that you are writing from your own knowledge about the topic instead of just what it says on the website. For your answers try to think of things to answer (even if they aren't asked in the question) about what kids might ask questions about, this way you are elaborating on your answers. (PST 5)

This PST gave a detailed description of how to search for the information *and* the importance of synthesizing the information. I wanted the PSTs to increase their science content knowledge, view science content from a teacher's perspective, and learn how to acquire, evaluate, and synthesize science content for teaching. My critical feedback on the PSTs' investigations was not sufficient to move them along this continuum of understanding my expectations. Rather, I needed to clearly identify the PSTs' positions on the continuum and implement targeted activities to help the PSTs achieve the course objectives.

Developing Teacher Identities

Understanding the components of a quality response to an investigation prompt is inextricably connected to thinking about content from a teacher's perspective. The purpose of the reflection activities was not only to remediate the PSTs' misconceptions and help them understand my expectations, but also to help the PSTs move from thinking like a student to thinking like a teacher. The PSTs, who persisted in *thinking like a student*, demonstrated many of the same perspectives that emerged after the first reflective journal assignment. For instance, earning a good grade continued to be these PSTs' primary focus. PST 1 wrote: "I feel that I now know how to earn high grades. One reason I know this is because we got a 97 on the last investigation." Not all PSTs had an internal gauge about the aspects of a quality response, but instead relied on external validation from me in the form of their grade. Some of the PSTs moved from thinking like a student to *thinking about teaching*. The PSTs indicated in their responses that they were considering their learning in the course with respect to teaching the content to K-12 students. For instance, PST 22 wrote: "This class has made me really think about how to teach to little kids instead of just having to 'present' in class." The PSTs, who were further along this continuum, were *thinking like a teacher*, considering the daily actions and decisions of teachers. For example, PST 21 wrote: "By spending more time on research and not just answering the question. I acted like I was actually planning on how to teach a science lesson by writing it out." As a TE, I expected the PSTs in this course to take on the role of a teacher (and think from that perspective). I realized that the PSTs remain students during this developmental process and that I must support them in their efforts to simultaneously understand and manage both roles.

Return to the Monarch Investigation

For the final investigation cycle, I reassigned the Monarch Investigation asking the PSTs to prepare a new report that responded to my criticism and feedback on their previous attempt and incorporate what they had learned through the interim activities. On the second Monarch Investigation, I observed more complete and complex answers to the investigation prompts. One group extensively described the migratory pattern of monarchs:

> Monarch butterflies have a distinct migration pattern that is characteristic only to them [and] takes up to three generations to fully complete. Their spring and summer homes begin to go through a change of season, and become colder and colder … This cold weather eliminates most of their food supply…Therefore, they must migrate south and west to reach warmer weather. Migration, with the first generation of monarchs, begins in Canada and the northernmost parts of the United States in late fall … with a final destination of the Oyamel forests in Central Mexico … Once they reach their roosting site, they cluster in large numbers in the branches and trunks of the Oyamel trees where they remain quiescent, or still with low metabolic rates, until mid-February … By the end of February, after living off their fat reserves all winter, only about half of the original roosting population survives and tens of millions of monarchs begin the spring migration back to their homes in Canada and the northern United States … During their return journey home, the second generation of monarch butterflies roost and reproduce, spawning the third generation of monarchs that will continue the migration into the following fall … Somehow these butterflies will fly back to the same tree in their winter home each year, even when they haven't been there before. (PSTs 10, 11, 17, and 19)

The PSTs' description explained what causes the migration to ensue, the starting point and destination, the Monarch's metabolic state during hibernation, the need for multiple generations to complete the migration, and the unique nature of this migration (as compared to other species migration). Moreover, the PSTs corrected the misconceptions that were present in the first iteration. Another group's description of metamorphosis demonstrated more sophistication:

> When the caterpillar has entered its fifth and final growth stage, many hormonal changes begin to take place … The caterpillar sheds its fifth and final skin at this point. The skin underneath … will actually start off very soft but will harden as the caterpillar hangs. This skin becomes the chrysalis. Inside the chrysalis, the caterpillar will release enzymes that actually digest the tissues of the caterpillar … There are "imaginal disks" inside the caterpillar and these are basically little groups of embryonic cell … Each little imaginal disk will form some body part of the butterfly … Every part of their body is broken down or digested and then rebuilt including the heart, the lungs, and the digestive system … This part of metamorphosis, or change, will last for about 3 to 4 days … The full transformation from caterpillar to butterfly is called holometabolism. (PSTs 5, 12, 22, and 23)

The PSTs' description of metamorphosis in this second attempt provides more depth and breadth to the explanation than was found in their initial responses.

Discussion

A major goal for PSTs as they move into a TEP from their prior StudentWorld and ultimately into the FieldWorld is for them to develop their professional teaching identity (Horn et al., 2008; Quebec Fuentes & Bloom, 2011). Throughout this progression, PSTs are provided many opportunities to experiment with provisional selves through approximations of practice (Grossman et al., 2009; Ibarra, 1999). As PSTs take on the role of teacher and achieve various levels of success and failure, they will quite naturally encounter various frustrations (e.g., Ma & Singer-Gabella, 2011; Smagorinsky et al., 2004). A key responsibility of a TE in this context is to support the PSTs through their frustration so as to prevent them from shutting down and, thus, ending the learning process as well as stifling the development of their teacher identity (Daloz, 1999; Horn et al., 2008; Kegan, 1994). In order to effectively accomplish this critical task, the TE must be able to take time to reframe the problem, and ultimately provide learning experiences to empower the PSTs to navigate through and learn from their frustrations. Self-study provides one window through which a TE can examine his practice to determine how effectively he is scaffolding the learning of PSTs (Samaras, 2011). With insight gained from self-study, a TE can modify his practice and incorporate new learning activities to help the PSTs develop.

In the context of the present study, the PSTs experienced frustrations as they transitioned from the StudentWorld to the TEPworld. The course described herein was early in the TEP and one of the first opportunities the PSTs had to experiment with provisional selves. Some of the challenges they experienced stemmed from the fact that the PSTs' provisional selves were informed by what they had seen and internalized about teaching during their K-12 learning experiences (Lortie, 1975; Quebec Fuentes & Bloom, 2011). Further, this was the first time the PSTs had to assume dual identities: that of student in the TEP course as well as future teacher. These challenges became evident in the context of the content investigation and presentation regarding monarch butterflies.

The conflict demonstrated that some aspects of my practice were not working as I intended. I decided to stop the course progression, rethink my initial perceptions regarding the PSTs' performance, and instead take time to identify the problem (Cuban, 2001) and turn the conflict into an educational opportunity. I chose to use reflection activities to accomplish this goal (Moon, 1999). Through the PSTs' initial journal responses and my reflections on them, I was able to identify the source of the conflict and the resulting tensions for my practice. The conflict was grounded in the fact that I was assuming the PSTs were operating from a TEPworld perspective while they were, in actuality, still approaching the course from the StudentWorld perspective. Through the conflict, I realized three tensions in my practice: telling and growth, safety and challenge, and confidence and uncertainty (Berry, 2007a, 2007b).

The telling and growth tension was evident in my struggle between (a) telling the PSTs what they needed to know in order to compose a quality investigation report and (b) wanting them to take my feedback and struggle to grow in their ability to self-assess the quality of their work. Being unwilling to provide clear instructions (e.g., rubrics) for the PSTs to follow led to a second tension: safety and challenge.

Because of my lofty goal for the course (to begin to move PSTs from the StudentWorld to the TEPworld) and the lack of clear direction on the major course assignments, the course was, by its own nature, quite challenging for the PSTs. My tension regarding safety and challenge centered on balancing the challenging nature of the course with a safe and productive educational environment that would support the PSTs in their teacher identity development. The Monarch Investigation served as a critical juncture in the course. The PSTs were frustrated and expressed feelings of being unsafe. This turning point allowed me to address the PSTs' concerns and work through this tension of safety and challenge to reassure the PSTs of the safe environment in which they were learning while persisting in my plans to challenge their growth. Dealing with the tension at this point in the course prevented the PSTs from shutting down and thus maintained their progression into the TEPworld.

The course activities and the approach that I took to encourage the PSTs to develop toward their teacher identity, by their own design created a challenging environment in which the PSTs felt discomfort. Taking this approach, and persisting with it in light of the two aforementioned tensions that it created, led to a third tension for my practice: confidence and uncertainty. I understood if I did not adequately support the PSTs through this uncomfortable learning experience, they could halt their learning and/or lose confidence in me. This created a sense of uncertainty for me. My tension focused on maintaining a confident demeanor while dealing with this uncertainty. Acknowledging the frustrations of the PSTs with respect to my practice in a public and transparent manner exposed this tension and simultaneously shared my vulnerability while maintaining the PSTs' confidence in my leadership.

To mediate the tensions, I used multiple means of reflection. Some of the reflection activities occurred individually while some occurred in collaboration with the PSTs and me. The PSTs reflected individually through writing responses to journal prompts that I provided. I reflected, via personal journal entries, on my teaching practices. Collaborative reflection occurred during class sessions when the PSTs and I openly shared and discussed our distinct perspectives. These reflection activities served several purposes (Moon, 1999). Initially, the reflection activities served to identify the sources of the conflict as well as the existing tensions for my practice. The PSTs' and my emotional responses needed to be rationalized. Journaling and subsequent class discussion allowed me to move beyond my initial interpretation of the event, namely that the PSTs were not putting forth much effort. The PSTs also recognized my intentions as less critical and more constructive. Further, the PSTs and I gained multiple perspectives on the conflict and better understood each other's positions.

Reflection was also used to address the identified problem for which there was no obvious solution. Using reflection, I was able to consider my practice in real-time, identify tensions in my practice, and modify my practice while still meeting the course objectives. Additionally, the modifications I made involved using reflection as a pedagogical tool. By giving the PSTs a voice in the learning process, I guided students in their professional identity development, developed a culture of trust and respect, and modeled a pedagogy of reflection.

In the final journal response, many of the PSTs' entries indicated a shift in their understanding of the course objectives and their role in the course. With respect to the investigations, the PSTs aligned with different positions on a spectrum of understanding the components of a quality response, ranging from harboring misconceptions to an emerging understanding to a full understanding. Similarly, on an identity spectrum, the PSTs ranged from thinking like a student to thinking about teaching to thinking like a teacher, a spectrum that parallels the framework by Sutherland, Howard, and Markauskaite (2010). These findings demonstrate that my approach of using reflection as a pedagogical tool was effective. I also realized my important role in the professional identity development of PSTs as well as the fact that the rate of growth among PSTs varies.

In addition to helping the PSTs grow in their identity development, I identified two more positive outcomes resulting from this self-study. As previously described, there was a significant conflict between the PSTs and me following the Monarch Investigation presentation. Through the reflection journals and class dialogues, I re-established and repaired the class culture. One PST described what she learned with respect to the classroom environment that I created through the reflection activities:

> I have also learned that the atmosphere of the class is very important and students have to feel comfortable enough to speak up when things are not going the way they think they should or they are confused about something. (PST 7)

The PSTs appreciated my flexibility by addressing the conflict and considering their points of view: "[I]t is nice to see a professor changing style and evaluating as the semester goes along and actually take students input into consideration" (PST 6). PST 17 acknowledged the importance of communication with me via the class discussions and journal prompts: "It is great to create a relationship with a professor where communication and compromise can occur on an everyday basis." I opened the lines of communication with the PSTs and provided them with the opportunity to share their perspectives through the reflection activities, thereby establishing a culture of respect and trust. This process allowed me to manage the tension between *safety and challenge* without compromising the challenging and somewhat unfamiliar nature of the course.

The PSTs not only appreciated my efforts to understand their views, they also realized the importance of listening to and communicating with their future students, especially when conflict arises. PST 1 wrote:

> I just wanted to say that at first I was sort of confused by the fact that we were taking away class time to discuss the investigation problem, but now it completely makes sense. I know this class is called "Science for Elementary Teachers" and so I was solely focusing on the fact that we weren't learning as much science, minus the investigations for the past two weeks. I now realize that this is also about being teachers in general. It has been an awesome experience because you have been a perfect example of how a professor/teacher should act if this situation or problem were to arise in one of our classrooms one day. So, thank you!!

Through the process of self-study, I modeled how to navigate conflict using reflection activities. Similarly, other PSTs connected their experiences in the course with her future practice:

> I have learned that as a teacher you really have to meet your students where they are and talk with them to see where there was miscommunication when problems arise. This class has made me realize the importance of discussing things in class and I have really enjoyed that aspect of class. (PST 7)

My use of reflection activities led to this unexpected outcome; that is, the PSTs also learned about the pedagogy of reflection: "I have really benefitted from seeing a class that is not so structured that the schedule becomes more important than learning. I think that is a very important lesson to learn before becoming a teacher" (PST 12). Similarly, PST 20 commented:

> I learned that it is critical to be open and honest with your teacher (or students) if you aren't receiving the results you want from each other. I know that sometimes it might be awkward and not easy, but the end result will be worth it. Communication is everything!

By adjusting my practice via the self-study process, the PSTs learned about gaining knowledge for teaching as well as the importance of reflection to support meeting course objectives.

Conclusion

Self-study allows educators to evaluate their practice, identify what is working and what needs improvement, and modify their pedagogical approach (sometimes in real time) to deal with problems, challenges, or tensions. Self-study is particularly important for TEs, as transitioning from a student into a teacher is a challenging process for PSTs, one which TEs must support. One reason this process is so challenging is that PSTs have dual roles of student and developing teacher. While PSTs will always have these dual roles, as they move along the continuum from student to teacher, they increasingly engage in their TEP coursework from the perspective of a teacher. The TE's role is to help move the PSTs along this progression, from thinking like a student to thinking like a teacher, while recognizing that the PSTs will often reflect myriad points along the continuum.

Enacting this role, however, can create tensions in the TE's practice as the PSTs experience this transition. The TE's tensions may reveal themselves in the form of conflict between the TE and the PSTs. Through self-study, the TE is able to address and investigate the conflict as well as the underlying tensions in his practice that the conflict reveals. One approach to accomplish this goal is the use of reflection activities to investigate (gather information about) and address (guide PSTs' learning through) such situations. In this way, reflection is used as both a research and pedagogical tool. The primary purposes of the reflection activities are to reframe the problem and allow the TE and PSTs to understand each other's perspectives. By collaboratively accomplishing these goals, the TE can modify instruction to address the conflict in a meaningful and productive way. In addition to the primary gains of employing reflection activities, secondary outcomes may also result. By giving voice to both the TE and the PSTs via reflective dialogue, a culture of respect and trust is fostered. In such an environment, PSTs more willingly share their challenges and struggles, thus allowing the TE to better understand PST needs (and thus meet them). Further, employing self-study in this manner models the pedagogy of reflection for the PSTs. The PSTs recognize the value in halting instruction to deal with challenges and employing this form of inquiry as they move into the complex profession of teaching. As such, the present research demonstrates the potential contribution of self-study to the pedagogy of science teacher education as well as K-12 instruction.

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Chapter 6
Exploring Our Theoretical and Practical Understandings of Enthusiasm in Science Teaching: A Self-Study of Elementary Teacher Preparation

Brent Gilles and Gayle A. Buck

Introduction

Many attributes of effective science teachers have been identified. Such attributes include content knowledge (Arnon & Reichel, 2007), caring and compassion (Breault, 2013), and enthusiasm (Kunter et al., 2008). Although studies have shown that the latter attribute, enthusiasm, has a powerful impact on learning (Kunter et al., 2013), it is among the least researched (Schutz & Pekrun, 2007). Thus, although commonly referred to in regard to teaching science, it is not always well understood. The contemporary literature base provides understandings on students' enthusiasm for science (Howitt, Lewis, & Waugh, 2009; Kirikayya, 2011) and enthusiasm as an effective teaching strategy in K-12 education (Hudson, 2007; Turner, Ireson, & Twidle, 2010). In addition, research on this topic can be found in other curricular areas such as physical education (e.g., Mitchell, 2013) or mathematics education (e.g., Kunter et al., 2008). There is a gap, however, in our understandings of the impact of teacher educators' enthusiasm in science courses for pre-service elementary teachers.

As science teacher educators, we have emphasized the importance of being an enthusiastic science teacher – especially in situations where the students tend to fear or dread science (Kunter et al., 2013). The "we" being both authors who teach the course. Unfortunately, our students have been quick to point out that this attribute is not as evident in the teaching of *our* science courses for elementary PSTs. Thus, we turned our attention to seeking a practical approach to our science courses for PSTs that would foster an understanding and practice of teaching enthusiasm. The purpose of this study was for the first author to understand how to model enthusiasm in our

B. Gilles (✉) • G.A. Buck, Ph.D.
Department of Curriculum and Instruction, Indiana University, Bloomington, IN, USA
e-mail: bgilles@indiana.edu; gabuck@indiana.edu

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science course. The guiding questions of the study were: (a) how am I demonstrating enthusiasm in my science classroom and (b) how are my students, elementary PSTs, responding to this attribute of my teaching practice.

Background

In 1986, Brophy and Good identified core teacher qualities based on what research has shown to be the teacher attributes that foster student achievement. Teacher enthusiasm was one of those qualities. More recently, Kunter et al. (2008) also identified enthusiasm for teaching as one attribute of a high quality teacher. Enthusiasm has been widely used to describe an effective method for delivering information to students (Shuell, 1996). Enthusiasm, however, continues to have several different definitions (Kunter, Frenzel, Nagy, Baumert, & Pekrun, 2011). A current definition for teacher enthusiasm is behaviors or expressiveness that denote a teacher's passion and enjoyment (Keller, Goetz, Becker, Morger, & Hensley, 2014). In instructional quality research, teacher enthusiasm is seen as the teacher's ability to transmit the importance and intrinsic value of learning content to the students (Patrick, Turner, Meyer, & Midgley, 2003). These actions are commonly defined as: rapid and excited speech, rapid eye movements, frequent and demonstrative body movements, changes in facial expression, highly descriptive word usage, acceptance of ideas and feelings, and high energy level (Collins, 1976; Rosenshine, 1970).

Enthusiasm as a Powerful Teacher Attribute

The positive climate that results from an enthusiastic teacher is critical for fostering students' motivation to learn (Meyer & Turner, 2006; Stipek et al., 1998). This type of resulting motivation is known as affiliative motivation that is defined as the motivation to be connected through positive relationships with others (Hill & Werner, 2006). Furthermore, individuals react to the emotional cues of the face and according to their perceived emotion of the other person (Turner, 2007). A person who is demonstrating enthusiasm is typically happy and thus they will translate that emotional energy to those around them. Ford (1992) stated that emotions such as enthusiasm are "an integrated part of motivational patterns" (p. 8). Enthusiasm is an aspect of building a positive learning environment that motivates students to be involved. This means that the energy level and enthusiasm that a teacher has will motivate students to stay on task (Bettencourt, Gillett, Gall, & Hull, 1983). Furthermore, findings suggest that teacher enthusiasm is just as important as students' initial interest in a subject (Kim & Schallert, 2014). Teacher enthusiasm can also be triggered by situational interest which can be "environmentally triggered, involving an affective reaction and focused attention" and leads to increased motivation on the part of the students (Hidi, 2006, p. 72). There is also evidence to suggest that natural enthusiasm is linked to higher student interest (Keller et al., 2014).

As it is intertwined with student motivation, teacher enthusiasm has been connected with higher student achievement (Bernstein-Yamashiro & Noam, 2013) and lower dropout rates (Pomeroy, 1999). All of this is, in part, linked to the finding that enthusiasm is a cyclical process where the students can initially feed off of the teacher's excitement and in turn the teacher is further energized by the student's enthusiasm (Frenzel, Goetz, Ludtke, Pekrun, & Sutton, 2009). Not surprisingly, classes that achieved higher mathematics scores and less disruptions were ones in which the teacher was most enthusiastic (Kunter et al., 2011). Students regularly identify teachers who show personal enthusiasm for a subject as a reason for being motivated to learn (Meyer & Turner, 2007). Obviously, enthusiasm is one of the teaching strategies needed in a teacher's repertoire (Mitchell, 2013). It should be noted, however, that teachers who attempt to continuously force enthusiasm are more likely to experience burn out (Keller et al., 2014; Metcalfe & Game, 2006).

Mathematics education has recently benefited from research on enthusiasm (Frenzel et al., 2009; Kunter et al., 2008, 2011, 2013). Frenzel et al. (2009) studied how mathematics teachers' enthusiasm was linked to student enjoyment. They found that student and teacher enjoyment were mediated by the teacher's enthusiasm. Kunter et al. (2008) distinguished the difference between enthusiasm for teaching and enthusiasm for mathematics. They found that teaching enthusiasm was a predictor of high quality teaching and that enthusiasm for mathematics was not. Teachers' also reported being more enthusiastic in classes that experienced less disruptions, higher student enjoyment, and higher mathematics achievement (Kunter et al., 2011). These findings connect with the findings that students who had teachers with better pedagogical content knowledge, constructivist beliefs, and enthusiasm for teaching showed higher achievement gains in their mathematics classes (Kunter et al., 2013). This suggests that teachers who observe best practices have students who are more enthusiastic which in turn creates more enthusiastic teachers. There is pertinent information in this research for science educators. Especially in the fact that students have consistently identified science as their least favorite subject (Obsorne, Simon, & Collins, 2003).

Research on enthusiasm from a science teacher educator's perspective is limited in science education. Turner et al. (2010) conducted a case study in which they found that students liked teachers who created a welcoming environment. Students identified science classes where their teachers used varied instruction and unusual learning strategies as being the most enjoyable. This type of creativity is an attribute of a teacher who is enthusiastic about teaching (Kunter et al., 2008). Student enjoyment is also a factor closely linked to teacher enthusiasm (Kunter et al., 2011). Kirikkaya (2011) looked at enthusiasm from the students' perspective. She found that students were most enthusiastic about science when they were doing hands on activities, group activities, and using technology. They were least enthusiastic when they were writing, reading, working alone, and performing mathematics operations. She also found that enthusiasm for science falls dramatically for students as they enter eighth grade as their perceptions of science being hard increased. This effect is only amplified when students have negative experiences with their instructor and/or the subject (Alsharif & Qi, 2014). This study seeks to continue the conversation on enthusiasm in science by addressing enthusiasm from the teacher's perspective and to address the gap in our understanding of enthusiasm in science education by exploring what enthusiasm is in a university science class designed for PSTs.

The Importance of Enthusiasm in Our Efforts in Pre-service Teacher Education

This study was aimed at improving our own teaching to, in part, provide an example and expectation that our own students will look to continually improve their own practice. This fits with LaBoskey's (2004) contention that we involve our students while challenging our own developing understandings of enthusiasm. It is necessary that we provide our elementary PSTs with learning experiences in a classroom that is structured around best practice. This could help to counteract the problem that first year teachers are influenced by practices within the school as opposed to the educational theories exposed in their pre-service program (Muller-Fohrbrodt, Cloetta, & Dann, 1978). Brouwer (1989) found that integrating our educational theories into our own teaching practices, we lessen the influence of school culture on a first year teacher's practice.

Korthagen and Kessels (1999) contend that in order for students to rely on theory in their practice that we must first help to provide useful experiences in which they can use the skills of best practice. Once we have done that then the interaction can be recorded and we can dissect and refine that experience with each student. It is important that we develop PST's practical experience that is based on theory which will lead them to rely on that experience as an in-service teacher (Korthagen & Kessels, 1999). Unfortunately, there is a dearth of research by science educators on their own practices of teaching PSTs (Bullock, 2012). This study is an attempt to address not only that need, but for our students to find emotional support, specifically enthusiasm, relevant to their preparation of becoming an educator. Trumball (2012a, 2012b) contends that being a teacher causes PSTs to create a new identity for themselves and we want to stress that enthusiasm is an important aspect of that new identity.

Loughran and Berry (2005) point out that many veteran and beginning teachers do not recognize a conflict between what they believe to be best practice and their actual teaching practice. Teachers may believe they demonstrate an enthusiasm for science, but their own students may actually view it as something different. This is something that we struggled with as our students questioned our own enthusiasm for the subject. This is important for our own understanding of teacher education which will help us to better communicate about teacher enthusiasm (Loughran & Berry, 2005).

Methodology

Self-Study

The complexities of teaching have renewed interest in faculty studying their own practices (Loughran, 2006). As a result, the field of self-study of teacher education practices has grown rapidly. For example, in preservice teacher education, Capobianco (2007) found that inviting pre-service teachers into reflective practice and modeling the development of professional practical knowledge allows them to better address the uncertainties in their own learning. Moscovici (2007) explored the power relationships in science methods courses. Nilsson and Loughran (2012) advanced their own understandings and practices by exploring their student teachers' self-assessments of developing pedagogical content knowledge. These scholars, and many others (e.g., Dias, Eick, & Brantley-Dias, 2011; Garbett, 2011; Trumbull, 2012a, 2012b), have showcased the challenges inherent in our teaching practice and ultimately advanced our understandings about the preparation of science teachers and teacher educators.

Self-study is a systematic and rigorous look into one's own understandings and/or practices, which leads to a deeper understanding of educational theory (Loughran, 2004). The purpose of self-study is to contribute to the improvement of the practice of teacher education, as well as validate professional expertise in a manner that contributes to an explicit pedagogy of teacher education (Vanassche & Kelchtermans, 2015). Vanassche and Kelchtermans (2015) proposed four general characteristics that constitute this approach. Self-study research (1) focuses on one's own teaching practice, (2) privileges qualitative research methods, (3) emphasizes collaborative interactions, and (4) bases validity on trustworthiness. Our study met these four criteria. It was designed to provide us with an understanding of how we model enthusiasm in our science course and its impact on our students. The focus was on our own understandings and practices involving enthusiasm. The process was a collaborative endeavor between two science teacher educators and 14 undergraduate students. We utilized a qualitative case study design that addressed construct and face validity. These characteristics are described in more detail below.

The self study research approach differs from reflection on practice in that the work is taken outside the individual and made public, thereby allowing for challenges, transformations, translations, and extensions by others (Loughran, 2004). Although the research focuses on the individuals and their practice, the discussion resides within the larger professional community of practice. This methodological approach is defined by the common focus of the studies, teacher educators' understandings and/or practices in regards to teaching. More specifically, it is about what is going on between the self (i.e., teacher educators) and their teaching practices (Bullough & Pinnegar, 2001). In this regard, our research is being offered through publications and presentations in an effort to continue the dialogue on enthusiasm in science teacher preparation.

The self-study approach, however, may differ in methodological design. Designs may include case study (e.g., Kroll, 2005), narrative (e.g., Kitchen, 2005) and heuristics (e.g., Oda, 1998). The methodological design used for this self-study was an exploratory case study design (Creswell, 2012). A case study is defined as an exploration of a "bounded system" over time through detailed, in-depth data collection involving multiple sources of information (Creswell, 1998). Case studies are particularly appropriate for understanding the details and complexity of a situation (Stake, 1995). Our case defined the duration of our self-study (one semester), the context (one course) and the student population (PSTs in one section). This was explored by a variety of data sources (described below).

Participants

Although the term self-study suggests one individual, this line of research is seldom an individual process. Self-study researchers often move beyond themselves to better examine their practical understandings of teaching and learning (Loughran, 2004). Our self-study group included 2 science teacher educators and 14 undergraduate students.

One of the educators, referred to as "I" throughout the findings section, was the course instructor during this study. He was a former high school science teacher and a new science teacher educator at the time of this study. He entered higher education as a self-described enthusiastic teacher who was prepared to foster such enthusiasm in future teachers. He was, however, challenged by his mentor on his notions and ideas of what that meant theoretically and practically. His practices in regard to enthusiasm and its impact on students became the focus of this study. As this inquiry was focused on understandings, the process was necessarily reflective and participatory. This process was assured by the inclusion of a critical friend (Schuck & Russell, 2005), the mentor. She also served as the course coordinator of this multi-section course and taught the course in the past. Her role was to advise in the methodological design, aid in the framing and reframing of classroom experiences, ask for clarifications in regards to intentions and rationales, generate more complex ideas of enthusiasm in science teaching; as well as challenge and be challenged on interpretations of the experience.

Going beyond the individual in self-studies on teaching also requires seeing the practice from the students' perspective (Loughran, 2004; Zeichner, 1999). Thus, this study was conducted with 14 undergraduate students. The students in this course were considered secondary participants. They included 13 females and 1 male in the class (up until the end of January there were 14 females and 1 male, but 1 female student dropped the class).

Context

This single case study was conducted in a semester long science content course designed specifically for elementary PSTs who were in their freshman or sophomore year. This was the students' first experience in an undergraduate science course. The class met 2 days a week for 1 h and 50 min each class. The students had minimal field experiences that equated to less than 40 h of observation. This class focused on giving the students an inquiry experience so when they take the science methods course they will be able to better incorporate inquiry into their lesson plans. The class consisted of three sections that split the semester into three equal parts. The first section of the class was focused on correcting student misconceptions about the nature of science and scientific inquiry. There were daily activities that were designed to introduce students to scientific inquiry and also get them comfortable with the inquiry process. The second section of the class was based around large guided inquiry-based environmental projects. Two of these investigations had the students outside and actually collecting data about the campus environment. The last section of the class involved independent inquiry-based projects. The instructor guided the students, but the students had control over their topics and investigative designs. Students would meet at the beginning of each class during this section and, after having questions answered and guidance given, they were free to leave the classroom and work wherever they felt would benefit them the most (though the instructor made himself available in the classroom during the entire class period).

Data Collection

The data collection tools included an instructor's daily journal designed to explore how the instructor felt about each day's lesson and to keep a record of any outside factors that may affect his energy and enthusiasm during that day. Journal entries included a pre- and post-class reflections focused on how the lesson went and how instructor's enthusiasm seemed to aide or distract from the lesson. Field notes were also made on student's responses during the class. Data collection also included student surveys. These Likert-scale surveys were designed to gauge how the students felt the lesson went and how animated and interactive they believed the instructor acted. This survey, a modified version of one developed by Mitchell (2013), was based on the definition of enthusiasm developed by Keller et al. (2014). The survey had two sections, the first section had ten prompts concentrating on the instructor. The survey was a Likert-scale consisting of the choices strongly agree, agree, disagree, and strongly disagree. The students would then circle the number (1-strongly disagree to 4-Strongly agree) that matched their view of the prompts on the survey. Some of the prompts included "Displayed excitement during class.", "Smiled frequently during class.", and "Praised student input." The second section of the survey had eight prompts that concentrated on the students. Those questions included “I enjoyed coming to class today.”, “I found the lesson to be interesting.”, and “I was excited during the class activity today.” These surveys were analyzed at five points during the semester so they could be compared with journal entries and changes could be made based on the feedback. The decision to not analyze the surveys after each class was made in order to allow for recognizable trends to be identified and prevent unexplored reactions to the previous class. Course evaluations also served as a form of data. These were analyzed for specific student references to enthusiasm. Additionally, approximately 60 h of classroom interactions were video recorded. The video camera, set up in the back of the classroom, focused on the entire room and the interactions within. The students were aware of the videotaping and had given permission for this to occur. Field notes from critical friend meetings were used as another source of data.

Data Analysis

The survey data was used as descriptive statistics in our qualitative analysis to further enhance our understandings of our practice. As such, the scores were not used to make generalizable findings; instead they were used to reveal trends and relationships that were then used as qualitative data.

The qualitative data was analyzed using an open-coding process. We segmented the various texts into meaningful units and assigned codes to label the segments (e.g., instructor’s tone, instructor’s rapid movements, student engagement). The final analysis involved comparing instructor data to student data, identifying classroom instruction occurring at certain points, and possible external influences (e.g., instructor’s lack of energy). We further analyzed the classroom video to ensure that the perceived practices matched the actual classroom practice.

Triangulation and Validation

The study was triangulated using multiple data collection tools and sources that included instructor’s journals, observations of students and instructor, field notes on class sessions, field notes from critical friends meetings involving the instructor and mentee, validated student surveys and student course evaluations. The study was also triangulated in regards to different theoretical schemes. These schemes were supported by the inclusion of the instructor, mentee, and students. In addition, the reflexive approach to data collection and analysis assured construct validity and the feedback from students and critical friend assured face validity (Lather, 1986; Loughran & Brandenburg, 2008). Finally, the reality-altering impact in terms of a gain in self-understanding and self-determination, catalyst validity, was realized in changes to previous understandings of the role enthusiasm holds in teaching and teacher education (Lather, 1986). This is further elaborated throughout the manuscript.

Findings

The guiding questions of the study were: (a) how am I demonstrating enthusiasm in my science classroom and (b) how are my students, elementary PSTs, responding to this attribute of my teaching practice. These questions are addressed simultaneously throughout this section. "I" is used throughout this section to reference the instructor's practices and understandings as they were collaboratively explored with the critical friend.

The Relationship Between Enthusiasm and Direct Instruction

As noted in context, the first section of the course timeline is aimed at addressing the PSTs' naïve and inaccurate conceptions about scientists and scientific inquiry. These topics are addressed in a series of short activities, mini-lectures, and guided discussions. I was enthusiastic about these lessons, noting in my journal that I was "looking forward to class today", "today is one of my more favorite classes", and "I was really energized today." Each time I noted a comment like that, every student agreed or strongly agreed that I was enthusiastic during the lesson. These ratings were directly aligned with the students' expressed interest in the lesson. This also supports the findings by Pickens and Eick (2009) that found that when a teacher enjoyed what they were teaching the students enjoyed the topic and the students were in turn more motivated in their work.

The second section of the course was concentrated on doing guided inquiry projects that required out-of-class research and follow-up lab reports. This was the point in the semester where I started to turn the direction of the learning process over to the students. There was a minimal amount of direct instruction. The analysis revealed both my level of excitement and the students' interest in the lessons now varied. Overall, once the activities became more student-led the direct relationship between my excitement and the students' level of interest did not hold up. For example, one inquiry project was focused on water quality. After some preliminary work, the students went to a creek to collect invertebrates. A few of the PSTs voiced displeasure for the activity before we went outside, however, everyone participated. This particular day happened to be quite cold and my journal entry after class illustrates how much even I struggled on this day.

> I really put on a brave face today because I was not looking forward to going out, but I knew that if I was not excited about it then they wouldn't be so I just pushed ahead with as much energy as I could in the hopes that it would rub off on them. I even realized how much I was forcing it (my energy) as we walked back inside and a colleague asked how it went. I put on a big smile and said science is great! Overall, I feel like my enthusiasm was helpful to them because otherwise it would have been more miserable than the cold made it. They were definitely cold coming back in, but I did not hear any complaints and there were even smiles as I was giving my science is great reply.

Table 6.1 Student exit surveys during water quality lab (outdoors)

Survey prompt	Strongly disagree	Disagree	Agree	Strongly agree
Instructor displayed excitement during class	0	0	3	9
[Student] enjoyed coming to class today	1	4	4	2
[Student] was excited during the class activity today	1	2	6	2

Note. This is an aggregate of all students present in class on this day

Table 6.2 Student exit surveys during soil quality lab (outdoors)

Survey prompt	Strongly disagree	Disagree	Agree	Strongly agree
Instructor displayed excitement during class	0	0	1	12
[Student] enjoyed coming to class today	0	2	6	4
[Student] was excited during the class activity today	0	3	5	4

Note. This is an aggregate of all students present in class on this day

Every student rated me as excited during the collection of observational data. However, they were not unanimous in regards to their interest in the activity. As seen in the example data provided in Tables 6.1 and 6.2 during the water quality investigation, five students reported not enjoying coming to class that day, while only two reported the same for the soil lab. The day we did the soil lab was considerably warmer and the temperature is likely the biggest reason for the discrepancy between the 2 days. However, I also noted some timid behavior, perhaps due to the students participating in some unfamiliar activities (i.e. digging and collecting earthworms) and I noted in my journal, "I felt myself kicking my energy up and being as enthusiastic as possible because I wanted them to stay positive through the experience." I also noted on this day that I wanted the students to be "excited about doing science" and this is why I put forth so much energy and enthusiasm both days that we were outdoors collecting data.

The final portion of the class was structured to facilitate independent student research. On the first day of the final inquiry project in the class I noted in my journal, "I find it absolutely fascinating what the students choose for their individual projects because it gives a window into them and their interests. It energizes me to watch them do something that they are really passionate about and their work really shows it." However, that enthusiasm did not last. On the fourth to last day I wrote in my journal "I've gotten comfortable with this class so I think my enthusiasm to see them and interact with them has really carried me through some of the days where my energy was less." In my journal I noted, "I'm passionate for their own projects, however, because I don't necessarily interact with all of them I am not sure if they pick up on that or not." The video confirmed that my time was being dominated by

Table 6.3 Exit survey questions during individual research projects reactions

	Class 18				Class 27			
Survey prompt	1	2	3	4	1	2	3	4
Instructor displayed excitement during class	0	0	6	6	1	2	5	6
[Student] enjoyed coming to class today	0	0	6	6	0	3	7	2
[Student] found the lesson to be interesting	1	0	6	4	1	0	7	3

Note. 1 = strongly disagree 2 = disagree 3 = agree 4 = strongly agree

a few of the students and I was not getting around to all of them. A question on the exit survey asked students if I "moved around the room to interact with students/groups on an individual basis" also identified that the students were aware that I was not doing a good job moving around the room and giving attention to everyone. The students also gave me lower ratings on my enthusiasm for that day on the exit surveys. These results could be due to the fact that I was not interacting with everyone and not all students had the opportunity to experience my enthusiasm for their project.

By the end of the semester, I was consistently remarking about how drained I felt before class writing in my journal, "We are wrapping it [final project] up so I don't find it terribly interesting, but we'll see."; "I'm a little tired today."; and "My enthusiasm wasn't there and I didn't even have time to think about faking it." The video also backs up this feeling as I was interacting with students in a more business-like fashion. The lively laid-back atmosphere that had been seen on video leading up to the inquiry-based projects had been replaced with a more stay-on-task atmosphere. The fact that I noted in my journal that I "did not feel like I was actively teaching science" did not leave me as excited for class at the end of the semester as it did at the beginning. This was further evidenced by the fact that my daily ratings of my own energy before class was consistently lower than at any other time during the semester. This is attributable to end of the semester deadlines and work outside of class that was demanding my attention and energy.

As noted, the students did not find me to be as enthusiastic once I gave them more control of the learning process. The enthusiasm scores I received were lower. It was at this point that an indirect relationship between my enthusiasm and their level of interest emerged. As can be seen from Table 6.3 from the beginning of the individual research project to towards the end (30 classes total) they viewed my enthusiasm as waning, even though they enjoyed coming to class and found it interesting. There were, however, consistently two people each class period that did not find class interesting or enjoy coming to class. There is, however, no way to know if it was the same two people each time. The students chose their projects and they were more interested in what was happening during class. I felt that my role had become more of a supportive role to help the students organize their research and help properly format it to the expected final product. The exit surveys showed that once I was no longer the focal point, my excitement ratings by the students were consistently lower.

Overall, the students had a positive view of my teaching style. On the end of the course assessment a student wrote “The instructor was always kind and seemed to enjoy teaching/helping the students.” A different student noted that my “teaching style was perfect for this class.” Both students are expressing characteristics that we consider to be enthusiasm which are behaviors or expressiveness that denote a teacher’s passion and enjoyment (Keller et al., 2014). The exit surveys never came out with more students disagreeing that I showed enthusiasm than showed it. Even though I struggled with my enthusiasm once direct instruction started to turn into student directed work there was always a majority of students who felt that I was being enthusiastic during class.

Attempts to Control Students by Stressing My Own Enthusiasm

Post journal entries also highlight my enthusiasm for teaching through disappointment. One particular instance came on a day when students were to explore and test ice balls (which they know nothing about and are not even told what they are made of). I introduced the activity as “quite possibly my favorite activity of the semester.” After class, I noted, “They enjoyed seeing how they [ice balls] were all different, but lost some of that fervor when it came time to actually collect observational data on them. I was a little disappointed by that and felt the need to inject as much energy into it as I could.” However, the students reported that they were nearly as excited as I. A review of the video did reveal my misconception on student excitement for that day. My idea of the students’ excitement is similar to what I defined as enthusiasm-which would be smiling frequently and making lots of rapid motions. These were actions that they displayed initially. After that initial show of excitement, they focused on the task. All students were observed to be on-task and focused on their investigations. Meanwhile I maintained my smiling, demonstrative gestures and moving around to the individual groups to inquire how each was conducting their investigations. Everyone agreed that I was excited during the lesson on the exit surveys, and just one student disagreed that they were also excited even though they displayed it differently than me.

Another interesting notion is that of Frenzel et al. (2009) that noted that enthusiasm was a cyclical process in which the students would become enthusiastic because the teacher was and vice versa. There were some days when this did not prove to be the case. The students noted that the instructor was excited during the class, but the students themselves noted that they were not excited about class that day. In each of the cases, the students reported that they had come to class in good moods. This dichotomy was strongest during a day in which the students were working on writing lab reports after having done an investigation of soil quality. All students surveyed, but one, noted that I was excited during class, giving positive feedback, and moving around the room and being interactive with groups and individual students (see Table 6.4). However, nearly half the class disagreed that they were excited during

Table 6.4 Soil lab report write-up class (indoors) reaction

Survey prompt	Strongly disagree	Disagree	Agree	Strongly agree
Instructor displayed excitement during class	0	2	6	4
[Student] was having a bad day before class	7	3	1	1
[Student] was excited during the class activity today	1	4	3	4

Note. This is an aggregate of all students present in class on this day

class that day. This was also the case in reverse when students were working on their independent research projects in the last section of the class they gave me lower excitement scores, but reported being excited themselves (see Table 6.3).

The Relationship Between Enthusiasm and Level of Content Expertise

This course is an interdisciplinary science course. As such, the instructors must address topics that include aspects of life, physical, and earth science. Many instructors at the college level, myself included, have content expertise in one area of science with a variety of possible other areas addressed at different levels (and some not at all). My background is in the physical sciences of physics, chemistry, and earth science. One lesson in particular dealt with content that was out of my expertise (more detail on this lesson is provided below). This lesson dealt with succession and the natural cycle of plants which my knowledge was limited to my own K-12 education. I taught myself as much about the information as I could, but this caused me to concentrate more on remembering and giving correct facts. The video showed that my demeanor had become more "business-like" in the way I taught the class and my physical stance became stiffer than other classes. I showed less outward signs of enthusiasm. There were no demonstrative motions, my facial expression did not change from a neutral position, and I had only two instances where I showed excitement. I also seemingly became glued to the front of the room where my notes were and did not move around the classroom casually and comfortably as I had in previous classes.

A subject I do know well is the nature of science and scientists. I am extremely passionate about science, I have worked in research labs and I like sharing my experiences as a scientist. During the class sessions on these topics, my enthusiasm was very high. I noted in my journal, "…I am looking forward to teaching today…", and "I really enjoyed watching what the students drew last semester (students drew what their idea of a scientist was) so today is one of my more favorite classes." There are many other instances similar to these where I start out before class noting how much I am looking forward to getting into the classroom with the students. Even in my post class journal my excitement carried through noting that "…I really felt like my energy ticked up once class started." and "I was really energetic today."

It was not hard to be enthusiastic about topics that I am passionate about. What I came to realize is that my enthusiasm for the content was not transferred to the students during the individual inquiry-based projects. In my journal I stated, "I've come to realize that what I thought was enthusiasm for the entire class was really just enthusiasm for the subject." This was a realization that I had during a meeting with my critical friend when she pointed out that when I discussed my enthusiasm for each class that it was centered on the content and not on the students or the class. This does not mean that I did not care about the students, but merely that I was excited about the content so much that my enthusiasm would have been high no matter the group of students. Regardless, I did enjoy this particular group of students as I wrote in my journal towards the end of the semester that "…my enthusiasm to see them [the students] and interact with them has really carried me through some of the days where my energy was less." After the first few weeks of class there is not a class period where I am not on video interacting with the students in a casual and friendly manner. What was lost in translation is the enthusiasm I felt and wrote about in my journal and the actual outward show to the students and their perception of while working on their independent inquiry projects. This suggests that my enthusiasm for the students was lost in my content enthusiasm during the first two sections of the course. I had also given up my control over the content to my students and their chosen topics for projects were not ones that I was as excited about as I was the content I had put together throughout the semester.

The Impact of False Enthusiasm

There was one lesson during the semester that I was not at all enthusiastic about teaching. I had taught it the semester before and did not enjoy the experience and felt that my students did not either. The lesson was focused on historical explanations in science. It was teacher-directed and involved a lot of reading material and history. The lesson was originally structured to be an introduction on how scientists go about proposing explanations. I wrote in my journal before class that day that "…this was the one day where my enthusiasm was rock bottom (last semester) … I can fight through that lack of enthusiasm to experience what it is like to have to force it." The idea was to challenge myself to be artificially enthusiastic about the lesson. I believed this was important to experience because there are times when these PSTs will have to teach lessons that they are not enthusiastic about. This might be due to numerous factors, but in a lot of cases teachers at all levels do not always have control over their own curriculum. I noted in my journal that "…I think my dislike stems from my lack of really understanding why I am doing this and not being totally comfortable with the whole thing because it is a lot of reading." Which is an emotion that I typically feel when I have no control over what I am teaching in the classroom.

Table 6.5 Historical explanations lesson reaction

Survey prompt	Strongly disagree	Disagree	Agree	Strongly agree
Instructor displayed excitement during class	0	1	3	8
[Student] enjoyed coming to class today	0	0	7	4
[Student] found the lesson to be interesting	0	3	5	3
[Student] was excited during the class activity today	1	3	4	3
[Student] liked class discussion	1	2	4	4

Note. This is an aggregate of all students present in class on this day

During the class I had to force my enthusiasm and afterwards I was surprised by the outcome. I wrote, "I was really surprised by how I did today. I did not feel as though I had to force myself to be excited throughout class. I think I was business-like during the historical explanations part, but I was not as actively down as I was last semester and I do not feel that I hate it as much as I did after doing it last semester." This was backed up by the exit surveys from the students. All but one student agreed that I was excited during the lesson. All the students reported enjoying coming to class that day. Three students, however, reported that they did not enjoy the lesson or like the classroom discussion and four students reported that they were not excited about the lesson (see Table 6.5). The fact that all of the students enjoyed coming to class could be implied that I had done a good job of building a pleasant and inviting atmosphere, but that once there the content and class activities dictate whether class is enjoyable. The video revealed that even though I was successfully forcing the outward attributes associated with enthusiasm, the lesson was still very business-like and did not allow for any student exploration other than some critical thinking. Student exploration in this case meant a hands on activity where they are actively engaged whereas this lesson was a simple cognitive exercise designed for them to think only. There was also very little interaction between students as they spent a large amount of the class reading passages silently to themselves. Given this evidence, I came to realize that although I was able to successfully fake my own enthusiasm, it did not impact the students' level of enthusiasm as I intended.

Discussion and Implications

With this study, we explored the theoretical and practical understandings of enthusiasm in teaching preservice elementary teachers. Our reflective journey has authentically complicated our understanding of this attribute of effective science teachers. First, we have come to realize that our initial theoretical notions, including the necessary characteristics, of enthusiasm were all concentrated on outward displays of emotion. We now understand that enthusiasm does not require that a teacher simply show an outwardly display of enthusiasm, but it does require passion, creativity, and excitement about teaching the lesson from the instructor before students even walk into the classroom. This attribute begins with the teachers' relationship with the topic, including how it relates to the students, and the students. We believe this now challenges our practical understandings. Our students, elementary PSTs, do not always enjoy teaching science. This may be because they do not have the necessary content knowledge (Abell & Smith, 1994) or don't find it particularly interesting (Pelletier, Séguin-Lévesque, & Legault, 2002). Interest being important here because of the relationship between interest and motivation, and subsequently enthusiasm (Long & Hoy, 2006; Kunter et al., 2011; Pelletier et al., 2002). Furthermore, emotions, such as enthusiasm, energize students which provides them with the motivation to participate in certain tasks (Turner, 2007). Our experience, however, seems to point towards intrinsic motivation being a more important factor in student motivation than a teacher's display of enthusiasm. In addition, setting up classroom norms that achieve a positive environment cultivate an environment where students are motivated to learn (Ritchie, Tobin, Hudson, Roth, & Mergard, 2011). Enthusiasm from the teacher is merely the outwardly display of the positive environment, but we have come to understand that a positive environment must be purposefully constructed through every aspect of planning classroom activities and interactions.

Second, we came to realize that Frenzel's et al. (2009) notion of enthusiasm being cyclical between teacher and students does not always hold up. We realize that, even if we succeed at getting our PSTs to be enthusiastic about all of the science topics in their curriculum, it will not be sufficient. Their own enthusiasm may increase the likelihood of their students being motivated, but not necessarily. Over the course of this self-study, we saw that although the students believed the instructor was very enthusiastic about the science topic, they did not come to share that feeling. Even though Bettencourt et al. (1983) identified an increase in on-task behavior, our students self-reported their on-task behavior as being consistent throughout the semester regardless of the instructor's enthusiasm. Our students being post-secondary and Bettencourt's et al. (1983) study being with four to six graders could make a difference because maturity and intrinsic motivations are likely to be different. This is complicated further by the fact that the reasons for a person's motivation is likely to change as they age (Pintrich, 2003). Another interesting outcome is that even though students might not have been excited during the lesson that did not necessarily keep them from participating. Many studies did cite an increase in motivation with enthusiastic teachers (Bettencourt et al., 1983; Kunter et al., 2011; Meyer & Turner, 2007; Stipek et al., 1998) and there was some cursory evidence that the instructor's enthusiasm had an impact on motivation as a student wrote in the end of course evaluation that "When I did not get a grade I wanted I tried hard the next assignment to get a higher grade and I noticed this with several other students. He makes the class feel comfortable and relaxed so that learning is promoted." However, this was not always the case. For instance, during the soil lab a student rated them self as fully participating in the activity, but rated them self as not being excited during the activity and this student even wrote "worms…" unsolicited next to that question. This suggests that although enthusiasm may be an important teacher attribute, there are other attributes that may be more important. One theory could be related to the setup of the class. Little is known about how the construction of a classroom climate (e.g., traditional vs. constructivist-inquiry) impacts motivation, but it is possible that our approach positively impacted student motivation (Pintrich, 2003). Pelletier et al. (2002) has suggested that environments such as ours, where students have more control, produces more intrinsic and self-determined motivation (Pelletier et al., 2002).

Third, we also realize that although enthusiasm is a critical attribute in science education, it may be more necessary in cases where the pedagogical approach is not particularly exciting for the students. In contrast, when the students find the learning process interesting (e.g., inquiry-based instruction), it may not be as critical to the learning process. In this study, there were certainly days where both the instructor and the students were enthusiastic about what was going on in the classroom. For instance during an activity where students designed spinning tops with different levels of instruction (to demonstrate inquiry) all of the students strongly agreed that they and the instructor were excited during the class. However, on days where the students gained more control over the learning process, they were motivated to learn despite the fact that they did not perceive the instructor as being particularly enthusiastic. This occurred during the final portion of the class when students were working on their own projects (described previously). The instructor consistently received lower marks during this time for enthusiasm while the students identified being enthusiastic themselves. Practically, we realize that as we prepare our teachers to relinquish some of the classroom control during open-inquiry projects, the class periods provided students with more choice and freedom. They were not stuck listening to a lecture or glued to one spot conducting an experiment. They had freedom to move and work with others and make decisions about what they were experiencing. Most importantly, they had control over the topic in which they had personal interest. This interest creates a positive emotion within the PSTs and provides them the motivation to tackle their own project (Turner, 2007).

Teacher enthusiasm appears to be more important during teacher-centered instruction, as was the case with the initial weeks of this study. Students need to see that the teacher is energetic when they are the main focus of the instructional process. Which helps to establish a positive classroom environment that motivates students to do their best (Marzano, 2013). When that process becomes more student-centered, allowing for more choice and interaction, the motivation stems from other aspects of the learning process. Even though it is important for a teacher to be positive in the classroom (Stipek et al., 1998), perhaps they do not have to force enthusiasm, as the instructor tried, if they have planned a lesson that students find interesting, can take ownership of, and be enthusiastic themselves. Lessons that allow students to collaborate and be creative seem to promote this quality. This was especially apparent during the tops activity, draw a scientist, and the final inquiry projects.

Some limitations in this study should be addressed. The first being that students took an exit survey at the end of every class. The instructor (first author) was always careful to leave the room so students would not feel coerced in filling out the surveys.

The second issue is the possibility that some students quickly filled out the survey at the end of each class without much thought. Though it does appear that the students put thoughtful consideration into the surveys at the end of each class, we cannot know this for sure. The last concern is the fact that students chose to leave questions blank on some days. There was no pattern to this activity and it is unclear why this was done though a student did informally mention to the instructor that if she did not feel she observed the question she left it blank. However, there were multiple students that left questions blank on the same day so we cannot know for sure if this was the reason for all of the students.

In regards to implications to future research, the results of this study do raise some interesting questions. The relationship between content knowledge and a teacher's enthusiasm is an important area that needs further analysis. This study suggested there is a positive relationship, but more research is needed. The next area is the idea that enthusiasm is cyclical. We found evidence to suggest that this in fact does happen, but not all the time. Perhaps there are other factors that excite students besides teacher enthusiasm. Further studies should investigate whether the relationship between student control and teacher enthusiasm are linked. Specifically how the relationship works on days where the instructor has control verse the days where students are in control. Finally, a look at how lessons themselves foster enthusiasm should be investigated. Our evidence suggests that a good lesson plan and adequate content knowledge play a role in both the instructor's and student's enthusiasm.

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Chapter 7
Response to Section II: Practicing, Modeling, and Influencing Approaches to Teaching: A Commentary

G. Michael Bowen

This section has four papers that have dealt with the *content* preparation of preservice science teachers (PSTs) so that they would have a more adequate background for teaching science. The research in these PST-focused content courses examines the role of the instructor and the practices they engage in, to understand the outcomes in these courses from a variety of perspectives. Each paper draws from a variety of methodological and analytical approaches consistent with the self-study perspective (many drawing on Loughran's work (2006) either directly or indirectly as a starting point).

In this commentary I'll draw some connections between the papers and their findings and the implications of those, but then I'll discuss a facet to consider that I believe is missing in these discussions of teacher education and what that might mean for future research in self-study and teacher preparation as well as in the selection of teacher candidates.

Three of the chapters examine elementary science teacher content courses, and one a secondary content course, but I'd suggest that the findings of each are generally applicable to other preservice teacher audiences (both grade-wise as well as subject-wise). The study by Gilles and Buck examined the role of "enthusiasm", a core teacher attribute that leads to improved student learning (Brophy & Good, 1986), framed with the context of "the teacher's ability to transmit the importance and intrinsic value of learning content to the students (Patrick, Turner, Meyer, & Midgley, 2003)" (p. 122, this volume) and various physical attributes such as speed of utterances, facial cues, descriptive speech, and energy level amongst others (Collins, 1976; Rosenshine, 1970; Turner, 2007). The authors reported that the preservice students found "real enthusiasm" motivating, but saw through "false enthusiasm" (as described by the teacher demonstrating it) and did not find it motivating,

G.M. Bowen (✉)
Faculty of Education, Mt. Saint Vincent University, Halifax, NS, Canada
e-mail: gmbowen@yahoo.com

G.A. Buck, V.L. Akerson (eds.), *Enhancing Professional Knowledge of Pre-Service Science Teacher Education by Self-Study Research*, ASTE Series in Science Education, DOI 10.1007/978-3-319-32447-0_7

although they were still motivated to learn during the inquiry investigation where it was displayed. The authors concluded that intrinsic motivation, perhaps deriving from a "positive environment" (Ritchie, Tobin, Hudson, Roth, & Mergard, 2011), was more of an influence than teacher enthusiasm on student's motivation to learn.

Gilles and Buck noted that as the students were left to be more in control of their learning environment during inquiry activities, as they were able to "move and work with others" (p. 137, this volume) this generated more positive engagement and increased their motivation. One can't help but notice that this parallels the "relational pedagogy" discussed by Trauth-Nare, Buck and Beeman-Cadwallader in their chapter. They also present a diverse series of activities and examined how relational aspects of the class improved learning outcomes in a class where traditional classroom discourse (i.e., teacher focused) was replaced with more peer-interaction and discourse and the teacher's role shifted to one of facilitator and co-learner. Trauth-Nare found that stepping back and giving students more room to have a voice resulted in improved learning opportunities and outcomes.

I was struck, however, by the self-criticism that Trauth-Nare engaged in when she was discussing her class overall:

> …the findings above indicate that sharing authority for teaching and learning was a difficult and hard-won goal for me. Class discussions proved most difficult for me to share authority. Clearly, I had an agenda for helping students to learn particular science concepts and this made class discussion a high stakes endeavor. The dilemma I faced lied in the fact that I had devoted instructional time to discussing an activity, project, or empirical research article as a way to promote understanding.

This seemed overly self-critical to me. Firstly, any individual activity needs appropriate scaffolding to achieve the desired learning outcomes of the course. For some activities/outcomes these can be achieved through negotiation and collaboration with the instructor being more of a bystander. For other activities it can be achieved through more traditional means. Or some mix thereof. Motivation (as noted by Gilles & Buck referencing Pintrich, 2003), not to mention what one needs from the instructor as a learner to learn effectively, changes with age. Children have fewer experiences to relate ideas, concepts and, even, stories to and thus are in need of more hands-on activities to provide the experiences they can align the concepts to. Adults, however, have far broader experiences and consequently can (often) get more out of direct instruction (i.e., being "told" something) because they have experiences they can relate those examples to. In a class full of adults with varied life experiences that means that their competencies are going to be wildly heterogenous needing more support in some areas than others both within and across groups because of variances in their Zone of Proximal Development (ZPD; as posited by Vygotsky, 1978). Consequently, this means that a teacher needs to vary their scaffolding quite substantially within any given class much in the manner of the actual practice described in the Trauth-Nare chapter. There might well be a tension with the instructor wanting to be "efficient" in their instruction in some places (thereby "telling") but in other places wanting to step back and engage in instructional approaches involving "multivoicedness" (Mortimer, 1998) thereby modeling classroom approaches that they would wish the preservice teachers to adopt with their own students in the future. Wishing to have a "better" classroom usually means using appropriate approaches in the necessary place, not engaging in a singular approach at all times, and sometimes that would mean using teaching approaches that work for adults but which wouldn't necessarily work for children.

This tension between needing to have preservice teachers knowing and understanding particular content while at the same time wanting to model appropriate teaching practices for science teaching with children is explored in Nyamupangedengu's chapter. Her findings were that an appropriately structured "content" course (in this case for secondary teachers) could indeed both teach the desired content as well as model variously appropriate teaching practices. This lies in contrast to "traditional" science content courses which generally use the transmission mode of teaching (i.e., lectures) supplemented by confirmatory laboratory activities which, in my experience, create secondary preservice teachers who are inclined towards the "lecture" approach to teaching because of the models for it which they can easily draw on. In my experience this entrenchment is so deep that although they might, after a year-long "science methods" course where hands-on inquiry approaches were both modeled and deconstructed (both experientially and conceptually in relation to the literature as per Loughran, 2006), profess that "inquiry" is an appropriate approach for science courses and one they wish to engage in, the classroom teaching they ultimately enact when they are in their own classroom is almost exclusively a traditional approach (i.e., teacher-directed, lecture-oriented, with confirmatory labs etc.) while at the same time they *talk* about their teaching practices as if they were engaging in inquiry investigations and multivoiced, relational teaching approaches (as commented by Hare (pers. comm.) when discussing Chap. 3 of Hare, 1985). That is not to say, however, that engaging in modeling approaches such as that practiced by Nyamupangedengu is without purpose, just that it is an attempt to counteract a teaching tendency towards pedagogical traditionalism which has the inertia of years of being lectured to as a student behind it.

Over the years I've perhaps become cynical regarding these issues of my (as an education faculty instructor) modeling "good teaching practice" whether it be regarding enthusiasm or relational pedagogy or hands-on inquiry practice or whatever, and that cynicism derives from my having lunch in the cafeteria at my university. The building I teach in is dominated by education students, and preservice education students exist in high numbers in the lunch area, so if I go and eat lunch at the right time I can eavesdrop on any number of discussions about our program (I teach a small minority of our undergraduate education students some years, and in other times teach none at all) as our second year students hold court for our first year students. I learn all sorts of things about my colleagues (many I'm quite sure they wish I didn't hear about) but I also learn that our post-baccalaureate education students are very good at being students. Very, very good. And by that, not to sound cynical, I don't mean in their enthusiasm or in their knowledge but rather in regard to the games they play as students to be successful in the program; and one of the biggest of these games seems to be "tell the prof what you know they want to hear so you get a good mark". Clearly, learning to be a teacher is a form of Wittgenstenian "language game" (Wittgenstein, 1958) as far as they are concerned, and for many of them the "game" part seems to be sticking with the core of their beliefs while professing otherwise (how else to explain the traditional nature of many of their teaching practices after they graduate?). Not to appear to be a "nattering nabob of negativism" (Spiro Agnew in 1970; discussed in Lewis, 2013) but either I and my many colleagues have been terrible instructors over the last 20 years (at least the amount of time we've been teaching our methods students to not engage in lecturing) or something else is going on...and I think it's the latter. We've modeled, we've taught, we've discussed, we've had readings with small and large group interactions, we've participated in inquiry with them, and we've involved them interactively in education research; and at times it seems to be to little or no avail, particularly when one's own children are taught electrical circuits in their grade 6 class through copying diagrams and memorizing the chapter by someone who was a well-thought of graduate from the local faculty of education at which one teaches. A bitter pill, but I think we have to at least look at the issue and how we might address our seeming ineffectiveness as instructors. In some ways, I think the chapter by Fuentes and Bloom starts to touch on what we've not considered.

Bloom sets himself up in his design of the content course for elementary preservice teachers so that a conflict arises between he and the students in mid-course. To his credit, rather than forging ahead he puts on the brakes and rethinks what was going on and his instructional approach and, the authors report, he then engages the students in a different manner through thinking about their identity development as a teacher. In other words, he considered their "identity" as one shifting from "student identity" to "teacher identity" and this meant engaging in teaching practices regarding the content of the course differently. This was driven, for instance, by his noticing in student reflective notes that students were looking externally for rules about what constituted high quality work rather than establishing those high expectations on their own accord (as a teacher might well be expected to do). In enacting his changed approach to teaching them he began engaging in what Loughran argues is the more effective approach of both modeling practice *and* engaging the preservice teachers in understanding the thinking, knowledge and reasoning that underlay choosing to engage in that practice (Loughran, 2006).

Yet, at the end of the day good praxis (that integration of practice and the theory that underlies it) such as Bloom was engaging in is not necessarily "good teaching" because we have no sense of those issues that other chapters in this section reflect. We don't know if he demonstrated enthusiasm (I'm sure he did, but…), we don't know if he demonstrated aspects of caring (not explicitly studied in these chapters, but a comment arising in several of them), and over and beyond that we don't know what attitudes about teaching teaching he modeled in his approach. At this point it's worthwhile noting that we don't, in science education, often talk about attitudes. I've personally always found that odd because so much of engaging in science effectively seems to reflect "attitude" as much as it does "practice" or "skill". An attitude is, according to the Oxford Pocket Dictionary, "a settled way of thinking or feeling about someone or something, typically one that is reflected in a person's behavior" (Attitude, 2009). Llewellyn (2013; p. 2) identifies a number of "habits of mind" that typify science (and other disciplines too), quite a number of which I would argue display an attitude inasmuch as they are a practice of science:

Commitment	Integrity
Creativity	Openness
Curiosity	Persistence
Diligence	Reflection
Fairness	Sensitivity
Flexibility	Skepticism
Imagination	Thoughtfulness
Innovation	Wonder

It's a considerable list, and yet if these reflect "science", then they surely should be modeled in teaching about science, or in teaching science methods for that matter.

Attitudes matter because the idea of identity and attitudes are closely interlinked (Smith & Hogg, 2008), yet it is unusual to see the concept of "attitudes" discussed in the science education literature, particularly in relation to preservice teacher preparation and more particularly in relation to developing those attitudes in any way that reflects "good teaching". Looking at my lunchtime experiences, I would point out that from the perspective of developing a professional identity the attitudes – towards the practices being taught – held by many preservice teachers do not seem to reflect the attitudes we would like them to hold. We would like them to take our arguments, our modeling, our readings about "good science teaching" and have them apply them to their own thinking about classrooms, but many seemingly do not. There are reasons for that.

As anyone who has worked in areas of racism, misogyny or even class-related issues knows, it can be remarkably difficult to change attitudes. There is a remarkably in-depth literature on attitude change in the social psychology literature, and for the most part science education literature neglects to engage it even when we discuss identity theory and the construction of science teacher identities. I'd argue that this is important because of what is known as the "backfire effect" and how it relates to attitudes and attitude change.

The "backfire effect" (Nyhan & Reifler, 2010) suggests that when presented with factual evidence that contradicts something about which people have strong opinions or attitudes, rather than changing their mind to align with the evidence people often continue to hold their original views more strongly than ever. Despite the contradicting evidence they hold those views, and even strengthen them. It is a motherhood statement in science education that people often teach the way they were taught, and that it is remarkably difficult to change that. The social forces in schooling, the influence of standardized tests, the intransigence of much formal curriculum certainly influences this difficulty, but in any system where those problems exist there are a few teachers whose identity AS a teacher has them engaging in practices we promote. I think our general lack of success at changing the rest of them is because we try and argue people out of the practices that they've experienced as students…we don't look at it as changing their attitudes about teaching instead our approaches are evidentiary-based…and the backfire effect kicks in.

At the end of the day there is nothing wrong with improving our use of modeling inquiry, of modeling enthusiasm, of engaging in relational pedagogy as instructors…these are all necessary to providing the foundations on which the development of a professional teaching identity based on more than just understanding pedagogy and content can be built, but overall as a science education community I think we need to work more seriously on the development of attitudes towards the teaching of science and attitudes towards the conduct of science and the associated "habits of mind" as part of that identity development. That, I suggest, means paying more explicit attention to the literature on attitude change in the future.

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Part III
Self-Studies and Elementary Science Methods Courses

Chapter 8
Evolving Goals, Pedagogies, and Identities as an Elementary Science Teacher Educator: Prioritizing Practice

Elizabeth A. Davis

Introduction

In this chapter, I explore the evolution of the work I have done as an elementary science teacher educator at the University of Michigan, focusing on my work in my science methods class for undergraduate preservice elementary teachers. I focus my analysis on three elements: (a) the *goals* I have set for my elementary methods class, (b) the *pedagogies* I have used and privileged, and finally (c) my own changing *identities* as a science educator, teacher educator, and science teacher educator. I draw on my syllabi and assignment descriptions over 17 years and my published scholarship generated in the context of the course (e.g., Davis, 2004; Davis & Smithey, 2009; Forbes & Davis, 2010). I engage in qualitative content analysis to discern themes and shifts in goals, emphasis, and expectations over time. I draw on my publications to complement these analyses as well as to characterize my own development as a teacher education scholar. These analyses show ways my work has reflected broader changes in the field.

I have conducted studies in my own teacher education classrooms with the goal of improving my own teacher education practice (Hamilton & Pinnegar, 2000) as well as that of others, and this body of work contributes to the literature base in the field (Zeichner, 2007). The individual studies I have published, however, lean closer to "formal research" than "practical inquiry" or "self-study research" (Loughran, 2007; Richardson, 1994). My work does not always reflect some of the key characteristics of self-study, such as the reflectiveness on the part of the practitioner (i.e., me) about how the research is affecting their *own* practice—in my writing I have emphasized implications for the field more distally—or fully bringing in the voices of the teacher education students. That said, in this chapter, I examine this

E.A. Davis (✉)
School of Education, University of Michigan, Ann Arbor, MI, USA
e-mail: betsyd@umich.edu

G.A. Buck, V.L. Akerson (eds.), *Enhancing Professional Knowledge of Pre-Service Science Teacher Education by Self-Study Research*, ASTE Series in Science Education, DOI 10.1007/978-3-319-32447-0_8

body of work, side-by-side with the artifacts of my work as a teacher educator. In essence, then, the chapter provides a meta-self-study, examining a science teacher educator's work and identity as evidenced both by instrumental artifacts of that work and scholarly products resulting from it. I use vignettes to provide a quasi-narrative window into the evolution of the work (and myself) over time.

Theoretical Framework

Changes in the theoretical stances I use have involved adding layers of complexity—not replacing one perspective with another. In my early work, I prioritized teacher knowledge, reflecting a cognitive and sociocognitive stance (Bransford, Brown, & Cocking, 1999). I used (and continue to use) knowledge integration as a frame, considering how ideas are added to one's repertoire, connected to other ideas, and distinguished from others (Linn, Eylon, & Davis, 2004). As I came to focus more attention as a scholar and as a teacher educator on curriculum materials, I saw these as conceptual tools in a sociocultural sense (Grossman & Thompson, 2008; Remillard, 2005), and I conceptualized these tools as being inherently situated in teachers' daily work (Ball & Cohen, 1996; Putnam & Borko, 2000). Now, focusing more on practice-based science teacher education, I explore multiple roles of "practice" in learning to teach science—both scientific practices (NRC, 2012) and teaching practice (Ball & Forzani, 2009; Lampert, 2010), and the interplay between the two.

Indeed, my development as a scholar has reflected key developments in the fields in which I situate my work: science education and teacher education. Both fields have shifted from valuing mainly conceptual knowledge and its application, toward an application of knowledge in the service of practice, and toward the meaningful integration of knowledge and practice.

In science education, since the 1990s, the field has moved increasingly toward an orientation toward scientific practice (e.g., Berland & Reiser, 2009; Gilbert & Boulter, 1998; McNeill & Krajcik, 2008; Zembal-Saul, 2009) and, currently in the US, toward "three-dimensional learning" that involves the integration of disciplinary core ideas such as biodiversity, scientific and engineering practices such as argumentation, and crosscutting concepts such as energy or size and scale (NGSS Lead States, 2013; NRC, 2012). The integration of content and practice, particularly, has driven much of my research and teaching.

At the same time, the field of teacher education has moved away from emphasizing mainly teachers' knowledge development and analytic skills—which was itself a reaction to the older process-product orientation of the teacher education field (Grossman & McDonald, 2008)—and toward what is increasingly referred to as practice-based teacher education (Ball & Forzani, 2009; Grossman, Hammerness, & McDonald, 2009). In practice-based teacher education, the goal is to support novices in becoming teachers who can engage with a threshold level of proficiency in a set of key teaching practices. In my own elementary teacher education program, we refer to this as aiming toward the development of "well-started beginners" who can effectively employ a set of high-leverage teaching practices, who have strong content knowledge for teaching and thus take subject matter seriously and teach content with integrity, and who meet a set of ethical obligations of teaching (Davis & Boerst, 2014). Again here, we see the importance of integrating knowledge and practice.

Because of the centrality of the construct of "practice" in this chapter, delineating its many meanings is key. Arias' (2015) analysis of how Lampert (2010) uses the term can help explicate how I use "practice" in reference to both science education and teacher education. Lampert refers to four meanings, and Arias explores three vis-à-vis teaching and science:

1. *A collection of practices*: In learning to teach, we refer to a set of high-leverage or core teaching practices. These can include planning practices (such as using curriculum materials for lesson planning) and interactional practices (such as eliciting students' ideas, meeting with a parent, or leading a whole-class discussion). In learning science, we refer to the scientific practices used to learn about natural phenomena; a canonical set (including, e.g., constructing evidence-based claims or using scientific models) is articulated in the *Framework for K-12 Science Education* (NRC, 2012).
2. *To practice*; *to rehearse*, *to do something repeatedly to study it*: In learning to teach, a beginning teacher may rehearse a lesson with her peers before teaching it to children. In learning science, a fifth-grader may work repeatedly on supporting claims with evidence.
3. *Practice as in a profession*: In learning to teach, the profession is teaching; in learning science, it would be a discipline of science, such as biology or geochemistry.

In the meta-self-study, I show the ways in which these different meanings of "practice" come to play increasingly prominent roles in my work as a science teacher educator.

Methods for the Meta-Self-Study

Instructional Context and Participants

I have taught elementary science methods since 1998, when I arrived as a new faculty member at the University of Michigan. Of the 17 years of the study, I have data associated with 16 instantiations of the class.[1] Throughout that time period, I have been the "lead faculty" for the class. Generally, this means I teach one

[1] I do not include the Fall 2007 version of the class in my analyses here. Two graduate student instructors taught the class that semester and I did not save a version of the syllabus or assignments.

(occasionally two) sections of the class (which historically has had two or three sections), and collaborate with the graduate student instructor(s) involved in the class, apprenticing them into the work of teacher education.[2]

The four-semester undergraduate program has had a consistently strong orientation toward content-area teaching and learning at the elementary level. It includes a field component, with preservice teachers having purposefully-designed clinical experiences for 6–9 h per week during the first three semesters of the program and a full-time student teaching experience in the final semester. The science methods class occurs in the third semester of the program.

The teacher education program underwent a significant redesign in the early 2010s (Davis & Boerst, 2014). The program became more purposefully oriented around three pillars: a set of high-leverage teaching practices, content knowledge for teaching academic subjects in elementary school, and a set of ethical obligations for teaching. While the redesign was in the planning stages for several years, it affected the science methods course starting in Fall 2011, at which time the class changed from being a full semester long to being 9 weeks long. Some of the substantive work of previous iterations of the class became central parts of other coursework, and thus could be removed from or reduced—yet reinforced—in the science methods course.

As a college student I majored in engineering and then worked as an industrial engineer before graduate school, where I was trained as a science educator and learning scientist. Unlike many teacher educators, my career trajectory did not involve a traditional classroom teaching job. During my graduate work, where I focused on middle school student learning, I did not have opportunities to apprentice in the role of teacher educator. I became interested in how new elementary teachers learn to teach science in part because I realized that as a new teacher educator and professor, I faced challenges that were similar to those my students were facing. I came to teacher education scholarship through my work as a teacher education practitioner.

Typically, there are 25–30 preservice teachers in a section of my science methods class. Most years, almost all of the preservice teachers are female, and most self-identify as white. In these ways, the participating preservice teachers are typical of the elementary teaching force in the US. Preservice teachers select a teaching major in this program; typically, approximately 15–25 % concentrate in science within their education degree.

The graduate students working with the class are typically working toward a doctorate in science education or, occasionally, teacher education. Most have science teaching experience at the elementary, middle school, or high school level.

[2] While still lead faculty, I did not teach the class in 2007, 2011, 2013, or 2014, due to sabbatical or administrative responsibilities. Note that because of the collaborative nature of the design and enactment of this course, when referring to our collaborative work on the course, I use first-person plural pronouns. When referring to my own work as a teacher educator or my work on the analyses for this meta-self-study, I use first-person singular pronouns.

These graduate students' progression as teacher educators follows a path similar to that described by Abell and her colleagues (2009).

Data Sources

Data sources for this study include my course syllabi (1998–2014), class assignment descriptions (1998–2014), and published scholarship focused on the class or my students. Here, I review each.

The structure of my syllabus has remained roughly similar over the 17 years of the study. Syllabus sections typically have included logistics about the class, course objectives, reading materials, requirements and grading, summary or overview of due dates, and tentative course schedule and assignments. In this study, I draw most heavily on the sections outlining course objectives and course requirements and grading. Reviewed holistically, all elements of the syllabus became more elaborated over the time period of the study.

The main categories of assignments or class requirements identified through open coding of syllabi include: (a) participation, (b) reflective journals, (c) versions of "reflective teaching" assignments (in which a science lesson is designed, enacted, and reflected upon), (d) unit or investigation plan (i.e., curriculum design), (e) science content interview with a child, (f) critique of lesson plan, (g) peer teaching (in which preservice teachers teach a small group of their peers), and (h) small science teaching experience (in which a portion of a science lesson is designed, enacted, and reflected upon; sometimes called "experience in the field" or EITF).

I turn to my published papers as a way of addressing questions about the evolution of goals, pedagogies, and identities—in particular, identities—over the time period of the study. Seventeen relevant published papers are used in this analysis. These were selected based on the following criteria: (a) published in a peer-reviewed journal, (b) focused on research questions related to the elementary science methods class or recent graduates, and (c) presented empirical research (i.e., not design approaches or research syntheses).

Coding and Analysis to Characterize the Evolution of Goals, Pedagogies, and Identities

I analyze the *learning goals* made explicit in my syllabi and assignment descriptions over time. I use open coding to develop a set of emergent codes. Within the first category, "curriculum", I coded for mention of standards, curriculum materials, unit planning, and critiquing lesson plans. Within the second category, "scientific practice", I coded for inquiry and investigation, explanation and sensemaking, scientific practices or scientific modeling, and the "four strands" of science proficiency (NRC, 2007) or "three dimensions" (NRC, 2012) of science learning. Within the

Table 8.1 Coding scheme for pedagogies of teacher education

Code	Instances of assignments
Pedagogies of investigation	Unit (or investigation) plan, Content interview with elementary child, Lesson plan critique
Pedagogies of reflection	Reflective journal entries, Reflective teaching
Pedagogies of practice	Reflective teaching, Unit (or investigation) plan, Lesson plan critique, Peer teaching, Experience in the field
Representation	Peer teaching
Decomposition	Unit (or investigation) plan, Lesson plan critique
Approximation	Reflective teaching, Peer teaching, Experience in the field
For *planning* practices	Reflective teaching, Unit (or investigation) plan, Lesson plan critique
For *interactional* practices	Reflective teaching, Peer teaching, Experience in the field

third category of "students", I coded for student ideas and equity. Within the fourth category of "teaching practice" I coded for high-leverage teaching practices and the idea of planning, teaching, and reflecting on lessons. Within the final category, I coded for identity. Through content analysis, I trace changes over time, using a matrix derived from the coded data (Miles & Huberman, 1994).

A similar approach is taken for the next set of analyses, but the focus is on the *teacher education pedagogies* used in the class. A taxonomy of teacher education pedagogies includes pedagogies of investigation, reflection, and practice (Grossman, Hammerness, et al., 2009; Grossman & McDonald, 2008). Pedagogies of investigation privilege analytic work (e.g., analyzing a case depicting a teacher's decision-making) and pedagogies of reflection privilege reflection on one's own or others' teaching. Grossman and colleagues' pedagogies of practice include decomposition (i.e., breaking teaching into its elements), representation (i.e., depicting teaching such as through videos or cases), and approximation (i.e., engaging in smaller or lower-stakes aspects of teaching; Grossman et al., 2009). In characterizing the teacher education pedagogies used in my classes, emergent coding highlighted the importance of one further breakdown, between pedagogies of practice supporting planning practices (e.g., lesson or unit planning) and those supporting interactional practices (e.g., eliciting students' ideas). Table 8.1 summarizes how the assignments from the class reflect the coding scheme. Assignments are coded because this shows what teacher education pedagogies were used to hold preservice teachers accountable. The syllabi are used holistically to add richness; while pedagogies are not necessarily explicit in syllabi, review at a gross level, using these codes as guides, provides further insight into the nature of the course.

Some assignments are superficially similar but enacted differently. One example is an assignment we now call "peer teaching."[3] Based on Grossman and colleagues'

[3] As noted in Davis (under review), we typically call these "peer-teaching" experiences, rather than "rehearsals" (see, e.g., Kazemi, Franke, & Lampert, 2009; Lampert & Graziani, 2009). While similar, in peer teaching, preservice teachers do not necessarily have the later opportunity to enact

notion of approximations of practice, peer teaching entails having preservice teachers teach segments of a carefully selected lesson intended to highlight common problems of practice in teaching science, such as working with data gathered by children. They teach these lesson segments to a group of peers and a teacher educator, who provides very specific, focused feedback. The focus is on one or a handful of specific teaching practices. Preservice teachers have the opportunity to rehearse these practices in ways that "quiet the background noise" (Grossman, Compton, et al., 2009; p. 2083) and lower the stakes. Early iterations of the class similarly involved preservice teachers teaching to one another. However, in those early years, I simply asked preservice teachers to select a lesson and teach it to their peers. The lessons ran a gamut (and often were more like art activities than science lessons), there were no focal science teaching practices, and participants (including the single teacher educator) did not provide specific types of feedback. As a result, while both versions are technically approximations of practice, only the later instantiation truly supports preservice teachers in deliberate practice (Ericsson, Krampe, & Tesch-Romer, 1993), in light of all three of Lampert's (2010) definitions of "practice."

The third set of analyses focuses on shifts in my own *identity* as a scholar, teacher educator, and science educator. Drawing directly on the publications that have emerged from my study of my methods course, I characterize the research questions of each of the relevant studies as focusing on knowledge, beliefs, practice, and/or other characteristics (such as identity or confidence). This serves as a proxy representation of "who I am" as a science teacher educator and scholar.

Because of the nature of this meta-self-study, I did not engage in traditional reliability and validity checks. However, issues of trustworthiness of the data and the claims about the data are important. I asked two graduate students who have taught this class with me multiple times and who are well-versed in the literature in science education and teacher education to read draft versions of this manuscript. Through conversation, we developed ways of addressing their recommendations. In general, they found the descriptions of the course, and my claims about it, to align with their senses of it. In this sense they served as critical friends in this analysis. More generally, they and the other graduate students with whom I work form the cadre of colleagues who have supported my own growth as an elementary science teacher educator, even as I have worked to support theirs.

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with children the lesson they were working on in the peer teaching. Like rehearsal, peer teaching grows out of the microteaching movement of the 1960s and 1970s and it has some similarities with that approach, as well. Both are intended to reduce complexity, allow for correction, and focus on decompositions of practice (Allen, 1967). The main difference between peer teaching and microteaching is in the nature of the decomposition of the task. Microteaching tended to focus on teacher behaviors deemed important in process-product studies (Zeichner, 1999), such as asking higher-order questions. Ball and Forzani (2009) note that a critique of microteaching has been its representation of teaching as "a set of decontextualized and atomized practices" (p. 508). In contrast, peer teaching focuses on meaningful lesson chunks.

The Evolution of Goals Over Time

Table 8.2 summarizes the characterization of the objectives articulated in the syllabi over the 17-year period of the study. This is complemented by a similar coding of assignments, because the assignments should reflect not just the explicit goals, but also perhaps any implicit goals of the course. Given that the plan/teach/reflect code indicates a more holistic goal, the analysis is consistent with an earlier description of the course goals as oriented around inquiry, curriculum materials, and student ideas (Davis & Smithey, 2009).[4]

Looking at the analyses of goals and assignments together, a few major trends can be identified. First, the focus on *planning*, *teaching*, *and reflecting* on science lessons—that is, putting the pieces of science teaching together—was consistent throughout the period of the study.

Second, the focus on *curriculum and curriculum materials* is most prominent prior to 2008, and drops off almost entirely starting in 2011, except for continued work on standards. This shift is explained by the program redesign, which affected the science methods class beginning in Fall 2011. In that redesign, we developed a course called Teaching with Curriculum Materials, which drew directly on much of the instructional work around lesson plan critique, adaptation, and use from the science methods course—yet was broadened to incorporate this focus for all academic

Table 8.2 Analysis of explicit course objectives over time

	F 98	F 99	F 00	F 01	F 02	F 03	F 04	F 05	F 06	F 08	F 09	F 10	F 11	F 12	F 13	F 14
CURR: standards	✓	✓	✓	✓	✓	✓	✓	✓	✓						✓	✓
CURR: curriculum	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				
CURR: unit plan	✓	✓	✓	✓	✓	✓	✓	✓								
CURR: critique					✓	✓	✓	✓	✓		✓	✓				
INQ: inquiry, invest., EEE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
INQ: explanation / sensemaking								✓	✓		✓	✓				
INQ: sci. practices / modeling										✓	✓					
INQ: 4 strands / 3 dimensions												✓	✓	✓	✓	✓
Ss: student ideas	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	✓	✓	✓	✓	✓	✓				
Ss: equity											✓	✓	✓	✓	✓	✓
TCHG PRAC: HLPs														✓	✓	✓
TCHG PRAC: P/T/R	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
OTHER: identity								✓	✓							

(✓) indicates goal was reflected in a main course assignment, but not in syllabus course objectives.

[4]The reflective teaching assignment, peer teaching, and experience-in-the-field assignments each relate to the capacity to plan, teach, and reflect on science lessons. The unit plan (or, later, investigation plan) and critique assignments all relate to the focus on curriculum. The content interview relates to the student ideas focus.

subject areas. Thus, the science methods course no longer focused on the use of science curriculum materials, because this was addressed in depth in the first year of the program.

Third, although the syllabus only listed a focus on *student ideas* as an explicit goal starting in 2004, the assignment analysis makes clear that there was a focus on student ideas (via the content interview) since the beginning of the class. In the program redesign, a new course sequence titled Children as Sensemakers took up in depth the ideas of how children make sense of scientific (and mathematical) phenomena, so this focus, also, was eliminated from the science methods class starting in 2011.

These changes due to program redesign should be considered in light of the intention to develop a more coherent and practice-oriented program. While the effect on the science methods course was to eliminate these explicit goals, the ideas were introduced earlier in the program and then reinforced through the science methods course and other subsequent learning experiences.

Fourth, each semester had a focus on *scientific inquiry or scientific investigation*. Over time, this became a much sharper focus on *scientific practice* (including, for a few years, scientific modeling), the *four strands of science proficiency* from *Taking Science to School* (NRC, 2007), and most recently the *three dimensions of science learning* from the Framework (NRC, 2012) and the Next Generation Science Standards (NGSS Lead States, 2013).

Fifth, in 2009, the course focus on issues of *equity* was made explicit as a goal and was addressed much more purposefully. Finally, in 2012, the course objectives began articulating specific *high-leverage science teaching practices* of focus, in keeping with the program's orientation as a practice-based teacher education program.

I identify four "eras" through analysis of these goals.[5] While most changes to a course are evolutionary, rather than revolutionary, such "eras" can be a helpful shorthand for depicting major thrusts. As such, we can refer to the early period (1998–2002) as the most *traditional*, with a focus on unit planning as the ultimate goal. This was followed (2003–2006) by the *curriculum materials and student ideas* era; here, I spent instructional time helping preservice teachers develop their capacities to (a) anticipate, elicit, interpret, and respond to students' ideas and (b) use science curriculum materials effectively. The period from 2008 to 2010 focused on *scientific modeling*; the emphases on student ideas and curriculum materials continued, but through the prism of modeling. This period also was the time when we introduced *peer teaching*; drawing on Grossman, Compton, and colleagues' (2009) ideas about approximations of practice, we began to focus on teaching portions of lessons as a way of developing high-leverage science teaching practices. The more *practice-oriented* era began in 2011, and was precipitated by the program redesign. At this point, the course became shorter, lost its explicit focus on curriculum materials and student ideas as indicated above, and developed a stronger focus on a specific set of high-leverage science teaching practices. This period also coincided with

[5] These "eras" are demarked in relevant tables using wiggly lines.

the release of the Framework and the NGSS, so the course continued its focus on scientific practice, but using language from the new reform documents. In this period, we also sharpened our focus on equity, developing a set of equity science teaching practices to use as touchpoints.

In selecting vignettes to depict some of these changes, I draw on one semester, Fall 1998, from the "traditional" era; one, Fall 2005, from the "curriculum and student ideas" era, to depict the focus on curriculum materials; and one from the most recent "practice-oriented" era, Fall 2012, to depict the focus on teaching practice.[6] For each vignette, I use a composite, fictional preservice teacher ("Jenny" in 1998, "Ashley" in 2005, and "Emily" in 2012) as a rhetorical device to contextualize novices' experiences in the class. Each vignette includes excerpts from the syllabus' course objectives and class requirements, gives a sense of how a week would be described on the syllabus, and describes my sense of the overarching flavor of the class.

Fall 1998: A Traditional Elementary Science Methods Class

Jenny read the following about the **course objectives** in her syllabus when she came to class in September 1998:

> ED421 will actively engage you in scientific phenomena, much in the way we hope you will actively engage your students. We will discuss the strategies you'll need to support learners in understanding fundamental science concepts, learning about vital scientific processes, and understanding the nature of science. … You will apply your growing understanding of science teaching by developing, enacting, and refining science curricula. [O]ne emphasis of this course will be on the idea of *preparing* to teach and *analytically reflecting* on your own and others' teaching. …

During this course, you will:

- become familiar with current resource materials like AAAS Benchmarks, state and district objectives, and numerous science curriculum programs,
- prepare to carry on inquiry-oriented activities by engaging in investigations involving exploration and discovery,
- gain experience in preparing, teaching, and analytically reflecting on elementary school science lessons while working with young students in local schools, and
- develop long-range teaching skills by preparing an in-depth science curriculum project.

As Jenny read on, she saw that the **class requirements** included participation, journal writing and "other analytic reflection assignments", an assignment that asked her to plan and teach two science lessons (including to her colleagues), and a final project that involved developing a unit plan.

(continued)

[6] These focal semesters are demarked in relevant tables using solid lines.

Skimming through the **description** of what they would do each week, she saw that 1 week, for example, they would explore how kids think about science, and she would do something called a "Draw-A-Scientist" interview with a child from her placement classroom. It looked like there would be a lot of readings and a lot of writing—but things seemed overall pretty manageable.

Overall, at the end of the semester, Jenny thought that a statement she had highlighted in the objectives in the syllabus captured the **overarching flavor** of the class: "one emphasis of this course will be on the idea of *preparing* to teach and *analytically reflecting* on your own and others' teaching." Jenny and her colleagues developed numerous science teaching plans, spent a lot of their time responding to journal prompts, and were essentially unsupported in learning to engage in specific science teaching practices.

Fall 2005: Analyzing Science Curriculum Materials and Working with Students' Ideas

Ashley walked into the science methods room in September 2005 and picked up a syllabus. In it, she read about the **course objectives**:

In ED421, our four main goals are:

- develop an understanding of scientific inquiry and inquiry-oriented science teaching… We will emphasize explaining using evidence …
- learn to anticipate and deal with students' ideas, including their prior knowledge and alternative (non-scientific) ideas
- develop your ability to critique and adapt curriculum materials so they're more inquiry-oriented and more appropriate for your classroom and your students
- help you start to think of yourself as a teacher and develop your abilities as a teacher

The objectives went on to describe that Ashley and her colleagues would become familiar with resources like the national and state standards; learn to teach "inquiry-oriented lessons… involving asking questions, making predictions, conducting experiments, collecting data, making observations, developing explanations, and communicating findings"; and prepare an "in-depth science investigation plan, building on existing curriculum materials."

Reading on, she saw the **class requirements**. Besides class attendance, participation, and various written assignments, the class requirements also included two "reflective teaching assignments", about which the syllabus said, "[Y]ou will develop a lesson plan by revising an existing lesson, teach it to children, reflect on your teaching, and analyze some student work." The last

(continued)

requirement was to develop a unit plan. She was used to doing big final projects in her classes, and she would also get to teach two science lessons, which sounded fun, if scary.

When Ashley looked at what would be happening **week-by-week**, she saw that the goals for each week were pretty extensive. For week 4, for example, she saw that the goals were to:

> Start to be able to anticipate kids' ideas about a specific science topic. Develop strategies for finding out about kids' ideas about a specific science topic. Consider how alternative ideas may be different for different students, for example, by gender, cultural background, etc.

She would do readings and written assignments most weeks (like the "Anticipating Kids' Ideas" homework mentioned for week 4 and assignments that would require analyzing and critiquing lesson plans other weeks). It sounded like there would be an emphasis on "scientific inquiry."

At the end of the semester, when Ashley thought back on the **overall flavor** of the class, she recognized that the class had focused on critiquing and adapting curriculum materials, working with students' ideas, and engaging students in scientific inquiry. Her professor thought that she and her colleagues had developed some skill in all of these areas (see Davis & Smithey, 2009). Compared to Jenny, who took the class in 1998, she did a lot less abstract reflection on teaching. Compared to Emily, who would take the class in 2012, Ashley and her colleagues worked in a less focused manner on teaching children to engage in scientific practices (though they did work on how to help kids construct scientific explanations).

Fall 2012: Increasing the Focus on High-Leverage Science Teaching Practices

Emily walked into the science methods classroom in September 2012, having made it through the first year of what her professors called her "practice-based" teacher ed program. She saw some familiar language about teaching practices and equity in the **course objectives** in the syllabus:

Our main goals are for you to:

- Describe the four strands of science learning—understanding scientific explanations…, generating scientific evidence …, reflecting on scientific knowledge …, and participating productively in science
- Incorporate the four strands of science learning into effective elementary science teaching …. Specifically, you will work on science teaching practices such as:
  - Appraising and modifying science lesson plans … to address a specific learning goal …

(continued)

  - Establishing norms and routines for classroom discourse and work that are central to science …
  - Choosing and using representations, examples, and models of science content
  - Supporting students in constructing scientific explanations …

- Identify and enact instructional practices that make science accessible to *all* students …
- Learn how to prepare, teach, and analytically reflect on elementary school science investigation lessons

When she looked at the **class requirements**, she saw that this class, like her others, would emphasize practicing lessons with her peers. Class requirements listed included:

> *Peer Teaching in ED421* (*three times*) …
>
> Each peer teacher will have a chance to lead their peer "students" through each of the following three elements of a science lesson: *engage with an investigation question*, *experience the scientific phenomenon* associated with the investigation, and *explain the phenomenon with evidence* to his/her peer teaching team. …
>
> *Experience Element in the Field* …
>
> Teaching the *Experience* element of a lesson will involve co-teaching a science lesson with your mentor teacher in your field placement classroom. The goal is to … practice small elements of science teaching, sometimes in low-stakes environments ….
>
> *Reflective Teaching Assignment* …
>
> … [Y]ou will analyze a science lesson plan using the lesson design considerations framework, develop your version of the science lesson plan using the instructional planning template, teach the lesson to children, reflect on your teaching using your video record, and analyze some student work.

She and her colleagues didn't always love rehearsing together—sometimes it felt awkward and embarrassing—but they usually felt it was helpful for improving their teaching. She also thought it sounded good that she'd be able to teach just a portion of a science lesson before teaching a full one.

When she looked at **each week's description**, she laughed about the length. Her professor had a lot to say! She saw each week's goals and how she could connect back to other classes, the syllabus listed out exactly what science teaching practices she'd work on each week, and it highlighted equity practices she would use.

By December, Emily realized that the **overall flavor** of the science methods class had involved deliberately practicing science teaching (through rehearsals and with kids). Her professor felt that she and her colleagues had learned about a range of scientific practices, gained expertise in science teaching practices, and developed ways to use language to support all students in engaging in rigorous and consequential science. Emily built on what she'd learned earlier in the program about lesson and unit planning and about students' specific ideas in science. Compared with Jenny and Ashley, Emily focused on these topics less within the science methods course itself, but more on actual teaching practice.

In sum, the early version of the class emphasized developing knowledge about and reflecting on teaching. A later class emphasized using student ideas and curriculum materials to support science inquiry. A more recent class emphasized the development of not just content knowledge for teaching, but also of teaching practices, supporting ambitious science teaching. Indeed, the course requirements demonstrate this shift; in 1998, the assignments showed a roughly equal emphasis on planning, enactment, and reflection; in 2005, the emphasis on reflection had fallen off; and in 2012, the main focus of the class requirements was on enactment, or practice. Due to these quite different goals, participating preservice teachers likely developed very different knowledge bases, skill sets, and even value systems. The goals themselves also became more transparent to preservice teachers, as rationales were included for assignments. Emily was more likely than Jenny or Ashley to recognize specific science teaching practices she could use (such as establishing norms for classroom discourse that emphasize science evidence), and she was more likely to have at least beginning levels of skill with these practices.

The Evolution of Pedagogies Over Time

My pedagogies as a teacher educator shifted over time, as well. Table 8.3 characterizes how each of the main assignments for the class reflect a range of teacher education pedagogies over time. This analysis shows a rough evolution from emphasis on pedagogies of reflection and investigation toward pedagogies of practice (Grossman, Hammerness, et al., 2009), and similarly from a focus mainly on practices related to planning to a greater focus on practices related to interactional work of teaching. This is in part because of the program shifts described earlier, meaning there was less need for the science methods course to fully address students' ideas (pedagogies of investigation) or lesson planning (pedagogies of practice for planning); instead, the course simply continued work preservice teachers had begun earlier in the program.

Table 8.3 Analysis of pedagogies reflected in main course assignments over time

	F 98	F 99	F 00	F 01	F 02	F 03	F 04	F 05	F 06	F 08	F 09	F 10	F 11	F 12	F 13	F 14
Pedagogies of reflection: Journals	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Pedagogies of investigation: Content interview	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓				
Pedagogies of practice – planning: Unit/inv. plan	✓	✓	✓	✓	✓	✓	✓	✓								
Pedagogies of practice – planning: LP critique*						✓	✓	✓	✓		✓	✓				
Pedagogies of practice – interaction: Peer teaching[a]										✓	✓	✓	✓	✓	✓	✓
Pedagogies of practice – interaction: EITF											✓	✓	✓	✓	✓	✓
Multiple pedagogies (reflection, practice): RT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

[a]Early versions of critique and peer teaching were originally incorporated into reflective teaching assignments and are omitted from this analysis for clarity, until they became explicit assignments

Choosing the same focal semesters—Fall 1998, Fall 2005, and Fall 2012—and using the same representative composite preservice teachers for a suite of vignettes allows illustration of this evolution. The third vignette, for example, depicts the approximations of practice (Grossman, Compton, et al., 2009) employed to engage novices in investigation-based science teaching through practice-based teacher education (Zeichner, 2012).

Fall 1998: Pedagogies of Reflection, Investigation, and Planning
Jenny looked at the handout delineating the many journal assignment options. Some required her to observe in her classroom; others just asked about her ideas about a topic. She read prompts like:

> Consider how you hope to use technology in teaching science. How would your plans differ given various technology set-ups (e.g., separate computer lab, … 2 computers in your classroom, 15 computers in your classroom, etc.)?
>
> Consider how your teacher tries to make science relevant to students' lives.
>
> Think about diversity in the context of your practicum classroom. What kinds of "diversity" do you see? Consider how your teacher deals with issues of diversity and equity in the classroom. How does your teacher's approach map on to what you consider the ideal?
>
> Reflect on the teaching of science, emphasizing how your ideas have changed over the course of the semester. … Look back at your original philosophy of teaching. Develop a new philosophy statement.

Jenny looked for more about the teaching assignment. In late October, she noticed that 1 week gave the following as an assignment: "*Turn in critique of an existing lesson plan. Enact in class*." The syllabus didn't say anything else about this, and there wasn't a separate assignment sheet for this, so she figured she had free rein for choosing a lesson plan and figuring out how she wanted to teach it. By late October, Jenny had worked with her cooperating teacher to identify a lesson to teach. It was from her first grade classroom's science curriculum and it involved having children (or, in this case, her peers) color pictures of the different life stages of a caterpillar (and butterfly) and then cut them out and paste them to a sheet of paper in the proper order of the life cycle. She had her colleagues do the activity. Her professor stopped by for a couple of minutes, but then had to rotate on to a different group. Talking with her professor afterward, she complained, "I didn't think this was worthwhile. My friends and I just chatted while we colored the pictures and cut them out." Her professor thought, "I agree. It wasn't very worthwhile!" But it would be a few years before she developed a better approach. In the meantime, preservice teachers weren't given guidance about what lesson to select, how to focus their enactment, or how to give one another feedback.

The Resulting Opportunities to Learn

The class emphasized reflective journals, unit planning, and the non-deliberate "peer teaching", demonstrating a mix of pedagogies of reflection, investigation, and practice. What the preservice teachers were able to get out

(continued)

of the pedagogies of practice, though, would have been almost entirely up to them. Furthermore, some of the pedagogies of reflection, too, were relatively dissociated from their own science teaching practice (see Davis, 2006a, for an analysis of one cohort's reflection on their own teaching). Thus, while Jenny and her colleagues undoubtedly learned some important knowledge related to science teaching, this class' foci were too diffuse to yield very effective learning outcomes for most participants. Participants had numerous opportunities for "studenting" but few that would prepare them for *teaching*.

Fall 2005: Pedagogies of Investigation Toward Planning Practices
Ashley saw that her syllabus mentioned a few "critique assignments." These built on one another over the semester, and in essence involved identifying key criteria along which to critique and adapt existing curriculum materials, analyzing the lesson plan to determine strengths and weaknesses along each criterion, and determining changes to make to address weaknesses.

For example, in early November, Ashley and her colleagues received Critique Assignment #2. On the assignment page, the criteria (which were developed as part of Critique Assignment #1 in early October and were elaborated in a class list) included:

1. *Questioning and predicting*
2. *Making explanations based on evidence*
3. *Communicating and justifying findings*
4. *Connecting to students' ideas*
5. *Promoting equity*
6. *Developing a sense of purpose*

The instructions provided to Ashley and her fellow preservice teachers stated:

1. Review the lesson plan you've received.
2. For today's critique, I'd like for you to focus on **making explanations based on evidence** as well as **one or two other criteria**. (Select your additional criteria based on what you think this lesson plan will allow you to go into depth on.)

For each criterion, they were asked to complete a chart with the following column headings:

- Aspect(s) of the lesson plan that **meet** the criterion
- Aspect(s) of the lesson plan that **do not meet** the criterion
- For the aspects that **don't meet** the criterion, how would you **change** this aspect of the lesson plan to better meet the criterion?

(continued)

The Resulting Opportunities to Learn

Ashley and her colleagues had the opportunity to explore science lesson plans as a result of engaging in these "critique" assignments, and developed skill in doing so (see Davis, 2006b, for an analysis of one cohort's experiences with these assignments). Using these critique assignments as a main thread running through the class supported a substantial emphasis on developing planning practices. These assignments also provided opportunities to work explicitly on planning for instruction around scientific practices—for example, in Critique #2, preservice teachers considered how the lesson could better support kids in constructing explanations. At the same time, the emphasis on lesson critique meant there was even less attention to the interactional practices of teaching than had been the case earlier.

Fall 2012: Pedagogies of Practice Toward Interactional Practices

Emily's professor had mentioned that one reason they would use rehearsals in science methods (in the "peer teaching" assignment) was because—as in most US classrooms—they were unlikely to get very many opportunities to teach or even see science being taught in their placement classrooms, which was definitely true for Emily. Emily read this about peer teaching:

> In the peer teaching assignments, you'll use either the *Stems* or the *Motion* Lesson (both from [the district's curriculum materials]) to teach a series of *Engage*, *Experience*, and *Explain with evidence* elements of lessons to your … peer teaching team over the course of the semester. When you are teaching, your colleagues will act as elementary students (intellectually, not behaviorally). The part of a science lesson that you'll teach (*engage*, *experience*, or *explain*) will correspond to the science teaching practices that we will model and discuss in class the previous week. … Immediately after you teach, we will "co-reflect" as a class…. This re-framing will let us all have a chance to talk about what went well and what could have gone better and work collaboratively on developing your science teaching skills.
>
> When you are not teaching your peers, you will fulfill the role of elementary students for your peer teacher colleague. … Your impressions and feedback for your peer teacher colleague will be invaluable for developing his/her teaching skills and will also help you think through your own science teaching. ….

The assignment also articulated expectations for peer teachers and peer students during enactment and collaborative reflection, including instructions such as "be responsive to your learners" (peer teacher), "think like an elementary student" (peer student), "be open to others' input" (peer teacher), and "refer to specific examples in offering constructive feedback" (peer student).

Because Emily was placed in a lower-elementary classroom, she was assigned the "Stems" lesson, which was intended for second grade. After co-planning for her "Engage" element of the lesson, the next week she taught it

(continued)

to three of her colleagues, as well as a science teacher educator, Maria, who had come to help her professor. (There was one teacher educator with each small group!) Emily knew that she was supposed to practice two main science teaching practices: eliciting students' ideas and setting up a question or problem for investigation. Emily's fellow preservice teachers and Maria gave her feedback specifically on those two practices. A couple of times, Maria asked Emily to pause her teaching, to try something again. Once Emily stumbled over how to word a question (her plan said "give scenario to ask about prior ideas" but she hadn't thought about how she would actually word this). Maria made a couple of suggestions and asked her to try it again, and it went much more smoothly the second time. Maria and her professor said this gave them a chance for what they called "deliberate practice."

The Resulting Opportunities to Learn

Through the peer teaching assignments, the class developed a more substantive focus on the interactional practices of teaching, not just the planning practices. In this way, the class also became less oriented toward (only) investigation or reflection. At the same time, the focus on *scientific* practice also increased, through the subsequent peer teaching lessons and other course experiences. The EEE framework helped link students' engagement in scientific practices with teachers' engagement in science teaching practices that support students in doing so.

Over time, the class shifted from emphasizing pedagogies of reflection and investigation, with the pedagogies of practice being largely idiosyncratic and unsupported, toward a more purposeful support for pedagogies of practice. Emily practiced her Stems lesson in a focused, meaningful way, whereas Jenny had "taught" her lesson on life cycles in a way that mainly entailed coloring and chatting.

The Evolution of Identities Over Time

I trace the character of my published teacher education scholarship through looking at whether the research questions explored emphasize knowledge, beliefs, and/or practice (or other elements such as identity or confidence, which were less prominent in my work). I illustrate these using time periods roughly parallel to those used for the vignettes, and draw on examples to show the thrust of the work. I use my publications' research questions as a window into my identity, as a reflection of how I represent myself as a scholar, recognizing the ways in which identity is constantly shifting and under development (Avraamidou, 2014). These identities reflect my values at given points in my career as well as my own skill sets and knowledge bases—which were developing in tandem. The identities also reflect shifts in emphasis in the fields in which I work as well as shifts in my own institutional and professional contexts.

My identity as a science teacher education scholar, then, has followed a similar path as the evolution of the class itself.

Early Work: Valuing Knowledge, Knowledge Integration, and Reflection

Sample Paper Titles and Research Questions

Example #1: "Knowledge integration in science teaching: Analyzing teachers' knowledge development" (Davis, 2004). The research questions included:

> First, in what ways is a prospective teacher's developing subject matter knowledge integrated with her developing pedagogical content knowledge (PCK)?
>
> Second, how do qualitative differences in her knowledge relate to the instruction—especially the instructional representations—she designs?
>
> Toward the goal of informing a larger question: In what ways is a knowledge integration perspective useful for analyzing a teacher's knowledge development?

Example #2: "Characterizing productive reflection among preservice elementary teachers: Seeing what matters" (Davis, 2006a). The research questions included:

> What aspects of teaching do preservice teachers consider, emphasize, and integrate when they reflect on their own teaching?
>
> What does their knowledge integration look like and how analytic are they when they reflect?

These papers thus address knowledge (including subject matter knowledge and pedagogical content knowledge), knowledge integration, reflection, and—to a limited extent—the planning practice of designing instructional representations.

What This Tells Us about Values and Identity as a Teacher Educator and Scholar

In these early instances of teacher education scholarship, I was building on my earlier work on middle school students' reflection and knowledge integration. I was interested in how the construct of knowledge integration (Linn et al., 2004) could help us identify a mechanism for the development of PCK, which seemed inherently to reflect "integrated knowledge." I was also interested in how reflection could promote knowledge integration among preservice teachers, given what I had explored with K-12 students. I took a mainly sociocognitive stance toward learning, and did not study these preservice teachers' actual teaching practice. The primary data sources in these papers were interviews and written artifacts from class.

Middle Work: Valuing Planning Practices and the Use of Curriculum Materials

Sample Paper Titles and Research Questions

Example #1: "Preservice elementary teachers' critique of instructional materials for science" (Davis, 2006b). The research questions included:

> What is the basis for preservice elementary teachers' critique of instructional materials in science?
>
> What criteria do preservice elementary teachers use for critiquing instructional materials when they develop the criteria themselves, and what criteria do they use when they are given a set of criteria from which to choose?

Example #2: "Curriculum design for inquiry: Preservice elementary teachers' mobilization and adaptation of science curriculum materials" (Forbes & Davis, 2010). Based on Forbes' dissertation work, the paper addresses research questions:

> How many and what types of curriculum materials do preservice elementary teachers use and what adaptations do they make?
>
> How inquiry-oriented are their lessons before and after adaptation?
>
> How do the preservice teachers' curriculum design decisions and inquiry orientations of the curriculum materials they use influence the inquiry orientations of their revised, post-adaptation planned science lessons?

Thus, these papers address knowledge and practice related to curriculum use and adaptation.

What This Tells Us about Values and Identity as a Teacher Educator and Scholar

In these pieces of scholarship, we see reflected the focus on curriculum materials identified in the early- to mid-2000s iterations of the class. I was focusing less explicitly on knowledge integration, though again, I was building on my earlier work through exploring the use of tools as scaffolding to support learning. I had begun to see curriculum materials as important tools for teachers, and I also was thinking about my own use of scaffolding as a teacher educator. The second piece also reflects another salient aspect of the identity shift I was experiencing as a teacher educator: I was working with graduate students whose work was expanding my own repertoire of ideas. In these pieces, while still adopting a largely sociocognitive stance toward learning, we were oriented more toward practice, though again, the focus was on planning practices rather than interactional practices.

Future Work: Valuing Interactional Practices as Well as Planning Practices

My interests are moving more toward exploring interactional science teaching practices as well as planning practices. I am interested in how teachers' knowledge and practice are intertwined as they develop capacities for supporting students in engaging in the kind of three-dimensional learning called for in the NGSS. Sample research questions might include:

1. How do preservice elementary teachers develop content knowledge for teaching science and a set of high-leverage science teaching practices through a series of university-based and elementary classroom-based approximations of practice?
2. What are the affordances and constraints of approximations of practice in an elementary science methods class for preservice teachers?
3. What science teaching practices are highest-leverage for supporting elementary students in learning disciplinary core ideas, scientific practices, and crosscutting concepts?
4. How can an elementary science methods class leverage the work on teaching practices conducted in the methods classes in other subject areas, given that elementary teachers teach each subject? What elements of teaching practice are straightforward to "transfer" or translate, and what elements are more challenging?

Conclusion: Tensions and Tradeoffs

In reflecting on these shifts in my own teaching and what it has privileged, I feel that the moves toward scientific practice and science teaching practice have been important for supporting novices in developing into elementary teachers who can engage their students in rigorous and consequential science learning. Practice-based teacher education can help novices be positioned to engage in ambitious science teaching (Windschitl, Thompson, & Braaten, 2008). Helping new elementary teachers be able to engage in the kind of teaching required by the NGSS will allow students to experience sophisticated science at even a young age (Lehrer, Carpenter, Schauble, & Putz, 2000; Metz, 2000). Table 8.4 summarizes the movement toward both science teaching practice and scientific practice in the course over time, as organized around Lampert's (2010) definitions of practice and Arias (2015) extension of those definitions to science teaching.

Table 8.4 Reflections of "practice" in course evolution

		Collection of practices	Rehearsal	Profession
F98	Teaching practice	Mainly planning practices	Some opportunity to rehearse interactional work of teaching, but unsupported	Mainly "studenting", not teaching
		Unspecified interaction practices		
	Scientific practice	"scientific processes"	No opportunity to rehearse scientific practices	No meaningful reflection of scientific profession
		Inquiry		
F05	Teaching practice	Critiquing lesson plans	No opportunity to rehearse interactional work of teaching	Stated goal of developing teacher identity
		Anticipating student ideas		
	Scientific practice	Inquiry	No opportunity to rehearse scientific practices	Investigation as reflection of scientific work
		Explanation		
F12	Teaching practice	Suite of high-leverage science teaching practices	Suite of approximations; scaffolded opportunities to rehearse interactional work of teaching	Elaborated syllabus using professional language
	Scientific practice	Range of scientific practices embedded in EEE framework	Multiple opportunities to practice explanation (and other scientific practices)	EEE framework and scientific practices as depictions of the work of scientists

The shift in the collection of teaching practices has been quite deliberate, as my own teacher education program moved to an orientation around a specific set of high-leverage teaching practices. Similarly, the shift in the focal scientific practices has moved away from mostly unspecified "scientific inquiry" toward (a subset of) the specific practices included in the Next Generation Science Standards and the Framework (NGSS Lead States, 2013; NRC, 2012). The move toward the purposeful use of approximations of teaching practice, along with multiple opportunities to work on the scientific practices, has been purposeful as well, and similarly driven by movements in the field (most notably, by Grossman and her colleagues' (2009) influential piece on approximations of practice and the Framework's articulation of the scientific practices). The evolution of practice-as-profession has been less influenced by changes in the field. In reflecting on how my materials show the profession of teaching, I have come to think that the shift (toward more elaborated and justified articulations) demonstrates my *own* growth as a professional who is increasingly aware of the need to portray teaching as a profession and who values supporting novice teachers in understanding the rationale behind instructional expectations and recommendations. The depiction of the science profession, in part, reflects our improved decomposition of the work of scientists. In sum, then, these shifts are mostly driven by growth in the field, but are at least in part driven by my own personal growth, as well.

I also, however, recognize tensions and tradeoffs in the moves I have made. Any science teacher educator faces challenges in determining what and how to teach. For example, which scientific practices are most crucial? What science content is highest leverage for a future elementary teacher? Which science teaching practices are highest leverage? In practice-based teacher education, how can we ensure that we provide high quality feedback to each novice teacher?

Beyond this, any teacher educator who studies the work happening in her or his own teacher education classroom faces certain challenges. Some of these include when and how to engage in data collection and data analysis, how to ask for permission to conduct research in a way that respects the instructor-student relationship, how to engage in data analysis that inherently cannot be anonymized, how to engage in member-checking, and many others. In my institution I have faced some additional challenges. For example, how to study one's elementary science teacher education when one's teacher education program is engaging in a major redesign? How to balance doctoral students' needs for teaching positions and dissertation contexts, with one's preservice teachers' needs as novice teachers, one's program's expectations, and one's own needs as a scholar? How to support doctoral students in learning to effectively support approximations of practice? While not unique to my context, these issues bear particular focus because of the important role that context must play in one's scholarship when the focus of that scholarship is one's own classroom.

Tradeoffs must be made in addressing some of these challenges. In my own work, for example, as a matter of principle I prioritize my preservice teachers' needs and my program's expectations before my doctoral students' interests—but those doctoral students' interests often in turn come before my own, as we collaboratively design teacher education experiences for our students. I have mostly privileged the scientific practices of scientific explanation and modeling—knowing well that, for example, scientific communication is also a critical scientific practice. I focus on science teaching practices I see as crucial (such as supporting students' explanations), but limit focus on others that I also see as crucial (such as responding to specific student ideas). The list of tradeoffs goes on. My intent here is not to prescribe solutions to these dilemmas for others, but rather, to acknowledge the issue of making such tradeoffs and to offer considerations for others' deliberation: one can conceptualize such choices in terms of one's own personal and professional situation, one's institutional context, *and* developments in the field that can push one's thinking forward.

In elementary science teacher education, I have found that focusing much more purposefully on scientific practices and science teaching practices helps me to support the development of what our program, as noted above, calls well-started beginners. I aim to help our graduates feel, and be, prepared to engage in science teaching that reflects the kinds of ambitious teaching called for in the field today. Elementary teaching is an incredibly challenging job; having deliberately practiced how one, for example, elicits children's scientific ideas, uses representations of science concepts and data, and supports students in constructing scientific explanations may make those challenges a little bit more manageable.

We should always endeavor to grow as educators not just based on our own experiences, but also through development in the larger field of scholarship. Elementary science teacher education will continue to benefit from ongoing studies that teacher educators conduct in their own teacher education classrooms, informed by and informing the larger field. Depicting the ways in which our classes change over time can help us gain perspective on the ways in which we, as scholars and practitioners, experience the changes happening in the field. This, in turn, helps to yield important professional knowledge about both novice teachers and teacher educators.

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Chapter 9
Our Journey of Understanding Through Lesson Study

Stephen Marble, Michael Kamen, Gilbert (Gil) Naizer, and Molly Weinburgh

Introduction

Proficiency in both the content and the practices explored in our methods classrooms are essential for teacher educators, but our prior experiences sometimes prove insufficient to prepare us to introduce new teaching practices to our students. Japanese Lesson Study offers such a case in point. Research suggests that it offers great promise (Lewis, 2000; Marble, 2006, 2007; Stigler & Hiebert, 1999), and we wanted to share this powerful professional development approach with our methods students. But we had little actual experience with the practical aspects of how it would work in our classrooms since none of us had engaged in lesson study as participants ourselves. To deepen our understandings of this process and our students' learning (Clandinin, 1985; Connelly & Clandinin, 1985; Connelly, Clandinin, & He, 1997), we undertook a study of our own classroom practices (Cerbin & Kopp, 2006).

So that we could more fully help our students understand lesson study, the authors decided to conduct a Japanese Lesson Study of our own collective efforts to teach our students. Specifically, we aimed to systematically explore our own strategies for incorporating the teaching of assessment into our elementary science methods classes.

S. Marble (✉) • M. Kamen
Southwestern University, Georgetown, TX, USA
e-mail: marble@southwestern.edu; kamenm@southwestern.edu

G. Naizer
Texas A&M University-Commerce, Commerce, TX, USA
e-mail: gilbert.nazier@tamuc.edu

M. Weinburgh
Texas Christian University, Fort Worth, TX, USA
e-mail: m.weinburgh@tcu.edu

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As a result of our participation in the lesson study activities, our discussions have turned to a more thoughtful examination of our shared understandings of the pedagogy of science teaching. This, in turn, developed into the present study – a self-study of our growth as science teacher educators as a result of having engaged in the initial Lesson Study. As our insights led to new questions and new perspectives, we have come to understand the important role of theory in our practices.

Theoretical Framework

Collectively the four authors share many theoretical perspectives on learning to teach science. Three specific areas of agreement stand out. First, we each base our teaching on sociocultural constructivism, emphasizing the collaborative nature of learning and the important roles played by more knowledgeable others (Luria, 1976; Vygotsky, 1978, 1986). We build on the work of Schon (1983) and Shulman (1986) who support the use of reflection to deepen understanding about both content and practice. In addition, we firmly believe in the value of creating learning communities in our classrooms (Bielaczyc & Collins, 1999; Stoll & Louis, 2007). Taken together, these three elements define the major parameters of our collective understanding that guides how we teach our students to become teachers. In the past, these elements have been combined loosely to function as tacit and assumed principles shaping our practice rather than offering a well-articulated robust theoretical framework.

In fact, specific theories and empirical studies describing and explaining "educators' expertise on teaching about teaching subject matter" (Berry & Van Driel, 2012, p. 120) are scarce. However, the three elements we tacitly shared strongly echo the work of Dana, Campbell, and Lunetta (1997), who claimed that teacher education had focused for too long on teaching techniques and methods grounded in an objectivist epistemology and had failed to engage learners in a more meaningful pedagogy. Dana and his colleagues challenged science teacher education reformers to move toward a new paradigm guiding elementary science teacher preparation based on three central constructs: constructivism, reflection, and professional community (p. 422–423). The tacit framework that the authors independently adopted in our individual practices powerfully suggests that such a paradigm has become widespread among science teacher educators.

Although the links between sociocultural constructivism, reflection and professional community are loosely defined, we would argue that these various dimensions outline an untested theory about teacher preparation that shapes our practice. In our early efforts to explore these ideas, however, it was the *practice* of teacher education that we were focused on improving. And, though our practices rested on dimensions that had not been fully examined as a coalesced theory, we did not consider our efforts to be a conscious exploration of the underlying theories on which they were based. But, because the contours of our study follow the lesson study work of Lewis (Lewis, 2000; Lewis & Tsuchida, 1998), we found ourselves engaged in just such an examination of theory. For example, rather than trying to reproduce what research suggested was 'good practice' for developing an understanding of teaching science, we tested this notion engaging in multiple trials of a lesson. We used data from each trial to refine our thinking as well as redesign our instruction. After the fact, we realized that the process and the product changed many facets in our individual science methods courses.

Participants

The researcher-participants in this study are the four authors. We each have taught K-12 prior to entering the university, have taught at research institutions, and are now employed at universities that focus on teaching and teacher preparation. At the time of the lesson study we were the only science teacher educators at our campuses, making the collaborative approach to investigating our teaching more attractive.

Collectively we entered the lesson study believing that there is much to be learned from students and that studying the complexity of lessons could help us become better teachers. With its emphasis on observing student engagement with lessons, lesson study provided an excellent venue to do this.

In addition to studying the change in our teaching of assessment that was the focus of our lesson study, we have now engaged in a study of self. This has moved our thinking to a more theoretical footing and has required additional reading, reflecting, and discussion.

Methodology

Self-study of teacher education practices (Pinnegar, Hamilton, & Fitzgerald, 2010) promotes the construction of knowledge about teaching from the collection and analysis of observational data. As knowledge is constructed, advocates posit, it becomes evident in teaching (Pinnegar & Hamilton, 2009). Thus, self-study involves critical analysis of ways of understanding and articulating knowledge of practice (Loughran, 2007). Because lesson study involves recursive observation and reflection on both teaching and learning (Kamen et al., 2011), it provides a solid framework for self-study. For those unfamiliar with this professional development strategy, a brief description is provided below.

> The premise behind lesson study is simple: If you want to improve teaching, the most effective place to do so is in the context of a classroom lesson. If you start with lessons, the problem of how to apply research findings in the classroom disappears. The improvements are devised within the classroom in the first place. (Stigler & Hiebert, 1999, p. 111)

Japanese Lesson Study was first described and has been widely promoted in the United States by Lewis (1995). She reported on this fairly common professional development activity in Japan and described five characteristics of lesson study necessary for its success: The lessons are planned collaboratively over a period of time; the taught lessons are observed by other teachers; the lessons intend to bring to life a particular goal or vision of learning; the lessons are recorded; and the lessons are discussed and shared with others. In Lesson Study the center of attention is shifted away from a particular teacher and his/her instructional actions and toward the resulting actions, words and ideas of the students in the class. Slowly gaining acceptance in the United States, many sites and resources about Lesson Study can be found on line. (See Note 1).

Context of Our 2005 Japanese Lesson Study on Methods Instruction

We entered our Lesson Study having read about the mechanics of the process (Lewis, 2000) and had even required our students to apply lesson studies in some of our individual methods classrooms (Marble, 2007), but as a group we had no deep theoretical comprehension of the inner workings of this approach. Unaware of Dana and his colleagues' arguments, our exploration of teaching teachers integrated each of the three elements he proposed: sociocultural constructivism, reflection, and professional community. Our PSTs first engaged in groups with a hands-on experience, reflected on their experiences together and then convened as a whole class to share ideas and understandings. We also included a fourth element stressed by Dana et al: the integration of science content and pedagogy. Teaching PSTs with limited experience in scientific inquiry and content is typical in pre-service elementary teacher education courses. We wanted to know how a hands-on exploration of a scientific concept (density) and the simultaneous exploration of pedagogical methods (assessment) could work to deepen our students' understanding of both.

We began with several meetings over the course of a semester brainstorming pedagogical strategies we found challenging in our teaching and we quickly agreed that teaching about assessment was an area with which we all struggled. As science teacher educators, we strongly believed that pedagogical topics for our methods courses should be contextualized with a specific science concept and we considered several concepts to deploy during our study of classroom practice. We wanted the topic to be complex enough to generate a range of understandings while allowing for an active hands-on inquiry experience. Ultimately, we selected an activity involving sinking and floating to deepen our PSTs scientific understanding. The lesson engaged the PSTs in exploring a variety of assessment strategies in order to capture their own developing understanding of the concepts of density and buoyancy as well as the pedagogy of assessing students for understanding.

In Japanese Lesson Study, teachers examine their practice by focusing on what the students say and do during the instructional activity. We designed our investigation to follow the protocols and structures of Lesson Study as closely as possible. The Assessment Lesson was taught three times, once on each of our home campuses to our own students. As many of the authors as possible observed the teaching of each lesson and, immediately following, we met as a team to debrief, sharing data and ideas about how the lesson had gone and what students had learned. Our initial research using lesson study allowed us to collect data on student engagement as a result of our instructional planning.

A final iteration of the lesson was taught as a public research lesson at an Association of Science Teacher Education (ASTE) conference session with a fourth group of PSTs from a local university and an audience of professional science educators attending the conference (Kamen, Weinburgh, Marble, & Naizer, 2006). Session attendees participated as observers in the final research lesson and debriefing. The conference session challenged us to explicitly and publicly share what we had learned and provided an opportunity for peer critique.

Several years later, we met again as a team to revisit our experiences and to explore its impacts on our long-term understandings and practices. During this later exploration, we have utilized a collective method that involves the "interactive exploration of an issue by a team of researchers" (Lunenberg & Samaras, 2011, p. 844).

Data Sources

Each time the lesson was taught, observers (science methods professors) concentrated on what the learners (PSTs) were saying and doing. Data (field notes, videotape record and artifacts) were collected from each lesson and analyzed by the team of participant-researchers. Immediately following each lesson, we met to debrief and reflect on the students' learning and to discuss ways we might modify the lesson. We also reflected on what we were learning about teaching elementary education majors about teaching science.

Prior to revisiting our experience for the second phase of the study, the authors viewed the video recordings of the original planning sessions, actual lessons, post-lesson debriefings, and the conference sessions. Additional data in the form of memories, analytic memos, and syllabi revisions were collected. In a brainstorming session, each author discussed what elements of the original study remained most salient and what each author thought was the major change in his/her teaching and understanding of how to best help pre-service teachers learn to teach science. Sharing through Google docs and multiple conference calls, each author captured ideas, questions, and concerns. As a result, we engaged in an ongoing and open dialogue in which we respectfully recognized the differences in each other's viewpoints and sought clarification and understanding.

Data Analysis

We used a grounded theory approach, employing a modified constant comparison (Glaser & Strauss, 1967) approach, as we examined the data individually and then collectively over several iterations. Each iteration of the research lesson conducted in 2006 provided the research team with raw data to analyze. Following the protocols of Japanese lesson study, each lesson had been taught, notes taken, and the team debriefed in order to continue to push understanding that would help us solve the stated problem of how to teach assessment to PSTs.

Data from the lesson study project were revisited in 2014 in order to move the analysis to a more reflective, conceptual understanding of teacher educator change. Each member of the team watched the original recordings of the lessons and reviewed written artifacts before making initial open codes. To tighten and provide checks and balances, the team held conference calls in which we served as critical friends to one another (Costa & Kallick, 1993; Miles & Huberman, 1994). The critical friend acts as both a highly trusted 'friend' and as a provocateur that challenges, questions and critiques. The critical friend provides context for the learner to push critical and supportive feedback on his/her work. From the sharing of individual codes, we developed our first set of theoretical codes and analytic themes (Charmaz, 2006). The next phase of analysis involved dialogue methodology (Lunenberg & Samaras, 2011) through which the team created the final list of themes. The last phase occurred during the writing as we continued to revise our thinking (Yagelski, 2009).

Key Findings

As a collective, we learned important ideas about ourselves and about teaching elementary pre-service teachers. Several key findings emerged very early in the process; others have emerged over time. Four of these are presented below.

The Complex Interaction Between Content and Pedagogy

We anticipated that both of the constructs under study would pose challenges for our students; in fact, that is why these were selected. The term "density" is used frequently in everyday speech in ways that promote confusion when the scientific conception is examined. A complex topic, density is often misunderstood and teachers working with the concept often fail to move beyond the hands-on experience to promote concept development. Our sociocultural constructivist approach first led us to have our PSTs use small group discussion to reexamine their prior understandings of density in order to develop more sophisticated ideas. We expected this activity would create discomfort, particularly in the public context of a classroom community. Moreover, we welcomed this discomfort, thinking it critical to the process of learning new ways of thinking.

Our lesson design called for the PSTs to expose their prior knowledge in discussion, test it through a group hands-on activity, reformulate their understandings of density, and then complete assessments to allow them to demonstrate their new understandings. During the assessment activity they would explore a variety of ways to demonstrate their new knowledge, including Multiple Choice tests, an essay prompt with model response, creating a model boat, or performing a skit. We thought of the lesson as helping each PST think about how to assess learning in science. The pre-activity of sinking and floating would provide context and an anchored experience about which to discuss assessments.

From the very first lesson we conducted, we observed our PSTs struggling to combine learning about new content with new pedagogy. We entered the study thinking that teaching simple content while simultaneously introducing new pedagogy would enable us to have the lesson serve two ends: the science content would provide a contextual vehicle for learning about assessment, allowing for a synergy that would deepen the PSTs understandings of both.

But quickly we saw and heard our students struggling much more than we had expected to attend to both problems simultaneously. While it came as no surprise that many of the students held incomplete or incorrect content knowledge of floating/sinking and density, we were frustrated at how powerfully these prior notions preempted their thinking about the quality and practice of assessment. Student comments such as "we didn't cover that" and "I'm not good at multiple choice" indicated our students were attending primarily to their own content knowledge rather than their developing pedagogical knowledge related to assessments. A majority of student comments referred back to the sink/float context despite our explicit intended focus was to have them explore the value of various assessment methods. One group of students was very excited that their clay boat floated, but even though they successfully completed the task, the students could not explain why their boat floated, and thus could not demonstrate any new knowledge of buoyancy and density.

As we progressed through the three iterations of the lesson, we revised the lesson to explicitly focus student attention on the role of assessment. Still students often reverted to questions or comments about the science content rather than engaging in any discussion about the various assessments. In the end they were unable to divorce themselves from efforts to extend their limited content knowledge, trumping any deeper reflection on the activity and its possibilities for understanding assessment.

Lesson Study as a Powerful Professional Development Tool

Secondly, we confirmed our intuitive belief that Japanese Lesson Study provides a rich framework for professional growth for teachers at all levels. As a group we now have a working familiarity with the process and an applied experience to draw on in helping our students understand and engage with this professional development approach. But even more importantly, lesson study helped us address major issues in our own practices of how to teach PSTs. One can be seen in how we now attempt to combine content and pedagogy in our lessons, described above. A second involves how we now focus on students. All of us now recognize and practice more "student centered" approaches in our own teaching, where students, their understandings and efforts are at the very core of our discussion and analysis. For example, one of the authors describes how, as he now prepares to observe student teachers, he asks them before hand what it is that they want him to attend to most closely. Another author was profoundly influenced by a change we made during one of the lesson planning meetings, a move from having students examine their own efforts to having them examine other students' work. She now exclusively uses the work of other students (often the work of K-6 students) to help her PSTs assess learning. And, for all of us, listening to students during our lesson study data collection observations has provided convincing evidence that it is not what the teacher does but what students understand that serves as a measure of effective practice.

Several of us have found ways to use lesson study in our methods courses while others are using lesson study elements. But all of us now incorporate two new approaches in our own instruction that grew out of the lesson study activities. First we each promote the practice of having the PST concentrate on student interactions in their planning, instruction and reflections. We find this challenging because PSTs want to think about their actions without thinking about the consequences for the learner, but that making the practice explicit helps them shift the focus from the teacher to the student. A second outcome of our lesson study concerns the role of lessons in the developmental process of learning. We each now emphasize that the process of planning, teaching and assessment is not one where the PST creates the 'perfect, finalized' lesson but rather as an organic process that must change in response to the contexts of the classroom.

The Value of Professional Community

A third outcome of our collaborative work involves how we now understand the value of professional community. Although we had read the scholarship on community of practice, this experience brought home the value of collaboration with others who are knowledgeable about our work. While all of the authors have been actively involved in the science education community, we all teach at small universities and may be the only (or one of two) science educators on campus. The lack of local colleagues with extensive knowledge of science methods and associated issues left each of us feeling somewhat isolated in spite of having good working relationships with peers. While we feel that a lot of common ground can be found with our colleagues in mathematics, social studies, language arts, or general teacher education, specialized knowledge required for science methods deepens from collaboration with other science educators. The lesson study process forced us to spend extended time focused on the teaching of assessment as well as the science content – pre-planning teach, debrief, second teach, debrief, third teach, debrief, public lesson and debrief. These repeated and intensive conversations promoted powerful reflections on our teaching and students' learning, rather than cursory self-reflection often done on the way back to our offices after class.

In addition, we have come to realize that our professional community extends beyond our collaborations in the classroom. The fourth lesson conducted at the professional conference involved colleagues in a unique experience. Rather than passively presenting our collaborative work to attendees, we actually invited them to join us to observe, discuss and reflect on the work in a lesson taught using PSTs in an elementary science methods class from a local college. This approach to a conference session substantially altered the relationship between the presenters and the audience, creating a collaborative public research community in which all of our ideas were shared and debated.

The Recognition of Practice as a Test of Theory

Finally, a key outcome of our work is that we now realize, though the lesson study activities were focused on improving our practice, we were also testing the theoretical framework on which that practice rested. Perhaps this should not have come as such a surprise, since we had built our practice on a loose association of beliefs about teaching without articulating for our selves or others how we embodied these notions and how they played out in our practice.

Our data collection and analysis intentionally focused on student learning during the lessons, but our debriefing sessions increasingly were spent clarifying our own content knowledge and tacit practices of teaching science teachers. Reexamining our taped debriefings, we found that we continually switched back and forth between reflections on the science content learning and how important or unimportant it was in order for students to be able to evaluate assessments on the topic. Our deliberations began to be dominated by what we had assumed true at the outset: that learners can learn new content alongside new pedagogical methods for teaching and assessing that content.

We were testing our underlying theories of teacher education through practice. The science methods classroom had become our 'laboratory' and each of the teaching sessions resulted in our changing a variable and observing the outcome of the variation. Our initial assumption that both new science content and pedagogy can be learned simultaneously was seriously challenged by the students' behaviors, resulting in our constant distraction from concentrating on their ability to learn about assessment. The interference was so strong we had to remind each other repeatedly that the goal of the lesson was related to understanding how to help PST's learn about assessment. If combining content and pedagogy proved so difficult for us, how difficult must it be for the PST learners in our classrooms?

Discussion

We did not enter our lesson study collaboration thinking of it as an experiment and of our classrooms as laboratories; rather we thought about our joint effort as a way to improve our practice. However, revisiting the data and reflecting on our work together reveals that our theoretical understandings were clearly put to the test during our lesson study. We created multiple recursive scenarios in which to observe how our instructional approaches impacted student learning and we systematically manipulated components of the lesson as we encountered problems or recognized opportunities that influenced the outcome. We changed such things as number of objects that the PSTs had to sink/float and how the assessment portion of the lesson was conducted. It was not just our practices that were under scrutiny, but our theoretical understandings as well. How does reflecting back on our experience with a theoretical lens using the methods of self-study make it richer?

Working from Theory

Fernandez (2002) noted that Japanese teachers working with lesson study had the benefit of significant direction to and experience with approaching the practice as "… a form of research that centers on conducting classroom experiments" (p. 400). She describes lesson study in Japan as informed by a systematic perspective that allows teachers to learn from each other. While working with teachers in the United States to learn about lesson study, she found they frequently struggled because they had not developed and could not deploy the research skills they needed to approach their examination of classroom practice in this way, and often were limited to considering their efforts as lesson building activities.

We recognize that our PSTs are similarly limited when it comes to thinking about their learning. They regularly approach classroom activities in our methods classes as a series of discrete opportunities to acquire skills rather than to support the development of a research-based perspective on teaching. In order to help them understand and employ lesson study in their practice, we enthusiastically agree that PSTs should experience and understand how their own research and that of others will enhance their classrooms. This raises the question of what is realistic for PSTs to have as theory and how can we move them forward? What are we really trying to accomplish in methods courses if students do not have a theoretical understanding of both the content and the pedagogy? Unfortunately, our lesson study experience suggests that we have a ways to go before we find answers to these questions.

Windschitl (2004) goes even further. His examination of the inquiry approaches of graduate science teacher candidates revealed that the great majority of them worked with "folk theories" of scientific inquiry that limited them to thinking of each experiment in isolation from any scientific theory. Even students with advanced degrees or work experience in laboratory science pursued versions of inquiry that notably lacked connections to theory or scientific models. He concludes by calling for deeper, richer inquiry experiences during pre-service methods classes, and requiring that those inquiry experiences be grounded in the students' theoretical knowledge.

We know our undergraduate methods students work with a more limited base of experience and knowledge than PSTs with graduate degrees in science. No doubt they need considerable time and engagement to begin to examine the theoretical understandings underlying either the content or the pedagogical issues we challenged them to confront. So how do we approach this problem of helping our students work with their theoretical understandings from the beginning of their teaching experience? How do we support our students' understandings that their actions in the classroom are grounded in theory whether conscious or not?

Problematizing the Curriculum for Students

We found the line between discomfort that mobilizes learning and discomfort that preempts learning is a very fine one. We witnessed our students' dual discomforts as they wrestled with the concept of density and then had to be public with their own lack of understanding. Our solution was to give them the assessment answers from students in other classes. This lowered the affective filter (Krashen, 1985) and allowed them to concentrate on what kind of knowledge each assessment could best capture. This, in turn, enabled them to address the questions of assessment but at a cost: their constructions of the density concept were only minimally explored in the final lessons. If new ideas in content and new pedagogy create interference, must one always be deferred? Is it always the case that we must make such a choice? What would a third space look like?

Furthermore, though we were successful in helping our students engage with the assessment goals of our lesson, we are not confident we met another instructional goal: helping our students think about and reflect on how this comfort/discomfort works with their own students? Our findings now make us want to ask the question, "How do we problematize the lessons so that our students engage with the multiple rich dimensions of pre-service practice?" We want them to think/reflect/struggle about how to work with students and to see that there is no 'formula' for a 'great science lesson' or a 'perfect assessment'.

Even as we felt the frustration of the time limits that the university class schedule put on the lesson for us, we want to foreground the decisions that teachers must make around time available and the depth of understanding that can be reached in that time. We know that it takes time to understand complex ideas and yet we tend to move through our own instruction at a very fast pace. This self-study of a lesson helped us to value and honor the slowing down process necessary if deep learning is going to occur.

The Public Nature of Practice

Sharing our classroom practices with colleagues who are critically watching our students' and their understandings created a certain amount of tension for each of us. Yet we found the collaborative discussions that surrounded our lessons provided a richness that might never occur to each of us working alone. And, over time, the shared experience among the four of us allowed a continuing dialogue about the results and our understandings long after the actual events.

One element of the systematic approach to Japanese lesson study is the public dissemination of results through multiple avenues, including the 'research learning presentation meeting' (Fernandez, 2002, p. 396). In the absence of such school based events in the United States, we undertook to accomplish this through the lesson presentation at ASTE. This going 'public' represented one of the most intimidating aspects of our lesson study. The risks were indeed high. We engaged in a lesson with students who were totally unknown to us and then exposed our lesson to critique from our peers. Again, we found the actual experience to be rich and valuable, enabling an even deeper dialogue that stretched our thinking and understanding. The move from our trusted group of four professors to the larger group provided the space for new ideas and further insight into our teaching. It also served as a venue for helping others learn about teaching science methods to PSTs.

Back to Theory

We are somewhat surprised that our lesson study work stimulated challenges to our theoretical understandings. And, even so, we might not have recognized these challenges if we had not later convened for a second round of self-study focused on our own growth as teacher educators. In our later discussions, important questions have been asked but not answered that will continue to influence our thinking as we move forward. For example, given the time it takes to learn and engage with the many complex ideas we believe that our PSTs need to know, might we look to a new model for teacher education that allows continuing engagement over multiple years rather than a single semester methods course? If so, then what role should the development of their theories of scientific understanding and classroom practice play in such an extended engagement? And is there a truly unique and distinct theory that might guide elementary science teacher education, or should our students be working to develop a larger, interdisciplinary understanding of teaching?

Conclusions

What began as a collective desire to learn more about a professional development approach became much more, both an exploration of each of our approaches to teaching as well as a deeper consideration of the theory underlying those approaches. Through our collaborative self-study, we each gained powerful personal and communal insights, in the process becoming more thoughtful, mindful teacher educators. Sharing our experiences with other science educators has done much more than satisfy our needs for professional community: it has revealed areas in which we can each grow and flourish with support from knowledgeable colleagues. Collectively our foci have shifted: from what we teach to what our students learn; to facing our trepidation of teaching as a public practice; and to recognizing the important role of theory in shaping both our understandings and those of our students. And our insights into how Japanese Lesson Study works and how to make it work for us have left us confident about using this professional development tool. It has truly been a journey, beginning with our collective need to know something new and leading us to challenge much of what we thought we knew already.

Note

1. There are a number of sites now dedicated to research and practice of Lesson Study. The Lesson Study Group at Mills College is perhaps the oldest of these and can be accessed at http://www.lessonresearch.net/. Also on line are sites for the Center for the Collaborative Classroom (https://www.collaborativeclassroom.org/lesson-study); the Lesson Study Project at the University of Wisconsin – La Crosse (http://www.uwlax.edu/sotl/lsp/); and the Chicago Lesson Study Group (http://www.lessonstudygroup.net/index.php).

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Chapter 10
How Science Teacher Educators of Color Conceptualize and Operationalize Their Pedagogy in Science Methods Courses

Karthigeyan Subramaniam, Sumreen Asim, Eun Young Lee, and Kia S. Rideaux

Introduction

This study explored how we, four science teacher educators of color, conceptualized and operationalized our pedagogy in elementary science methods courses. Conceptualization and operationalization in this study refers to the methodological tactics (Matias, 2013) we constructed in response to the particularities impacting our substantial selves and situational selves within the context of our teaching spaces. Particularities refers to the challenges, tensions, and problems impacting our substantial selves and situational selves within authentic settings during the process of educating our teacher candidates in the science methods course. In this study, we perceive methodological tactics as the modifications/transformations made to syllabi, course requirements, lesson plans, instructional strategies, skills and actions, and resulting classroom activities to circumvent and/or counter the challenges, tensions, and problems implicitly and/or explicitly created by teacher candidates. Substantial selves refers to the action of teaching (knowledge-in-practice) (Goodwin et al., 2014), learning about teaching (knowledge-for-practice), and researching about teaching (knowledge-of-practice) (Goodwin et al., 2014; Loughran, 2014) that essentializes us as science teacher educators while situational selves refers to ourselves as science teacher educators of color instructing teacher candidates on how to teach science within the authentic setting of a K-6 teacher education program. The research question that undergird this study was: "How do we as science teacher educators of color conceptualize and operationalize our pedagogy in elementary science methods courses?"

K. Subramaniam (✉) • S. Asim • E.Y. Lee • K.S. Rideaux
University of North Texas, Denton, TX, USA
e-mail: Karthigeyan.Subramaniam@unt.edu; Sumreenasim@gmail.com; EunYoung.Lee@unt.edu; Kia.Rideaux@unt.edu

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A review of the literature on teacher educators reveals that there is a trend towards investigating the pedagogy of teacher education especially in light of teacher educators playing an important role in the preparation of high-quality teachers (Berry & Van Driel, 2013; Goodwin et al., 2014; Loughran, 2014). So far, studies within this research context have examined how teacher educators perceive teacher education within their institutions (Mevorach & Ezer, 2010; Murray, 2005; Murray & Male, 2005); how teacher educators perceive their preparation as teacher educators; how teacher educators' expertise, and their experiences as teacher educators informs their practice and their profession (Goodwin et al., 2014; Hinchman & Lalik, 2000; Johnston & Settlage, 2008; Loughran, 2014; Williams, 2014), how teacher educators' roles and identities impact the quality of teacher education (Genor & Schulte, 2002; Livingston, 2014); and how teacher educators' backgrounds in terms of demographics informs and impacts their practice (Atwater, Butler, Freeman, & Parsons, 2013; Cochran-Smith, 2003; Goodwin, 2004). Collectively, these studies are contributing to the limited knowledge base on what teacher educators know, "how they act and why" (Berry & Van Driel, 2013, p. 118).

In a similar fashion, scholars within the science teacher education research context are also investigating science teacher educators' expertise in instructing teacher candidates on how to teach science. For example, Berry and Van Driel (2013) investigated and articulated the specific expertise of 12 experienced science teacher educators, while Atwater et al. (2013) examined the constructed meanings of Black science teacher educators about their pedagogy for science teacher education that took into account their expertise with multicultural science education, equity, and social justice. Inclusive to this genre of studies is the recent call to investigate science teacher educators' expertise and experience in relation to Next Generation Science Standards (Lederman & Lederman, 2013).

Lacking within the aforementioned (limited) studies are the complex demands of the process of teacher education especially when teacher educators are faced with challenges impacting their substantial selves and situational selves within authentic settings. Above all, studies, frameworks, and perspectives fail to tap into the "rich mosaic of knowledge related to teacher educators themselves" (Martinez, 2008, p. 36) and ignore their lived experiences as teacher educators instructing teacher candidates. Moreover, most of the empirical studies and/or theorizing have proposed frameworks, and perspectives in relation to transitional spaces (teacher to teacher educator, doctoral student to teacher educator, teacher educator to teacher educator researcher) encountered by teacher educators. Additionally, these studies empirically investigated transitional spaces through surveys and follow-up interviews (Goodwin et al., 2014); interviews (Goodwin, 2004; Williams, 2014), retrospective interviews and essays (Vescio, Bondy, & Poekert, 2009), interviews and artifacts (Hinchman & Lalik, 2000), questionnaires (Mevorach & Ezer, 2010), metaphors (Mevorach & Ezer, 2010; Williams, 2014), and interviews, drawings and storylines (Berry & Van Driel, 2013). This is despite the calls for the use of self-study methodology to study practitioner research. For instance, Loughran (2014) claims that:

> There has been a growing momentum in practitioner research as methodologies such as self-study have created new ways for practice to be better understood, more highly refined, and increasingly more cogently codified. Self-study of teacher education practices (S-STEP) has proved attractive to many teacher educators because it places teaching and learning about teaching at the center of the research endeavor (p. 278).

In essence, the developing knowledge base for a pedagogy of teacher education and/or a pedagogy of science teacher education has made limited inroads into the pedagogic expertise developed in authentic settings: the knowledge "situated and constructed in response to particularities" (Cochran-Smith & Lytle, 1999, p. 262) within the "context of teachers' and teacher educators' teaching spaces" (Goodwin et al., 2014, p. 286).

Most importantly, the experiences of teacher educators of color has received minimal attention within this research context. Whatever limited studies there are seem to be concerned with teacher educators of color and their experiences with imparting and/or being experts in multicultural issues (Atwater et al., 2013; Goodwin, 2004; Vescio et al., 2009) or culturally responsive teaching (Goodwin, 2004) rather than how they conceptualize and operationalize their pedagogy for educating teacher candidates. Additionally, the research on teacher educators, so far, has neglected the "demographic imperative" (Cochran-Smith, 2004, p. 4) that demands a need for social justice and equity in education by being considerate to and inclusive for all actors involved in the education of teachers and students. Based on this standpoint, teacher educators of color and how they instruct teacher candidates need to be focused on and be studied especially in light of their teaching spaces being dominated by White female, middle class, and English speaking 18- to 22- year olds lacking "cultural frames of reference" for the *Other* (Cochran-Smith, 2004, p. 4).

Significance

The significance of this study was twofold: First, the study aimed to highlight the insights of practicing science teacher educators of color, especially the methodological tactics used in relation to their preparation of a predominantly White female, middle class, and English speaking elementary school teacher candidates. This is significant because the current literature landscape on science teacher educators of color and their work of educating predominantly White female, middle class, and English speaking teaching force has been relegated to knowledge of their demographic backgrounds, and their capacities as multicultural and social justice role models. Second, the study aimed to provide a counterstory in response to the science teacher education literature, and teacher education literature about knowledge-based approaches to preparing a predominantly White female, middle class, and English speaking teaching workforce which is still being empirically studied from the standpoints of the mainstream White teacher educator.

This study is unique because it sought to contribute to the developing knowledge for a pedagogy of teacher education and specifically for a pedagogy of science teacher education from a standpoint of ourselves as teacher educators of color engaging in inquiry about how we conceptualize and operationalize our teaching space when educating teacher candidates. The resulting complex constructions of how teacher educators conceptualize and operationalize their teaching spaces can provide insights into the ongoing processes of changes in identities experienced by teacher educators in response to the personal, contextual, pedagogical, sociological, and social domains within the process of teacher education (Goodwin & Kosnik, 2013). Moreover, teacher educators of color inquiring into their own processes of teacher education can provide insights into how they construct teaching and learning actions in teacher education programs (Atwater et al., 2013).

Next, the discussion shifts to the review of the limited literature from both the teacher education literature and the science teacher education literature that currently attempt to construct plausible explanations about teacher educators and the process of educating teacher candidates.

Review of Literature

Although studies from both general teacher education, and science teacher education are limited, the similarity between the two research contexts lies within the aim of developing frameworks for a pedagogy of teacher education, or in the case of science teacher education, a pedagogy of science teacher education. Goodwin et al. (2014), borrowing from Cochran-Smith and Lytle's (1999) review of the research on the relationships of knowledge and practice, provide a tripartite approach to a pedagogy of teacher education: the knowledge-in-practice (action of teaching), knowledge-for-practice (learning about teaching), and knowledge-of-practice (researching about teaching) (Table 10.1). Basically, this tripartite framework for a pedagogy of teacher education focuses on providing explanations for the

Table 10.1 Tripartite knowledge structure for pedagogy of teacher education

Knowledge-for-practice	Knowledge-in-practice	Knowledge-of-practice
Externally generated	Internally generated	Composite of externally and internally generated knowledge
Formal knowledge acquired during	Situated knowledge acquired from	Knowledge acquired through
Doctoral program	On the job experience and reflection	Participation in K-12 teacher education empirical research
Formal study to teach K-12 science methods	On the job experimentation and practice	
	Observations of peers/colleagues/mentors who teach K-12 science methods	
	Emulating peers/colleagues/mentors who teach K-6 science methods	

Table 10.2 Tripartite knowledge structure for pedagogy of science teacher education

Knowledge-for-practice	Knowledge-in-practice	Knowledge-of-practice
Externally generated	Internally generated	Composite of externally and internally generated knowledge
Formal knowledge acquired to	Situated knowledge acquired from	Knowledge acquired through
Promote the development of teacher candidates as future science teachers	Reflection and analysis of one's own science teaching/ science teacher education practice	The study and dissemination of empirical research that contributes to the field of science teacher education
Model current and accepted science teaching strategies	Designing and engaging in experiences that promote meaningful and appropriate learning for all participants in the learning to teach science process	
Develop an understanding of the nature of science and its relevance to science teaching/learning		

professional identities, roles, and understandings that teacher educators need to acknowledge, exhibit, and practice within transitional spaces (Margolin, 2011) they encounter. Transitional spaces include doctoral programs, college/university-based teacher education programs, and teacher education research contexts.

Berry and Van Driel (2013), adapting Loughran's (2006) framework for a pedagogy of teacher education, provide a version of a pedagogy of science teacher education. The constructs that make up this a pedagogy of science teacher education are presented in Table 10.2 and have been assimilated into the tripartite approach to a pedagogy of teacher education to create a tripartite approach to a pedagogy of science teacher education.

Counter to the aforementioned pedagogies of teacher education and science teacher education, some scholars have proposed other pedagogies for the process of teacher educating. Goodwin et al. (2014) describe the pedagogy of survival tactics that is opposite to the accepted knowledge-in-practice in the tripartite approach to a pedagogy of teacher education as put forth by Cochran-Smith and Lytle (1999) and their own adaptation of the tripartite approach. Goodwin et al. (2014) contend that the pedagogy of survival tactics is the knowledge-for-practice that are basically the teacher educators' "understandings acquired through experience and on the job whether through own experimentation and practice or by observing and emulating peers/colleagues/mentors to teach K-6 science methods" (p. 296). Additionally, they claim that the pedagogy of survival tactics has similarities to the methodological strategies of K-12 novice teachers as both are constructed without theoretical underpinnings and are born out of the necessity to keep one's job intact and/or sustain one's daily perfunctory approach to instruction.

Matias (2013) provides the label "pedagogy of trauma", derived from her own experiences as a teacher educator of color that is basically a pedagogy to overcome and endure the racial microaggressions inflicted on her by both the teacher education institution and by her White teacher candidates. She characterizes this pedagogy of trauma as "a survival mechanism" (p. 54) which functions as a methodological tactic, a version of knowledge-in-practice that counters the persistent cognitive resistant reactions and self-affirmed colorblindness (racial microaggressions) of White teacher candidates. Most importantly, she claims that these survival tactics transform microaggressions into an awareness for the propagation of racial equity.

Methodology

The decision to explore how we conceptualized and operationalized our pedagogy in elementary science methods courses in relation to the challenges, tensions, and problems impacting our substantial selves and situational selves during the process of educating our teacher candidates cohered with the growing popularity for the methodology of self-study (Dinkelman, Margolis, & Sikkenga, 2006; Kaufman, 2009; LaBoskey, 2004; Loughran, 2014; Pithouse, Mitchell, & Weber, 2009) and its focus on "teaching and learning about teaching at the center of the research endeavor" (Loughran, 2014, p. 278). Apart from this coherence, self-study as a suitable methodological framework for this study was underpinned by the constructs from the literature on self-study. Feldman (2003) and Kaufman (2009) claim that the methodology of self-study is suitable for one's inquiry into their own practice because it provides clear and detailed data collection procedures, flexibility in representation of data, variety of data representations, and the need for catalytic authenticity when undertaking self-study of practitioner knowledge.

Moreover, the pragmatic nature of our decisions and the context-specific nature of the research question were key determinants in choosing the methodology of self-study. A number of scholars claim that methodology of self-study (1) provokes and challenges one's current norms of practice, (2) emphasizes the quality of inquiring into one's practice as being disconcerting rather than confirming, (3) supports the intentionality and systematic inquiry into one's practice using personal, formal and substantive theories of knowing, and (4) situates one's inquiry into their own practice within a verified epistemological way of knowing (Dinkelman et al., 2006; Kaufman, 2009; LaBoskey, 2004; Loughran, 2014; Pithouse et al., 2009). Apart from the aforementioned claims, scholars also claim that methodology of self-study de-emphasizes (1) the need for generalizability to confirm and conform, and (2) the accepted norms of methodological rigor (validity, reliability and objectivity).

Our Substantial Selves and Situational Selves

Three of us, Karthigeyan, Kia and Sumreen taught the K-6 science methods course using a standardized syllabus with similar course elements like textbooks, assignments, course readings, and activities while Eun Young taught science methods as a component of an early childhood (K-3) methods course. The conceptual structure of both types of science methods courses was underpinned by an inquiry-oriented focus to science learning. In view of the teacher education program's accreditation efforts all syllabi and assessments within the K-6 teacher education program were standardized. Eun Young, Kia, and Sumreen were graduate teaching assistants as well as doctoral candidates while I, Karthigeyan, held the appointment of assistant professor of science teacher education, and was the lead instructor for the K-6 elementary science methods courses. In this institution graduate teaching assistants/on-campus doctoral graduate students teach one to two undergraduate courses per semester.

We taught our respective science methods course in the same semester and were assigned to teach the science methods course because of our experiences (1) with field supervision of elementary teacher candidates, (2) as teachers in K-12 school settings, and (3) as mentors to teacher candidates. Most importantly, our preparation as K-12 science teachers in university-based teacher education programs was a key determinant for being a participant in this self-study. Williams (2014) contends that the aforementioned criteria are important because field supervision experiences, mentoring experiences, and K-12 teaching experiences are the common contexts that most teacher educators have experiences in and thus, provides some generalizability across teacher education programs. Above all, our knowledge and experiences of supervision of teacher candidates in the field, as teachers in K-12 school settings, and as mentors to teacher candidates cohered with tripartite knowledge structure of knowledge-for-practice (K-12 science teacher preparation), knowledge-in-practice (teaching in K-12 school settings and field supervision) and knowledge-of-practice (K-12 science teacher preparation and mentoring). Table 10.3 provides background information about us, our knowledge-for-practice, knowledge-in practice, and knowledge-of-practice, and the transitional spaces we were situated in during the study.

During the semester when this study was conducted, the 96 teacher candidates enrolled in the K-6 elementary science methods sections, taught by the four of us, were predominantly White female candidates (84 %) while the rest of the female candidates were Hispanic (8 %); Asian (4 %) and African American (2 %). Two percent of the teacher candidate population was male. Teacher candidates were in their final semester of coursework prior to student teaching practicum, all candidates had to have a minimum grade point average of 2.75 for all the teacher education courses and all candidates had to have completed 12 semester credit hours of science (four courses), selected from the biological sciences, chemistry, physics, geology, environmental science or astronomy.

Data Collection, Sources and Analysis

The study composed of two data collection phases. Phase 1 comprised the collection of two sets of metaphors: (1) a metaphorical statement that captured our practice of teaching the elementary science methods course, and (2) "*Elementary science*

Table 10.3 Our profiles

Name/current status	Years as teacher/ teacher educator	Tripartite knowledge structures	Transitional spaces
Karthigeyan Subramaniam Asian-American Male Assistant Professor	8/10	Knowledge-for-practice: I have a masters in science teacher education. My doctoral dissertation was on science teaching. I have taken multiple professional development courses throughout by years as science teacher and as a science teacher educator	Teacher educator to teacher educator researcher
		Knowledge-in-practice: I have eight years of teaching experience in K-12 science content in both private and public schools. This is my tenth year in higher education and I have taught general teacher education courses but my main teaching load is science methods course	
		Knowledge-of-practice: I have conducted a number of empirical studies related to science teacher education and presented at a number of conferences on science teacher education	
Kia Rideaux African American Female Doctoral Candidate (ABD)	10/2	Knowledge-for-practice: I don't recall any of my coursework during my doctoral program focusing on teaching science methods	Teacher to teacher educator
		Knowledge-in-practice: Professional development during my classroom teaching experience with organizations such as Project Wild, Aquatic Wild, and Fort Worth's Children Museum provided. Professional Experience as a curriculum writer for a local district	Doctoral student to teacher educator
		Knowledge-of-practice: Observation of preservice teachers during visit to Informal Science Center on campus for science methods course. Participation in peer's study on informal science teaching methods	

(continued)

Table 10.3 (continued)

Name/current status	Years as teacher/ teacher educator	Tripartite knowledge structures	Transitional spaces
Eun Young Lee Asian Female Doctoral Candidate (ABD)	3/2	Knowledge-for-practice: I have a master's in Curriculum and Instruction. During my course work, I took a course about how to teach math and science for young children	Teacher to teacher educator
		Knowledge-in-practice: I have taught early childhood courses for undergraduate students pursuing an education major in EC-6. These experiences have provided me an opportunity to not only learn how much preservice teachers know about science content and pedagogical knowledge but also practice my knowledge and experience to my students	Doctoral student to teacher educator
		Knowledge-of-practice: I have written many papers with various topics related to science education for young children and preservice teachers. While working on my doctorate, I have done many independent studies with professors in science education and have assisted a professor in his science methods course for a semester	
Sumreen Asim Asian-American Female Doctoral Candidate (ABD)	5/3	Knowledge-for-practice: I have a master's in Elementary Education, as well as a master's degree in Science and Environmental Education. During my coursework as a doctoral student my focus surrounded the Project Wild curriculum. The coursework has allowed me to better understand the layout, theories and goals that were taken into consideration when creating this particular curriculum. Knowledge-in-practice: I have taught as classroom teacher and a specialist in a K-6 settings. I was fortunate to have a science lab and taught science using *Science Curriculum Improvement Study* (SCIS) curriculum, an activity-based program, for students in a K-6 settings. I also have the experience of teaching as a facilitator for colleges. Knowledge-of-practice: My research interests have evolved from both my course work, my dissertation study, my professional experience as a K-12 science teacher, and as a science methods course instructor for K-12 preservice teachers	Teacher to teacher educator Doctoral student to teacher educator

teacher educator as …" metaphor. Phase 2 was comprised of a focus group interview where I (Karthigeyan) was a focus group participant together with Sumreen, Eun Young, and Kia and also took on the additional role as moderator. Table 10.4 shows the timeline for the phases of data collection (and analysis of data). Collectively, the choice of metaphors and a focus group interview as methods of data collection facilitated "a stepping back, a reading of our situated selves as if it were a text to be critically interrogated and interpreted within the broader social, political, and historical contexts that shape our thoughts and actions and constitute our world" (Pithouse et al., 2009, P. 45). This cohered with the pragmatic nature of our decisions, the context-specific nature of the research question, and choice of a methodology of self-study. Additionally, the choice of metaphors and the focus group interview as primary qualitative methods of data collection provided varied accounts of our inquiry and satisfied what LaBoskey's (2004) contends are integral aspects pertinent to the process of utilizing a self-study methodology.

Phase 1-Writing Metaphors

In the field of explicit metaphorical statements research, metaphors have been used to investigate (1) the images of how practitioners view themselves and their learners in the classroom (2) the images that practitioners have of themselves in fulfilling their roles; and (3) the images of personal practical knowledge (Inbar, 1991, 1996). The underlying themes in the utilization of metaphors in these areas of research were based on the assumptions that "images lead to metaphors"; "metaphors provide a careful means for clustering images"; and "images are metaphorically embedded" (Bullough, 1991, p. 200). In this respect, the use of metaphors as data sources helped us, the practitioners, to shed light onto our own images and thereby capturing and encapsulating our practice, and the knowledge that structured and enabled our instruction (Mevorach & Ezer, 2010; Williams, 2014).

Data collection for this part of the study consisted of three steps. First, each of us individually wrote down a personally constructed metaphor in the form of an explicit metaphorical statement. Second, each of us individually wrote narratives that expressed the meanings encapsulated within our individual metaphorical statement. The final step of this data collection stage involved the derivation of "*Elementary science teacher educator as …*" metaphor. In this step each of us read and re-read our own personal narrative and then wrote down another personally constructed metaphor, the "*Elementary science teacher educator as …*" metaphor. This step gave us an opportunity to individually reflect on our own practices, and look at the language we had assigned to our practice. This was also a way for us to individually refocus our construction of metaphorical sentences and related narratives, and contextualize our teaching actions into another metaphor, thereby structuring our practices and making explicit personal practical knowledge. Moreover, this process enabled us to get a further set of coherent and consistent metaphors that alleviated the major concern of single metaphors not being enough to describe the complexities of our practice.

Table 10.4 Timeline of study: conceptual structure of the course and phases of study

Week	Conceptual structure of the course	Phases of study
1.	Course introduction	Phase 1:
		Writing a metaphorical statement that captured our practice of teaching the elementary science methods course
2.	Discovering science through inquiry	Individual analysis of metaphorical statement
3.	Planning for inquiry: 5E learning cycle	Writing a narrative encapsulating the meanings of the metaphorical statement that captured our practice of teaching the elementary science methods course
4.	STEM and science instruction	Individual analysis of narrative: Reading and re-reading of narrative followed by the derivation of "*Elementary science teacher educator as …*" metaphor from narrative
5.	Inquiry and assessment	
6.	Inquiry experiences for all children	
7.	Inquiry learning opportunities	
8.	Inquiry learning opportunities: informal science instruction	
9.	Mid-term exams	
10.	Field trip	
11.	Microteaching: lesson presentation	
12.	Microteaching: lesson presentation	
13.	Microteaching: lesson presentation	
14.	Microteaching: lesson presentation	
15.	Microteaching reflection and debriefing	
16.	Final exam	Phase 2:
		Focus group
		Collective analysis of metaphorical statements, narratives, and "*Elementary science teacher educator as …*" metaphor
		Individual and collective analysis of focus group transcripts: verification and consolidation of themes

Phase 2-Focus Group Interview

Phase 2 comprised of a focus group that was grounded by the following questions:

1. Please share your *Elementary science teacher educator as …* metaphor and describe it.

2. Please share your metaphorical statement that captures your experiences of teaching the elementary science methods course and describe it.
3. Share your experiences in teaching the elementary science methods course.
4. What would you change, and not change in your teaching in your future/continuing role as a science teacher educator.

The focus group was chosen as another approach for data collection because focus groups generate high-quality data in a social context thus enabling the collection of data that highlights the collective concerns within an open and supportive environment (Cochran-Smith, 2003). According to Krueger and Casey (2008), focus groups generate large amounts of data in less time than other methods and give rise synergistically to insights that may not occur in individual interviews resulting in greater depth and details. They also claim that focus group interviews also enable participants to recognize “hidden parts” of themselves and reconstruct opinions from other’s stories unfolding in discourse. The adoption of this qualitative method enabled us to substantiate each other’s interpretations within the study’s context: the culturally patterned signs and symbols extant within the science teacher education context in which we were situated. One focus group interview lasting about two hours was conducted at the end of the semester. As metaphors were the predominant data in this study and collected throughout the study, we did not want to have a focus group prior to the end of the semester since a focus group, with its shared agenda focus, might contaminate and/or provide checks and balances on our developing and evolving metaphors. Clearly, our intent on using the focus group was to recognize hidden parts of ourselves and reconstruct opinions from each other’s metaphors and narratives, collected and shared at the end of the science methods course.

Data Analysis

The data were analyzed using inductive analysis and thematic analysis. Both these approaches to analysis were used because of the limited previous studies dealing with this phenomenon. Inductive analysis utilized Thomas’s (2006) general inductive approach for analyzing qualitative data while the thematic analysis was guided by Braun and Clarke’s (2006) thematic analysis approach. Thematic analysis was used to interpret discernible patterns within the narratives and the focus group interview transcript. The purpose of the inductive analysis was twofold. First, we sought to see similarities and differences in our interpretations of the instructional practices. Second, we sought to identify the challenges, tensions, and problems impacting our substantial selves and situational selves within the methods sections. We first familiarized ourselves with the data corpus by reading and re-reading each data set (metaphors, narratives, and focus group transcript) and identified meaningful data extracts, and created and assigned a code for each data extract (the text segment). Text segments containing similar assigned codes were grouped together and assigned codes were developed into distinct categories. The distinct categories were then cross-referenced to identify relationships, and causal sequences between categories. Following this, a thematic analysis approach to data was carried out. In constructing preliminary themes we grouped together categories across data sets to seek coherent and meaningful patterns that were relevant to the study's research question. For example, data extracts categorized by the notion of "*acquiring a role*" across data sets were further analyzed for coherence with our verbal descriptions within narratives and the focus group interview transcript. In doing so, the preliminary theme of "*acquiring a role*" was constructed. The preliminary theme of "*acquiring a role*" was then reworked into all coded and categorized data extracts across data sets to seek patterns that confirmed, disconfirmed, expanded upon and/or clarified the preliminary theme of "*acquiring a role*". As a result of reworking the preliminary theme of "*acquiring a role*" across data sets, we were able to refine and thus further define this theme. Analyzing data with the preliminary theme of "*acquiring a role*" enabled the identification of different roles: leader, choreographer, and captain. As a final step in the thematic analysis process we weaved together the constructed themes resulting from the identification of consistent and predominant patterns across the data sets for relevancy with the study's research question.

Trustworthiness

Figure 10.1 indicates how the claims made in this study were substantiated in three ways: firstly, each of us, as a researcher, individually reflected on the phenomenon through the construction of our personal metaphors and narratives, and individually analyzed the metaphors and narratives to construct individual meanings of how we perceived the phenomenon; secondly, as a group we collectively analyzed the metaphors and narratives within a focus group setting to construct shared meanings of how we perceived the phenomenon; and thirdly, as a group we analyzed the resulting focus group transcript to further seek consensus on the shared meanings that underpinned our perceptions of the phenomenon. By looking at the phenomenon from three vantage-points we were able to corroborate, confirm and/or disconfirm the underlying shared meanings of how we perceived the phenomenon. It is obvious that triangulation metaphor is suitable in describing this process for seeking trustworthiness.

Additionally, analysis strategies were collectively orchestrated by the four of us and were underpinned by systematic steps to seek agreement and/or disagreement to validate the themes (Kurasaki, 2000). We sought to collectively replicate each other's work of assigning codes/patterns to data and assess insights arising from agreements and disagreements during the process of assigning codes/patterns to data through verification and validity (de Wet, 2010). The focus group interview and resulting focus group transcript served as the sites of this collective analysis process to seek inter-coder agreement/disagreement on evolving themes in this study. Lastly, to enhance the rigor of analysis, raw data from transcripts (Jordan & Duncan, 2009) are provided in the findings section to enable the reader to generalize the findings to his or her contexts.

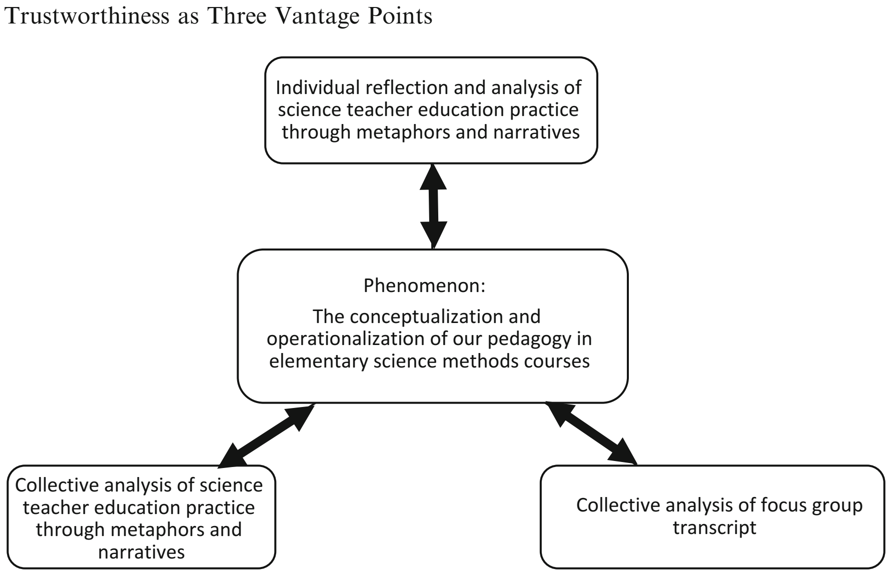

Fig. 10.1 Trustworthiness as three vantage points

Findings

Analysis of data revealed that we conceptualized our pedagogy in two ways: (1) we conceptualized our pedagogy within a role, and (2) and we conceptualized our pedagogy as needing safety nets to remove barriers that impinged on our professional roles. Each of these conceptualizations were in reaction to our experiences of dealing with teacher candidates' predetermined notions about us. These predetermined notions were (1) teacher candidates seeing us, the science teacher educators of color, as different from themselves and from mainstream White science teacher educators; (2) teacher candidates perceiving our attempts to include/integrate personal experiences, multicultural strategies, social justice issues and diversity issues as a "minority problem"; (3) teacher candidates not acknowledging us as science teacher educators who were modeling the practice of science teachers; and (4) teacher candidates perceiving the process of science teaching as fixed products or "recipes" to be delivered to K-12 students.

Conceptualization as a Leader

Analysis of data revealed that three of us, Karthigeyan, Kia, and Eun Young conceptualized our pedagogy within a role. Metaphors in Table 10.5 illustrate these roles as "a choreographer" (Kia), "a captain" (Karthigeyan), and "a solitary leader" (Eun Young).

Table 10.5 Our metaphors

Authors	Metaphorical statement	"*Elementary science teacher educator as* …" metaphor
Karthigeyan	Teaching elementary science methods courses is a force to reckon with, the mostly winter wonderland terrain is filled with avalanches waiting to be triggered; one's safety is always the first thing to consider	The elementary science teacher educator as the captain of an already capsizing ship with powers to righting the ship, most of the time
Kia Rideaux	To teach the science methods courses is to teach in a sterile operating room, a methodical and privileged space with zero room for error. All eyes are on the surgeon/expert	The elementary science educator is choreographer attempting to lead the troupe, yet assisting each future educator to perfect their own individual craft. While the teacher educator of color might see teaching the methods course an opportunity to infuse different genres of dance or to invent a new style, all the audience (the preservice teacher) seems to want is Swan Lake
Eun Young Lee	Teaching elementary science methods courses is doing a density experiment to see layered liquids with oil and different less dense liquids with different colors in a narrow cylinder. The oil goes first and all the different liquids go next one by one forming layers with different densities and colors. They never mix, but when you dump the oil and liquid into the sink they a totally new color, something that is not tangible and difficult to fathom	The elementary science teacher educator is a solitary leader crossing a desert with people who watch for their opportunities to raise rebellions. The leader is looking for an oasis but it is always a mirage. The leader is always on the look-out as there are always perilous burglars approaching and cajoling the people to usurp leader
Sumreen	Teaching elementary science methods courses is a way to clear the unpaved path that is unfamiliar and unknown to help discover the amazing wonders of species new and familiar, and terrain that can be smooth as a frozen lake, choppy as the waves of the ocean on a stormy night, as well as ornamented as a tree with icicles	The elementary science teacher educator is the icing of a decorative cake that hints to the layers and the flavors that are inside waiting to be discovered through the use of the person's five senses along with the choice of the plethora of tools at hand given a place and time

Collectively, these three roles were underpinned by the notion of a *leader* who was in constant battle with his/her *subordinates* (the predominant White preservice teacher candidates): "… captain of an already capsizing ship with powers to righting the ship, most of the time", "… attempting to lead the troupe, … all the audience (the preservice teacher) seems to want is Swan Lake", and "… leader is always on the look-out as there are always perilous burglars approaching and cajoling the people to usurp leader." These roles to us were in response to teacher candidates, especially, White preservice teacher candidates' seeing us, science teacher educators of color, as different from themselves and from mainstream White science teacher educators. Eun Young's comment, "they see themselves as them and me as different" characterized this barrier that centered on color and ethnicity as determinants of our worth as science teacher educators. Support for this conceptualization was also evident within our metaphorical statements that contained glimpses of challenges in carrying out the task of teaching teacher candidates: "All eyes are on the surgeon/expert", "a force to reckon with", and "They never mix …."

Taking on the role of leader was more of "trying to prove" ourselves as being science teacher educators or perceived as being a constant tussle to always prove ourselves as science teacher educators. Within this context we were encountering our substantial selves and situational selves as somewhat of a penalty, and thus, we resorted to taking on leadership roles like choreographer, captain, and solitary leader. The analysis of narrative data and focus group data indicated that we wanted to move away from the conceptualization of a leader who was constantly scrutinized as being "a force to reckon with". For example, the following focus group excerpt indicates that the we were proposing a need for both teacher candidates, science teacher educators of color, and other teacher educators to focus on understanding the practice of teacher education as a holistic endeavor for supporting the success of each teacher candidate and this endeavor be equally shared by all teacher educators, no matter their ethnicity and/or color.

Sumreen:	When we step into the science methods class I am already barricaded by a painted picture of me as different from the other teacher educators.
Kia:	Yes. They already see us as different not as a science teacher educator or even as a science teacher.
Eun Young:	They see us as different not as an educator.
Karthigeyan:	It is different with their other teacher educator methods professors who they seem to identify with because of similarities in ethnicity and color.
Kia:	Yes. They see us a certain way, different from the rest of the teacher educators.
Sumreen:	Yes.
Eun Young:	Okay, true.
Karthigeyan:	There needs to be common cultural frame. I mean a frame that sees us and all teacher educators as using our experience, expertise, and knowledge for the success of the teacher candidates and not a cultural frame centered on ethnicity and color.
Kia:	True, the cultural frame now is based on appearance
Sumreen:	It is more about the powerless and the powerful.
Eun Young:	There needs to be change, teacher candidates need to understand themselves as professionals who are going to teach a diverse population and us as professionals who bring about this change.

Karthigeyan: Change, needs to come from all involved in teacher education, it is not only us, teacher educators of color. The frames from which other teacher educators work from and from which we work from needs to be shared. By doing so we might be able to understand the causes for the constant need to prove oneself and move away from our narrow perception of a leader. Our expertise should not be at stake because of our ethnicity or color.

As evident from Table 10.5 and the analysis of data, Sumreen's metaphors were different from the rest of us. In fact her metaphors and narrative helped us as a group to define and refine our collective analysis of data. In doing so, we were able to see, with clarity, how our roles were distinct from that of Sumreen's and how our roles were dominant. Eventually, as we proceeded with the collective analysis in the focus group and in the analysis of focus group transcript we did see that Sumreen was in consensus with the rest of us on the theme of conceptualization as a leader: "When we step into the science methods class I am already barricaded by a painted picture of me as different from the other teacher educators" and "It is more about the powerless and the powerful" (Focus group transcript).

Conceptualization of Pedagogy as Safety Nets

A common pattern that was inherent in all data was our conceptualization of our pedagogy as needing safety nets to remove barriers that impinged on our professional roles. We as science teacher educators felt that teacher candidates' predetermined notions of us were detrimental to our work as science teacher educators. Anything we did to change these predetermined notions were seen as going against the norm. Kia remarked that that teacher candidates "wanted a recipe" for teaching science and any integration/inclusion of personal experiences, multicultural strategies, social justice issues and diversity issues or modeling of science teaching practice that were different were met with unfavorable responses. The following quote captures the essence of this resistance: "Does she know what she is talking about", and "… they want a science teacher with recipes to teach not a science teacher educator" (Kia, Focus Group Interview). Karthigeyan's narrative also sums up this resistance:

> Teacher candidates are always looking for you to fumble over something, this could be science content, the syllabus, the questions on the quiz, etc. I am already shortchanged in these teaching situations, my color, and my accent are penalties that act against me in every science methods class I teach. They see me as someone who is different and thus inferior and less able to teach science content. Every lesson I teach, I have to have safety nets to protect myself from being singled out because of my penalties. Safety nets include the watering down of the science content in lessons I model, not using too many multicultural examples, not giving graded assignments in class, etc. I do all this to avoid the confrontations that are waiting to explode. Their lack of science content and/or their weakness in science content must not be judged as I am already assumed to be less able to teach science content even though most of my teaching career was teaching high school biology, chemistry, and physics.

The quote above also reveals how we operationalized our instruction in the science methods courses. We emphasized the need for safety nets ("a methodical and privileged space with zero room for error", "one's safety is always the first thing to consider", and "always on the look-out") to protect ourselves from repercussions from teacher candidates. Finally, the analysis of narrative data and focus group data indicated that we wanted to move away from the conceptualizations that were making our pedagogy subjugated by the constant need to stand guard against possible resistance. For example, the following focus group excerpt indicates that there is a need for both teacher candidates and science teacher educators of color to engage in dialogue and this should be centered on the changing demographics of student populations in today's science classrooms.

Karthigeyan: I see that we need to get our teacher candidates to imagine themselves as someone who is different from the students they will be teaching.

Eun Young: They need to hear our voices in their heads and they need to acquire the role of someone who is different, like if they imagine they are me, a minority teacher educator, teaching them.

Sumreen: Yes. True. Diversity is not only in the textbook, it is all around us, in classrooms, universities …

Kia Agreed. We need to move on. A change towards a better understanding of us as science teacher educators of color.

Karthigeyan: Vocational socialization with the teaching profession needs to include walking in each other's shoes and feeling one's frustrations and joys and not only be about learning the skills for the effective teaching of science content.

Discussion

Tripartite Knowledge Structure for the Pedagogy of Science Teacher Education

The findings of this study provided only a limited perspective into the lived experiences of ourselves as science teacher educators of color in relation to how we act and why within the context of science teacher education. This study highlighted how our knowledge as science teacher educators of color was situated and constructed in response to particularities (Cochran-Smith & Lytle, 1999) of ethnicity, and resistances (Goodwin et al., 2014; Matias, 2013) within the context of our teaching spaces (Goodwin et al., 2014); and, within personal, pedagogical, and social domains of educating predominantly White teacher candidates (Goodwin & Kosnik, 2013). However, our conceptualizations and operationalization of our pedagogy as a role, and as needing safety nets did provide a lens into the complex demands of science teacher education. Conceptualizations were in response to the complex demands of dealing with teacher candidates' predetermined notions about us. Indeed for us, these predetermined notions seemed to form the problems and tensions and were of concern even though we had been exposed to the tripartite knowledge structure for the pedagogy of teacher education (Cochran-Smith & Lytle, 1999; Goodwin et al., 2014) and for the pedagogy of science teacher education (Berry & Van Driel, 2013).

Looking at both the conceptualizations and operationalization of our pedagogy of science teacher education it seems that the conceptualizations and operationalization share similarities with Matias's (2013) methodological tactics and Goodwin et al.'s (2014) survival tactics. First, both were constructed in response to teacher candidates' predetermined notions about science teacher educators of color. Second, both were constructed to avoid resistances in the process of teaching science teacher candidates and were not substantiated by accepted theories. Our choice to transform the inherent predetermined notions and resistances through dialogue in the focus group interview suggested that we were keen on changes and that our methodological tactics were not static but being challenged. Most importantly, the pragmatic nature of our decisions to transform certain elements of our practice resonated from within our knowledge-in practice.

Finally, the notion of transitional spaces (Margolin, 2011) as an element that impacts the development of pedagogy of science teacher education was not obvious (Berry & Van Driel, 2013; Cochran-Smith & Lytle, 1999; Goodwin et al., 2014; Loughran, 2006; 2014) in this study. Even though, Sumreen's transitional space differed from the rest of us, collectively the conceptualizations and operationalization of all our pedagogy were more in reaction to the particularities Cochran-Smith & Lytle, 1999) of ethnicity, and resistances (Goodwin et al., 2014; Matias, 2013) within our teaching spaces (Goodwin et al., 2014).

In sum, our tripartite knowledge structure for the pedagogy of science teacher education was influenced by our teacher candidates' predetermined notions about science teacher educators of color. Basically, our conceptualizations and operationalization of our pedagogy of science teacher education showed some signs that were indicative of the pedagogy of survival tactics (Goodwin et al., 2014) and the pedagogy of trauma (Matias, 2013). Additionally, conceptualizations and operationalization of our pedagogy of science teacher education was more in-tuned with the knowledge-in-practice component of the tripartite knowledge structure for the pedagogy of science teacher education: the situated knowledge acquired from reflection and analysis of one's own science teaching/science teacher education practice. In contrast, the methodological tactic of needing safety nets while instructing teacher candidates how to teach science was lacking in theoretical soundness.

Self-Study Methodology

According to the teacher education literature, self-study methodology is a useful tool for teacher educators in inquiring into their own processes of educating teacher candidates (Dinkelman et al., 2006; Feldman, 2003; Kaufman, 2009; LaBoskey, 2004; Loughran, 2014; Pithouse et al., 2009) and in this study the self-study methodology provided a lens to examine our pedagogy of science teacher education. Specifically, the use of self-study methodology together with qualitative methods like metaphors and the focus group interview helped us to reflect onto our pedagogy of science teacher education within our own teaching spaces. The use of metaphors was unique in that it helped us to relate our pedagogy of science teacher education into images about our practice, images about our roles; and the images of our personal practical knowledge. Moreover, unlike interviews that produce data in response to interviewer agenda and questions, the use of metaphors helped to bring forth the challenges inherent in our practice of educating science teacher candidates from our substantial selves and situational selves. The use of the focus group interview did provide an avenue for us to share our collective concerns within an open and supportive environment (Cochran-Smith, 2003) and additionally, enabled us to substantiate each other's interpretations within the study's context: the culturally patterned signs and symbols extant within the science teacher education context in which we were situated. Furthermore, it was obvious to us as researchers studying our own practice that we were engaging in knowledge-of-practice, a component of the tripartite knowledge structure for the pedagogy of teacher/science teacher education. In doing so, our study substantiates the role of self-study as a purposeful methodology that maps the outcomes of teacher educators' inquiry into their own instructional practice.

Conclusion, Implications, and Challenges

This study showed how the four of us, science teacher educators of color, conceptualized and operationalized our pedagogy and especially how we overcame and endured our teacher candidates' predetermined notions about us and our practice of science teacher education. Even though our self-study of our practitioner knowledge, through metaphors, narratives and a focus group interview, revealed that we had aspirations to help transform our pedagogy of science teacher education for the success of our teacher candidates, these transformations were situated within tensions of role, identities and methodological tactics for survival. More research is needed to study how science teacher educators of color conceptualize and operationalize in response to the particularities within the context of their teaching space so that counterstories and/or counternarratives are produced to substantiate/refute the tripartite knowledge structure for the pedagogy of science teacher education. Most importantly, this needed research must be situated within the challenges, tensions, and problems impacting science teacher educators' substantial selves and situational selves. An additional implication is that components of the tripartite knowledge structure for the pedagogy of science teacher education, knowledge-for-practice, knowledge-of-practice, and especially knowledge-in-practice need to be approached in conjunction with the research on preparing a predominantly White, middle class, female teaching workforce, and from the standpoints of the mainstream White teacher educator. As this study has shown, these two factors form the basis of the teacher candidates' predetermined notions and which in turn impact science teacher educators of colors' instructional practice.

Based on our self-study of how we conceptualized and operationalized our instruction in science methods courses we acknowledge the following challenges that impact our pedagogy of science teacher education. First, we argue that tripartite approach to a pedagogy of science teacher education is predominantly focused on how to educate teacher candidates and lacks the substantial knowledge-base for science teacher educators to look inwards into their substantial selves and their situational selves. Above all, the specific challenge we faced was the lack of discourse structures that we could use to unveil the unique ways of how we as science teacher educators of color conceptualized and operationalized our instruction in science methods courses to a predominantly White teacher education faculty.

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Chapter 11
Uncertainties of Learning to Teach Elementary Science Methods Using Engineering Design: A Science Teacher Educator's Self-Study

Brenda M. Capobianco

Introduction

Recent reform documents including *A Framework for K-12 Science Education*: *Practices*, *Crosscutting Concepts*, *and Core Ideas* (National Research Council [NRC], 2012), *Next Generation of Science Standards*: *For States*, *By States* (NGSS Lead States, 2014) and *STEM Integration in K12 Education*: *Status*, *Prospectus and Agenda for Research* (NAE & NRC, 2014) highlight the significant role reform in science education plays in the preparation of the next generation of science teachers. The NGSS, for example, calls for refocusing K-12 science to not only improve college preparation and STEM career readiness but also enhance the preparation of science teachers. The *NGSS* recommends an integration of engineering into science through two ways: (1) as a pedagogical approach to teaching science content and (2) as content area in and of itself. Underpinning these calls for reform is attention to preparing science teachers with the skills, knowledge, and dispositions to teach science using both scientific and engineering practices. This means science teacher educators must be well-equipped and well-positioned to know what engineering entails and how engineering practices frame preservice teachers' learning of science and learning to teach science. This places the science teacher educator in a vulnerable position whereby he/she must be self-directed as well as self-reliant on learning about what engineering entails, how it is taught and moreover, how engineering practices intersect as well as parallel scientific practices. It requires a degree of risk-taking in one's practice with the potential of losing something of value, perhaps a loss in his/her performance as a skilled science teacher educator. Risk-taking is an inevitable behavior that changes and thereby presents some degree of uncertainty about the future (Le Fevre, 2014). In this self-study, I reflect on my attempts at

B.M. Capobianco (✉)
Purdue University, West Lafayette, IN, USA
e-mail: bcapobia@purdue.edu

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integrating engineering design in my elementary science methods course. While assisting my preservice teachers to study their own learning to teach science in the elementary science classroom, it comes easily, almost naturally, for me study my own practice of learning to teach science through engineering design. My aim is this chapter is to shed light on the dilemmas I faced when attempting to learn how to integrate a novel form of instruction – engineering design-based science instruction – in the elementary science methods classroom. Underpinning this examination of my own practice is how I utilize self-study practices to uncover new understandings of my learning and teaching about engineering design-based science instruction and the uncertainties I encounter along the way.

My Knowledge of Engineering Design in the Elementary Science Classroom

As a science teacher educator examining my practice of integrating engineering design-based science instruction, I think it is important that I articulate what I know about engineering design. At the heart of engineering practices is the engineering design process. Engineering design is a recursive, creative activity resulting in artifacts (physical or virtual) and processes. Design involves both the use of existing information and knowledge and the generation of new information knowledge. From a science education perspective, design entails the use and application of science concepts to inform a design, explain the results of design testing, and improve a design. There are several characteristics of good engineering design task: (1) science (and mathematics) concepts and ideas are often embedded, if not connected, in the tasks; (2) the tasks are open-ended and accessible for all students; and (3) the tasks require students to justify and explain their thought processes as they engage in the task. For students to create a prototype of a prosthetic limb, they would use and apply their knowledge of movable joints as well as properties of levers, make observations of how a hinge joint operates by observing the movement of their own ankle, knee or elbow, and justify their use of materials and explain how their prototypes function.

From an instructional perspective, I situate the engineering design process as a form of problem solving that is *not* taught as a separate topic in my curriculum but more as an integral part of science learning. This means that I must create and select appropriate tasks, monitor the placement of these tasks in my curriculum, and orchestrate classroom discourse to maximize learning opportunities for my students. In this capacity, I am more of a facilitator, scaffolding students' learning by revisiting the essential elements of the design problem and confirming students' ideas through productive questioning, open dialogue and collaboration among students. I may scaffold learning by sequencing, modeling, coaching, and giving feedback. For instance, in the canal task, I scaffold students constructing and articulating scientific explanations when they test their canal designs. What follows is a description of the methods course and the design principles I incorporated into the course.

Overview of Engineering Design-Based Elementary Science Methods Course

I developed the goals and objectives of the elementary science methods course to mirror current science education reform documents. Attention was given to creating opportunities for my students, preservice teachers, to ask questions and define problems; develop and use models; plan and carry out investigations; analyze and interpret data; and construct explanations and design solutions. In addition, I challenged preservice teachers to investigate their own teaching and that of others with a desire to help them perceive themselves as resources for their own learning. We discussed topics such as the nature of science and engineering, conceptual change, productive questioning, inquiry- and engineering design-based science teaching, and assessment. Class assignments included preservice teachers interviewing children, engaging children in process-oriented science and engineering activities, and gathering children's ideas about scientists and engineers through drawings to construct a comprehensive learner profile. Additional assignments included the development of a curriculum unit plan, an assessment plan, and a multi-day lesson plan that preservice teachers implement in their field experience.

Unique to my course was the emphasis placed on how students learn science by engaging in an engineering design challenge. I developed a series of design tasks that were grounded in standards my students would be teaching during the semester and in their student teaching. Each design task is presented in the form a design brief, a narrative that describes the problem. A design brief includes the following essential features: (1) client-driven and goal-oriented; (2) provides an authentic context; (3) includes constraints; (4) integrates the use of tools and materials familiar to students; (5) yields a product or process; (6) multiple solutions; and (7) requires team work (Capobianco, Tyrie, & Nyquist, 2013). One example of a design task I use to early on in the course is called Lifeguard Chair. In this task, students work in teams to design a prototype of a lifeguard chair for a local pool. Students are given a set of criteria, constraints, and a limited number of materials (e.g., index cards and masking tape). Using what they know about tensile and compressive forces, students test their structures and discuss the direction and amount of force applied to their chairs when a lifeguard (stuffed animal or action figure) is positioned on top. As an introductory design activity, students learn engineering design concepts such as criteria, constraints, end user as well as the problem solving process engineers engage in when working with different clients.

In addition to learning about design through different tasks, I challenge students to think about their own conceptions of engineers. I instruct my students to complete the Draw-An-Engineer Test (DAET) (Capobianco, Diefes-Dux, Mena, &

Weller, 2011). Similar to the Draw-A-Scientist Test (DAST), students draw an engineer doing engineering work. From these drawings, I can identify different conceptions students have about engineers. Often times my students' conceptions mirror the conceptions held by elementary school students including conceptions of engineers as mechanics, laborers, and technicians. As a follow up activity I encourage students to further explore the field of engineering and technology by interviewing an engineer and preparing a slideshow of images of where engineering and technology exist in our lives.

Prior to lesson planning, I spend considerable time with my students discussing the role of curriculum in the science classroom. Students work in small teams to review existing state and national elementary science curriculum, kits, and related resources. I extend this class assignment to include a review of existing elementary engineering curriculum. Students quickly learn that there is a limited number of high quality engineering design-based science curricular materials and soon realize that they must devise their own ways of building students' understanding of engineering practices.

Incorporated into the course is an 8-week field experience entitled "theory-into-practice" or TIP where preservice teachers observe teachers and students engaged in science lessons, work in concert with their TIP classroom teacher to co-develop and co-teach an engineering design-based science lesson focused on one or two academic science standards and related practices. The cumulating activity for the course is an electronic portfolio that consists of multiple artifacts (i.e., lesson plans, reflections, and children's class work) the preservice teachers develop, collect, and assess over the course of the semester as evidence of his/her practical and pedagogical knowledge.

Context of the Study

The context for my self-study is an undergraduate elementary science methods course. Elementary education majors generally take my class the semester prior to student teaching. By the time students reach my class, they would have taken up to 15 credits in science including a two semester biology course sequence, one semester of chemistry, one semester of physics, and two semesters in earth, atmospheric and planetary sciences. These science courses are designed purposefully to build content knowledge among elementary education majors through a range of inquiry-oriented experiences. Students only experience with engineering and engineering design-based learning experiences is my elementary methods course. To succeed in the elementary teacher education program students must maintain a grade point average of 2.80 or higher. The 22 students (17 females and 5 males) who participated in my self-study had an overall grade point average of 3.00.

My methods class is one of three sections of the elementary science methods offered each semester. My class is distinctly different from the other sections. Although I incorporate several similar course assignments, I purposefully enhanced the course to demonstrate a balance between the roles of science and engineering in the elementary science classroom (see course details below). I titled my section, "Teaching Science in the Elementary Classroom through Engineering Design" and students have the option to register in advance to either my section or one of the other existing sections. Several years ago I began recruiting students to my course by giving short presentations in other elementary education courses the semester prior to my methods course. In my presentation I outlined some of the goals and expectations of the course as well as how the course was different from the other sections. My aim was, that if given advanced notice, I would get students who wanted to be in the course. Interestingly, when I met the students the first week of the semester of my self-study, I learned that more than half of the students purposely registered for the course, while the remaining students (~30 %) registered by default. These students stated that they were placed in the section because "the other sections were full," "this section was the only time that accommodated their schedules," or "they did not have a choice." Furthermore, these students were quick to express their concern and anxiety about "studying engineering," suggesting that it was "hard," "had to be good in math and science," or "required more time to learn." My initial observations were that there were students in the class who did not elect to be in this class and held misconceptions about engineering.

Theory Framing the Study

My self-study is guided the construct of teacher uncertainty. Floden and Clark (1988) suggest that there are several different sources of teacher uncertainty including a teacher's doubts about her influence on student learning; her knowledge of instructional content; her authority in the classroom; and her ability to change and improve her own practice. Examples include concerns regarding whether or not I have sufficient knowledge about engineering design-based instruction, how best to facilitate productive design thinking, and my capacity to change and improve my practice in response to my students' engagement. Underpinning each source of uncertainty is the capacity for the teacher to accept uncertainty and develop expertise in order to improve her practice. According to Wheatley (2002), the ability to 'make peace' with uncertainty is both a feature of teachers' ability to know and inherent to the human ability to make decisions. This becomes important when testing out a new pedagogical strategy, incorporating a new curriculum unit, or implementing a new course.

In my self-study I utilized teacher uncertainty as a way of making meaning of my practical experiences with implementing engineering design-based science instruction in the elementary methods course. When I initially developed the course syllabus, I questioned my capacity to devise a course that was somewhat novel and innovative in elementary science teacher education. I had doubts about whether or not I knew enough about engineering design-based instruction and began journaling my questions, concerns, and dilemmas. Additionally I questioned how I could balance my curriculum and instruction with scientific practices. Journaling allowed me to chronicle these experiences as well as situate my practice in a context where I could gain new knowledge and grow professionally. In short, I wanted to make the process of thinking and re-thinking about this course transparent, engaging, and productive. Hence, I used teacher uncertainty as means of clarifying and interpreting my doubts, questions, and tensions.

In effort to deal with uncertainty, LeFevre (2014) suggest risk taking. Risk-taking is an inevitable behavior in any environment that changes and thus presents some degree of uncertainty about the future (Zinn, 2008). Risk and risk-taking are critical components of innovation and change (Jaeger, Renn, Rosa, & Webler, 2001) and are important elements to consider in processes of educational reform. I contend that risk taking and teacher uncertainty go hand in hand. To confront uncertainty, a teacher must take risks. When taking risks, uncertainty can prevail. Because risk is significantly defined by the context in which it is embedded, I elected to exercise risk to better address and understand my uncertainties within my practice. In my self-study I first identify some of the uncertainties I experience and further describe the risks I take in an effort to not only embrace my uncertainties but ultimately transform and improve my understanding of my teaching practice.

Design of the Study

This self-study is guided by a methodology quite familiar to the field of self-study research – action research. Action research has had a strong influence on self-study research and has been referred to as a "useful tool for self-study" because it provides a method to conduct systematic inquiry into one's teaching practices (Feldman, Paugh, & Mills, 2004, p. 970). Drawing from the work of Carr and Kemmis (1986), action research involves a systematic approach to problem solving. Teachers and teacher educators engage in action research (McNiff, 2013) to examine their teaching and their students' learning as a basis for making changes. Feldman, Paugh, and Mills explain "action research provides the methods for the self-studies, but what made these *self-studies* (italics in original) were the methodological features" (p. 974). Self-study researchers use their experiences as a resource for their research and "problematize their selves in their practice situations" with the goal of reframing their beliefs and/or practice (Feldman, 2002, p. 69). Action research is more about what the teacher does, and not so much about who the teacher is.

Data Sources and Analysis

In this vein, I elected to focus on *how* my pedagogical actions of integrating engineering design impacted my beliefs about preparing the next generation of elementary preservice science teachers and furthermore explored the types of uncertainties

I encountered along the way. These uncertainties signaled opportunities to take risks, to use my energy, and to try something new. What kinds of risks do I take in response to these uncertainties and to what extent do these risks inform my professional learning?

Through the use of personal journal writing, field notes from my planning and instruction, individual semi-structured interviews (Patton, 2014) with the preservice teachers, and collective reflection between the preservice teachers and myself, I attempted to capture both insider and outsider perspectives of what was happening during my implementations of engineering design-based science instruction. Before and after each class I recorded my personal thoughts, ideas, and questions. I conducted a series of semi-structured interviews with the preservice teachers at the beginning, middle, and end of the semester during the self-study. During my instruction, I recorded short notes of what I perceived was taking place in real time while noting the preservice teachers' responses to some of my questions and actions. Throughout the semester the preservice teachers maintained a reflective journal where they recorded their ideas, questions, and thoughts about what and how they were learning. Collectively we, the preservice teachers and I, read aloud our reflections, acknowledging our doubts, anxieties, and apprehensions.

As a form of naturalistic inquiry (Lincoln & Guba, 1985), my data analysis was driven by two goals. First, I wanted to accurately interpret and describe the full range of my experiences with learning to teach science through engineering design. I also attempted to locate predominate themes, concerns, and uncertainties associated with the process of learning how to teach science through design. I analyzed my journal writing, field notes, interview transcripts, and collective reflections for elements of teacher uncertainty. This process entailed reading and re-reading all of the data, noting recurring and common ideas.

In dealing with issues of teacher uncertainty, it has been suggested that individual efforts to improve perceptions of personal efficacy in the face of uncertainties are unproductive: the life of the "lone inquirer is difficult" (Dana & Yendol-Silva, 2003, p. 7). To overcome this, collaboration is often cited as a strategy to positively influence teachers' acceptance of uncertainty (Capobianco, 2011; Helsing, 2007). Collaboration that challenges teachers' thinking, encourages reflective experimentation with new behaviors, practices and ideas, and understands that success is often preceded by failure has been shown to build a common sense of purpose and agreement as to what constitutes good practice (NRC, 1996). What follows is my explanation of how I established collaboration – a central tenet of self-study research (Hamilton, 1998) – in the form of a critical friendship.

Role of Critical Friends

According to Stenhouse (1975), "critical friends" are people who take a proactive role in helping other researchers bridge the gap between theory and practice. Critical friends listen carefully, ask serious questions to evaluate the quality of research, encourage reflective practice, and build professional relationships among researchers. For the purpose of this self-study, I characterize a critical friendship as involving a trusted person who is committed to fully understanding a person's situation, the work involved, and the goals and intentions the person is working toward. In the context of this self-study, the preservice teachers served as my primary critical friends. Sam, a colleague from biomedical engineering, served as my secondary critical friend. Sam has a graduate degree in biomedical engineering and co-taught the methods course with me during the course of my self-study. In this capacity, the preservice teachers and Sam listened to my ideas, questions, and reflections; asked provocative questions; and encouraged me throughout my inquiry. At the same time, I served as a critical friend for them. In addition to listening to one another and providing constructive feedback, we observed one another teach, implement new ideas, and make meaning of our respective attempts at improving our practice. Early in the semester, the preservice teachers and I discussed the importance of sharing our reflections and furthermore, discussed ways of establishing trust in our critical friendship. We outlined our respective roles within the critical friendship; negotiated these roles; and demystified any expectations and implications for those who did not wish to engage in the open dialogue. I often questioned whether or not I knew enough about engineering practices and therefore, on occasion, shared my thoughts and ideas with my colleague from biomedical engineering. It was during these reflective situations when I often experienced a heightened sense of uncertainty.

There are several aspects of critical friendship that can be identified in my working model (or definition) for critical friendship. First, the critical friend must offer a critique. Many authors stress the issue of finding a balance between being critical and offering critique, and at that same time being a trusted person and a friend (van Swet, Smit, Covers, & van Dijk, 2009). Second, the critical friendship requires an examination of data "through another lens" (Costa & Kallick, 1993). By looking through or using another lens, the critical friend may ensure a sense of trustworthiness, validity, and/or reliability (Damen, 2007; Etherington, 2004; Ponte & Zwaal, 1997). Furthermore, this form of critical external reflection (as opposed to private reflection) (Damen, 2007) provides a filter that aids in how the person perceives and evaluates things, perhaps even de-contextualize his/her experiences, beliefs, and/or "mental models" (Senge, 1990) of what is happening around them. Lastly, the critical friendship is centered upon strong lines of communication. By implementing the critical friendship strategy, I was able to diffuse my sense of doubt, negotiate any tensions and conflicts, and furthermore, elicit the help of my colleague and the preservice teachers for guidance, expertise, and/or wisdom. The combination of guiding and supporting one another served purposeful and productive in helping me recognize, accept, and address my uncertainty.

Recognizing My Uncertainties

Based on my analysis of the data, I generated several themes that represented uncertainties I experienced as I attempted to incorporate engineering design-based science instruction. These findings are organized around three themes: finding and defining my own sense of competency, reservations with and resistance to reform, and beneficial risk of sharing. The first theme illustrates a type of uncertainty focused on my self-doubts about my knowledge of design-based instruction and its impact on my students. The second theme depicts my initial reluctance to embrace engineering design-based instruction. As a result, I questioned, the relationship between design and science learning. The last theme describes the connection I made between uncertainty and risk tasking and the unintended benefit I gained by sharing reflections with my students. Here I discuss how my sense of uncertainty encouraged me to take risks in my teaching and what I gained by doing so.

Finding and Defining Competency

> It's the first week of class and I feel very confident in my plans to introduce my methods students to the notion of engineering design. I am excited about beginning the first day with an actual design task. I am a little worried that I may not come across as knowing enough about the engineering practices and being able to provide enough productive learning experiences for them. I think a lot of this is going to be trial and error (Brenda, Journal entry/pre-lesson reflection, August, 2011).
>
> I would have to say the first day of class was really tough for some of us. I felt like we were learning a whole new language. 'Client, end user…constraints'…these were terms we had never heard of in our science classes…we didn't know there would be this much engineering stuff to cover. I know for myself, I was not sure how to work through the first design task with my team…we weren't given any handouts about how to set up a procedure or collect data…like we did in chemistry class (Jess, Interview #2, October, 2011).
>
> The students appeared a little surprised…maybe even turned off from the lesson. They appeared a little apprehensive…maybe it was because it was the first day, new class, etc. I think I am having a hard time deciding on which topics and concepts to spend more time on. There's part of me that wants to teach science through design by immersing them in an actual design task and allowing them to engage in the process as a whole. Then there's this other part of me that thinks I should break down the design process and focus on individual stages with my students…maybe I could blend both approaches?? (Brenda, Journal entry/post-lesson, August, 2011).

As the semester started, I felt confident early on yet this diminished by the second week. My waves of self-doubt about which direction to take in my instruction were coupled with the preservice teachers' reluctance to participate in what was perceived as ill-structured and unfamiliar. This sense of uncertainty sent me to enlist the help of my biomedical engineering colleague. Yet, even Sam questioned my instructional intentions.

> Sam: So you give your students a design brief that requires them to work in teams to design a prototype of a life guard chair for the local community pool. What do you want your students to be able to do by the end of the task?

Brenda: I want them to be able to develop a feasible solution by using engineering design. I was hoping that they would also use what they learned from an earlier inquiry activity about forces, tension, stress, and load to construct the prototype.

Sam: You want them to be able to solve the problem using design and use science conceptual understandings to inform their designs. Do you think you met your objectives?

Brenda: Well each team created a successful solution but I am not convinced they demonstrated conceptual understanding of why their structures worked.

Sam: How could you find out if students really know the science behind this type of design?

Brenda: I am not sure…maybe spend more time with testing their designs and talking aloud the results from their testing? (Critical friend debrief, September, 2011).

According Floden and Clark (1988) teachers "face both action and knowledge uncertainties" (p. 8). This includes teachers' own personal questions about content knowledge as well as the impact of their classroom practice on student learning. In other words, the teacher inevitably faces important, difficult decisions about coverage and emphasis. What do I cover when it comes to engineering design and what do I want to place emphasis on? When talking with Sam, it became clear to me that my understanding of how to facilitate the preservice teachers' understanding of forces within the design task was incomplete. If I place more emphasis on design and less on science content, then I run the risk of the preservice teachers not learning how to teach science through design. I also think I made the assumption that my students would be able to identify the forces placed on their structures and determine how to adjust parts of their structures based on the properties of compression and tension. My next steps were to place emphasis on both.

Several weeks later I implemented a task that required the preservice teachers to design a canal to carry water from a lake to a local water park. In this task, students study the phenomenon of erosion. By the end of the lesson, students describe how elements such as wind or water shape and reshape land surfaces by eroding rock and soil in some areas and depositing them in other areas over time. In the canal design students incorporate a mechanism to control erosion while moving water from a local lake to town water park. To complete this task, the preservice teachers must know what erosion is, different types of erosion, and how to control it. The task has been implemented in local elementary schools. Interestingly, elementary school science teachers often review vocabulary, at length, with children then introduce the task. In the past, I introduced erosion by gathering students' prior knowledge through questioning and illustrations depicting different types of erosion. Students then engage in an inquiry activity to determine if the size and type of material effect the level of erosion using different types of rocks and stream tables. From their results, students looked at patterns in the data and discussed concepts such as erosion, run off, drainage, and sedimentation.

When I approached the unit this time, I elected to introduce the task without reference to earth science principles or concepts. I wanted to see what kinds of solutions the preservice teachers could create. After many failed attempts, I then asked, "What do you need to know in order to make this canal?" The preservice teachers asked for information about which materials to use, how best to prevent erosion, and what other techniques have been used. We then engaged in a discussion about erosion, identified different forms of erosion and participated in an inquiry activity using erosion tables. I then returned to the task and instructed the preservice teachers, "Using what you recently learned about erosion, how can you design a canal to transport water and control for erosion?" The preservice teachers worked in teams to create a variety of successful solutions including structures that represented rubble, fiber rolls, and mulch. Together we shared our journal reflections of what it means to learn science through design.

Tim: I wrote in my design journal… 'I thought I knew enough about erosion to solve the task the first time around. What I didn't realize is that I needed to know about how to control it…like what kinds of materials to use…to actually test them first.'

Brenda: In my reflection I wrote down the following question: 'Are they able to use their conceptual understandings of science to design the canal?'

Abby: Yes…I think we learned more by actually trying to build a canal first then discussing what we did and did not know. I especially liked testing the different materials because then I could use what I learned from those tests to inform my final design.

Lauri: You really could not build a good canal unless you knew exactly how you could control erosion. You had to know how to design the slope of the canal to prevent overflow of water…you had to know which materials to use and where to place them…I think we definitely used science concepts maybe even math concepts to build our designs (Collective reflections, November, 2011).

By taking a risk of implementing the design task in this manner, I learned to reframe my way of teaching design as an introductory activity and allow preservice teachers to explore different ways of learning to teach the engineering design process as well as apply science conceptual understandings. My initial concerns about where and how to place design relative to students' science conceptual understandings were unsettling. I grappled with exactly how to let design facilitate students' understanding of erosion. The canal task provided an opportunity for me to rethink and reposition design as a mechanism for students to utilize science to inform their designs. An unintended result of reframing my approach was students' heightened understanding of how design granted them multiple opportunities to revisit their knowledge of erosion and apply it accordingly. Sharing our reflections confirmed for me that the preservice teachers not only succeeded at identifying effective engineering design-based science instruction but more importantly confirmed for me that I needed to confront my uncertainty by becoming responsiveness to my students and change my practice.

Reservations with Reform

As the semester progressed, the preservice teachers began to question why we were spending more time on engineering design rather than "just science". Their journal reflections included questions and statements such as "Why do we need to know engineering?" "Are we really going to be responsible for having elementary school children know design?" "Engineering seems more like a topic covered in middle schools, not elementary schools."

Like the preservice teachers, I questioned the role of engineering in science teacher education. For several years I grappled with finding effective ways of alleviating my preservice teachers' anxiety with teaching science, augmenting their subject matter knowledge, and modeling productive ways of teaching science. I, too, had reservations when I first learned about the role of engineering in the next generation of science standards. My initial concerns were that my existing course syllabus was already quite full; the preservice teachers did not always walk away with a complete understanding of inquiry-based teaching; and not enough time is devoted to teaching science in the elementary schools. Other concerns included gaining access to adequate knowledge of engineering to be effective at showing preservice teachers how to teach science through design, including how best to address the relationship between science content and engineering. More specifically, determining if design problems are used to teach science or to help students learn how to solve design problems using science? As previously discussed, my approach is to position design as a mechanism for students to use and apply science concepts to inform a design, explain the results of design testing, and improve a design. As a result students develop a deeper understanding of the concepts. I also harbored reservations about whether or not the preservice teachers could teach science through design after having spending a semester immersed in design-based experiences.

Throughout the semester the preservice teachers and I explored science content by engaging in engineering design-based science tasks to build their knowledge and possibly change their mindset about the role of engineering in the elementary classroom. They slowly exhibited a change in their beliefs about science teaching and learning, noting that their engagement with the content in the methods course showed them "how science and engineering practices related to one another" (mid-semester interview) and how it was preparing them to teach science to children. When preservice teachers were instructed to devise an alarm for a school locker, I used inquiry activities, such as, building a simple circuit with a battery, bulb, and wire, to facilitate their learning of open and closed circuits. I then introduced the design task of making an alarm for a locker and further encouraged them to test their systems in an actual locker. What follows are preservice teachers' thoughts expressed in their interviews.

> I think engaging in design tasks, like the alarm system, helps us to recognize authentic situations, real world applications (Grant).

For me to create an alarm system for a locker, I need to know how to assemble a circuit. This type of problem solving is different than how I solved problems in my other science classes (Hillary).

When we did the alarm task I was beginning to see what I learned from the simple circuit activity and how that influenced by design. Making the actual system, testing it out in a school locker made it real for me. I think having that kind of authentic experience is important for students (Ben).

These comments suggest a change in the preservice teachers' approach to teaching science through engineering design, beliefs in the effectiveness of engineering design-based science instruction, and a growing understanding that knowledge can be constructed through experience. Similarly, I was finding that engagement in science teaching through design was changing my understanding of teaching methods that were most effective for preservice teachers. The following is an excerpt from my journal:

I am beginning to see how design can help facilitate my students' understanding and use of different science concepts. One thing I noticed is that *where* I place a design task in my instruction. Early in the semester I used the Lifeguard Chair as an introductory activity and assumed that students would use what they knew about forces to inform and explain their designs. I used the canal task as a way of gauging students' prior knowledge of erosion and quickly noticed that they needed to know more about ways to prevent erosion. I then re-introduced the canal task a way for students to apply what they learned after their inquiry experiences. Door alarm was another task that allowed students to apply what they learn them questions about their thinking and see first-hand if they understood the original problem, its goal, and how to approach the problem. I could see if they were using what they knew about erosion or simple circuits to solve the problem. Initially I thought I could place the tasks wherever I wanted; however, I am now seeing that *where* I position the tasks in my instruction and *how* I facilitate my students' understanding of both design and science are interconnected (Journal reflection, November, 2011).

This shift in my initial reservations with engineering design-based science instruction to one of acceptance and enthusiasm was most prevalent when I observed the preservice teachers implement their lesson plans. I saw the preservice teachers ask productive questions, scaffold their students' engagement in the design tasks through teaming, and use modeling as a strategy to reinforce a particular concept. I was surprised to observe the preservice teachers implement strategies I modeled for them. In addition, I was surprised to see how the children in the classroom responded to the preservice teachers' instruction. The children asked questions, challenged classmates about their designs, and constructed viable solutions to the design problems. My reservations about engineering design in the elementary science classroom and the preservice teachers' capacity to teach science through design seemed to diminish.

Beneficial Risk of Sharing

One interesting and unexpected result from my self-study is that I now position uncertainty in a positive light. By embracing my uncertainties with learning to teach science through engineering design, I can imagine and construct new and more effective ways of preparing preservice science teachers. Sharing my reflections, ideas, and insights about my developing practice with the preservice teachers and my colleague contributed greatly to reducing my uncertainties and influencing my responses to my uncertainties. To some extent, this sharing demonstrated a high level of risk for me. Implicit is my initial perception of risk was the fear of failing. I did not want to fail nor come across to the preservice teachers as an ineffective teacher. I also thought the risk of sharing implied losing control of what was being taught and how it was being taught.

It is my contention that this risk-taking experience of sharing was both positive and productive. When asked by Sam, why I was so willing to make changes in my teaching, I wrote:

> I think that it is part of who I am… change for me is a necessity when I have a better understanding of what I believe…For me, engineering is as important as science, so it is my professional belief and obligation to instill those principles in my preservice teachers. I am doing my students a dis-service if I don't prepare them effectively. To me, there is too much at stake (Reflection, December, 2011).

According to Shapira (1995), if perceptions of what is at stake in a risk-taking situation are outweighed by those of what can be gained, then people are often more willing to act and to take risks. What was at stake for me was my perception of being responsible for creating ill-prepared teachers; however, I knew what was possible by changing my pedagogy. In effect, this vision of possible positive and valued outcomes for my students, the preservice teachers, enabled me to exercise agency (Jaeger et al., 2001) in acting to attempt to shape future positive outcomes for the preservice teachers in my class.

Concluding Thoughts

Through self-study of my instructional attempts and interactions with the preservice teachers, I am able to better understand my own uncertainties about what engineering entails, the role of engineering design in science teacher education, and how best to teach science through design. One of my initial challenges was determining how to facilitate my students' learning of science through design as well as how to scaffold my students' learning of design as form of problem solving. Another challenge was overcoming my own self-doubts about whether or not I knew enough about design-based teaching. I have a better understanding of my own premises about what I believe to be effective teaching. I was intrigued and surprised by my degree of risk-taking and rewards from doing so. While I have been involved in previous self-studies that examined my formative practices in elementary science teacher education, it was this particular study with a focus on valuing uncertainty and risk-taking that led me deeper into my own notion of self as a teacher educator.

What has changed is my understanding of engineering design as a pedagogical approach to building preservice teachers' understanding of science and its application. Teaching science through engineering design goes beyond the add-then-stir approach where the teacher inserts an engineering design task wherever it seems to fit. It involves thinking critically about the goals and intentions of the design task. The orientation of a design task is dependent upon what and how students will learn as a result. Additionally, the role of the instructor and how she facilitates her students' learning while engaging in the tasks is detrimental to what students gain from the experience. The preservice teachers in my self-study helped me understand that there are different ways of thinking about design as well as different ways of using design to build students' conceptual understandings. Moreover, the preservice teachers helped me embrace my uncertainties with this new form of pedagogy and challenged me to take risks in my instruction that I may not have taken. My sense of uncertainty regarding my competency as a science teacher educator teaching engineering design-based instruction has changed such that I feel more confident in my instruction. I have a better understanding of how I can balance the role of scientific and engineering practices in my curriculum and how and why engineering design plays a role in learning to teach science at the elementary school level. I can anticipate preservice teachers' questions and issues with learning this new form of instruction and support them through this process. The role of critical friends and the use of collaborative reflections were instrumental in helping me reach this point in my growth as a teacher educator. Lastly, what I have learned is that the risks teachers take with giving up a sense of certainty are the very same ones that may enable them to rethink and reframe their teaching. For it is only when teachers allow for some uncertainty about the validity of their own teaching practices and beliefs that they can begin to imagine and construct new and more effective ones. McDonald (1992) explains that "facing uncertainty is an indispensable step toward a genuine questioning, without which all the things one might read about improving teaching and schooling cannot sink in" (p. 41). Uncertainties "become the means by which we may see beyond what we think we know" (p. 7).

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Chapter 12
Self-Studies of Elementary Science Teacher Educators: Insights, Implications, and Future Research Directions

Lucy Avraamidou

Self-study research has gained growing popularity and interest the past few years in social research (Lassonde, Galman, & Kosnik, 2015; Loughran, 2014; Loughran, Hamilton, LaBoskey, & Russell, 2004) and especially in the area of science teacher education (Bullock & Russell, 2012). As Zeichner (1999) argues, it is important that teacher educators study their own practices:

> The disciplined and systematic inquiry into one's own teaching practice provides a model for prospective teachers and for teachers of the kind of inquiry that more and more teacher educators are hoping their students employ. These studies represent a whole new genre of work by practitioners that we will be hearing a lot more about in the years to come. (p. 11)

The chapters of this section are exactly about *science teacher educators examining their own understandings and practices through self-study*. Collectively and individually, the four chapters reviewed here constitute a valuable source of empirical evidence about science teacher preparation, and offer concrete examples of a variety of approaches to self-study. The chapters are grounded in the common assumption that if we (as teacher educators) aim to make meaningful and transformative changes in science education, we ought to engage in a systematic process of evaluating and re-evaluating our theoretical understandings and practices – a process grounded within the theoretical construct of *reflection* (Schon, 1983). The authors of the chapters take on various aspects of elementary science preparation, share different perspectives about the design of their methods courses, and delineate a range of approaches to self-study methodologies.

In this commentary chapter, I first provide a brief overview of the four chapters around four main areas of interest, as they stood out for me while reading them: (a) Intersections of self-study, teacher preparation, and reform recommendations;

L. Avraamidou, Ph.D. (✉)
University of Groningen, Groningen, The Netherlands
e-mail: L.Avraamidou@rug.nl

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(b) The value of uncertainty as a theoretical construct in self-study; (c) Pedagogies of social justice from the "Other's" standpoint; (d) Self-study complementing other research approaches. Following that, I offer a discussion across the chapters regarding their unique contributions alongside their implications for teacher preparation and future research directions.

Overview of the Chapters

Intersections of Self-Study, Teacher Preparation, and Reform Recommendations

In *Evolving goals*, *pedagogies*, *and identities as an elementary science teacher educator*: *Prioritizing practice*, Elizabeth Davis explores the evolution of her work as an elementary science teacher educator over a period of 17 years (1998–2015). In so doing, Davis focuses on three main areas of interest in this self-study: (a) on the *goals* she has set for an elementary methods class; (b) the *pedagogies* she has used; and, (c) her own changing *identities* as a science teacher educator. In this chapter, the author offers a qualitative content analysis of her syllabi, assignment descriptions, and published scholarship, which characterizes her own development as a science teacher educator and illustrates broader changes in science education, namely, the move towards an emphasis on *practice*. First, the author reports on the analyses of the *goals* in the syllabi and assignments, and identifies four chronological and conceptual 'eras' which are aligned with broader developments and reform efforts in science education: (a) 1998–2002: traditional era with focus on unit planning; (b) 2003–2006: era of curriculum materials and student ideas; (c) 2008–2010: scientific modeling era; and, (d) 2011: practice-oriented era. Following her analysis, the author offers a discussion of the analysis of the main assignments for the course in order to trace the evolution of her own *pedagogies* as a teacher educator and how these shifted over time. Similar to the goals of the course, the author's pedagogies evolved from an emphasis on pedagogies of reflection and investigation toward pedagogies of practices. Looking at her published teacher education scholarship, the author goes on to explore how her *identities* as a science teacher educator have evolved over time. In so doing, three main assertions are made: (a) valuing knowledge, knowledge integration, and reflection; (b) valuing the planning of practices and the use of curriculum materials; and, (c) valuing interactional as well as planning practices. As evident in these main assertions, the evolution of the author's identities are directly linked to her pedagogies, which followed a similar path as the evolution of the course itself, and are also aligned with reform efforts and developments in science education. This is where, in my view, the main contribution of this chapter lies: it offers a concrete example of how research informs teacher preparation, and how reform recommendations are put into practice to frame the design of the science methods course.

The Value of Uncertainty as a Theoretical Construct in Self-Study

Brenda Capobianco, in *Uncertainties of learning to teacher elementary science methods using engineering design*: *A science teacher educator's self-study*, explores new understandings of her own learning and teaching about engineering design-based science teaching and uncovers the uncertainties she encounters along the way. Like Davis' study, Capobianco's study is situated within the elementary science methods course. Theoretically framed within the construct of *teacher uncertainty*, in this action research the author attempts to make meaning from her practical experiences with implementing engineering design-based science instruction in the elementary methods course. The sources of data for this study included personal journal writing, field notes from the author's planning and instruction, individual semi-structured interviews with the preservice teachers, and collective reflection between the preservice teachers and the author. In analyzing these data, Capobianco generated several themes that represented uncertainties she had experienced as she attempted to incorporate engineering design-based science instruction: (a) finding and defining competency; (b) reservations with reform; and, (c) beneficial risk of sharing. In discussing these findings, the author focuses on understanding her own uncertainties about what engineering entails, the role of engineering design in science teacher education, and how best to teach science through design. An important insight from this self-study, as acknowledged by the author, is that she positions uncertainty in a positive light, as a result of the process of engaging in the self-study. The findings of this study point directly to the value of the construct of uncertainty and of engaging in effective and reflective practices when conducting self-studies.

Pedagogies of Social Justice from the Other's Standpoint

The chapter entitled, *How science teacher educators of color conceptualize and operationalize their pedagogy in science methods course*, by Karthigeyan Subramaniam, Sumreen Asim, Eun Young Lee and Kia Rideaux, reports on the findings of a study that explores how four science teacher educators of color conceptualized and operationalized their pedagogy in elementary science methods courses. In this chapter, the authors address an underexplored area of research related to the experiences of teacher educators of color, and how they instruct teacher candidates. This is of particular significance, given that, as the authors rightly point out, teaching spaces are dominated by white, female, middle class, and English speaking preservice teachers. Specifically, in this chapter the authors explore how they conceptualized and operationalized their pedagogies in elementary science methods courses in relation to the challenges, tensions, and problems that impacted them during their instructional practices. The data for this study consisted of two sets of writing metaphors and a focus group interview with two of the authors. The analysis of these data, according to the authors, illustrated how they conceptualized their pedagogy in two ways: (a) conceptualization of pedagogy within a role (i.e., a choreographer, a captain, a solitary leader); and, (b) conceptualization of pedagogy in need of safety nets to remove barriers that impinged on their professional roles. What is perhaps more important than this finding is the fact that these conceptualizations were formed as a result of the experiences the authors had, after dealing with teacher candidates' predetermined notions about them as teacher educators of color. Several such notions included seeing them as different to themselves and from mainstream, white science teacher educators; perceiving attempts to integrate personal experiences and social justice issues as a "minority problem"; and, not acknowledging them as educators who were modeling the practice of science teachers. The findings of this study offer a significant contribution to the literature not only because the participants (teacher educators of color) are an under-represented group of researchers but because the findings also provide fresh perspectives on diversity and equity in science education from a different point of view – the Other's standpoint.

Self-Study Complementing Other Research Approaches

In *Our journey of understanding through lesson study*, Stephen Marble, Michael Kamen, Gilbert Naizer and Molly Weinburgh examine, through self-study, how a lesson study project they had carried out 6 years ago in three different methods classrooms, continued to influence their thinking and practice in the long term. Data for this study were collected in the form of memories, analytic memos, and syllabi revisions. In addition, as the authors mention, they met to discuss which elements of the original study remained most salient and what each author thought was the major change in his/her teaching, to best help pre-service teachers learn to teach science. In sharing the findings from the data analysis, the authors reflect on both their students' learning as well as their own growth as teacher educators. They organize the discussion around the following four themes: (a) working from theory; (b) problematizing the curriculum for students; (c) the public nature of practice; and, (d) back to theory. What is perhaps most striking in the discussion is how the authors' engagement in self-study and, particularly, their revisiting of the data and reflecting on their work made it clear that both their practices and theoretical understandings were put to test during their lesson study. This reveals not only the value of self-study methodologies but also the value of combining self-studies methodologies with other methodologies as part of the same research project. Even though the self-study reported in this chapter was carried out 6 years after the initial research study, it complements the initial findings regarding preservice teachers' development nicely, given that it adds the perspectives of the teacher educators. Combined, the two studies offer a well-rounded and comprehensive approach to examine the impact of the lesson study project on both teachers' and teacher educators' understandings about science teaching.

Contributions and Implications

The four chapters collectively offer a range of important insights and contribute in novel ways to self-study research both at a theoretical and methodological level. Each chapter proposes a unique theoretical construct to self-study research: identity, uncertainty, pedagogy, and lesson study. As such, the authors/researchers offer unique theoretical lenses to examining teacher educators' learning and development, as they place emphases on different aspects of their learning and development. Despite the differences in aspects of their learning and development that the authors chose to address in their self-studies, all four point to the value of reflection in shaping and re-shaping their understandings and practices as teacher educators. The ability to engage in reflective practices has been widely addressed in the literature as one of the most important activities associated with the development of professional knowledge (Dewey, 1933) and specifically the ability to "reflect-in/on-action" (Schon, 1983). The studies reviewed here constitute empowering examples of the various ways in which self-studies can be framed, and document the various processes through which teacher educators can engage in reflecting in- and on-action, and refine their practices as a result of these processes. As Feldman (2002) states, self-study researchers use their experiences as a resource for their research and "problematize their selves in their practice situations" aiming to reframe their beliefs and/or practice (Feldman, 2002, p. 971). The notion of "problematizing one's self" is probably more prevalent in Capobianco's chapter, who examines her own learning and teaching through the uncertainties she encountered as she implemented engineering design-based instruction in the science methods course.

Each individual chapter highlights unique aspects of self-study research and provides unique theoretical contributions. Davis' self-study, framed within the construct of *identity*, offers a proposition for the use of a multidimensional, sociocultural lens to study her development. The construct of identity has, in the past few years, been receiving a growing interest in science education, as researchers have started to look at how teachers view themselves, how they are recognized by others, and how their race, gender, personal histories, and emotions shape who they are (Avraamidou, 2014). In framing her study within the construct of identity, the author, in line with contemporary approaches in studying teacher learning (e.g., Luehmann, 2007; Moore, 2008; Rivera Maulucci, 2013), offers a more comprehensive conceptualization of teacher-educators' development, which goes beyond mere cognitive aspects of learning. Such a conceptualization offers important implications for further research at the intersection of reform recommendations and teacher identity. More narrowly, future research could address the following questions that remain largely unexplored: What constitutes a reform-minded science teacher educator's identity? What is the nature and characteristics of a reform-minded science teacher educator's identity? How do teachers construct reform-minded identities?

Framed within the construct of uncertainty, Capobianco's study introduces engineering in the context of the science methods course, and examines how her own *uncertainty* encouraged her to take risks in her teaching, and what she gained by doing so. In examining how her own understandings (or lack of them, at times) of engineering design played out in her uncertainty, the author highlights in subtle ways the importance of subject-matter knowledge and how it connects to self-confidence, self-efficacy and competency. The vital role that subject-matter knowledge plays in supporting a teacher's self-efficacy and, subsequently, her instructional practices, has been well documented in related literature (Helms, 1998), and has important implications for the design of teacher preparation, and specifically, the science methods course.

In the chapter that follows, Subramaniam, Asim, Young Lee and Rideaux, frame their study within the construct of *pedagogy*, and explore how they conceptualized and operationalized their pedagogies in the context of their elementary science methods courses. The theoretical contribution of this chapter, in my view, goes beyond the use of the fresh construct of "pedagogy of teacher education" and lies within the fact that it is drawn upon the perspective of the "other". In this case, the "other" are the researchers as teacher educators of color. As such, the researchers bring to the study, their experiences, perspectives, goals and challenges in attempting to teach science to a group of white preservice teachers. The findings of this study point to important and timely issues in science education associated with social justice, equity, and finding ways of addressing discrimination and inequality in the school system. To do so as teacher educators, we need to consider the characteristics of an era of globalization. Such characteristics include, for example, the diverse culture and the racial origins of both students and teachers. Global social changes, such as migration, call for a re-visioning of science education which involves a conceptualization of science that goes beyond the binary oppositions of "western" and "non-western" science, and which moves beyond borders and boundaries in science teacher preparation in order to embrace diversity.

Marble, Kamen, Naizer and Weinburgh introduce *lesson study*, a growing professional development approach, which has its roots in Japan and refers to a process in which teachers jointly plan, observe, analyze, and refine actual classroom lessons called "research lessons". Lesson study provides an interesting context and framework for self-studies given that they both rely heavily on *reflection*. Underlying this interesting contribution, however, exists, in my view, another significant contribution and possibly, a worthwhile future research direction: positioning self-studies within larger research programs in an effort to gain a more comprehensive and holistic understanding of a phenomenon. An interesting step forward, would be, for example, an exploration of how the findings of this self-study of teacher educators relate (or not) to the findings of the initial study carried out 6 years earlier. What would be even more interesting is if these two studies were happening concurrently and so the teacher educators/researchers would, at the same time, serve as researchers for their students' learning as well as their own.

In conclusion, the four chapters reviewed here constitute a beginning for rethinking self-study research, especially within the context of teacher education. The authors provide us with an array of fresh theoretical framings and a set of methodological approaches (e.g., use of metaphors, critical friends) to self-study research. Taken as a whole, the chapters provide us with empowering, concrete examples of self-studies whose findings offer important implications for teacher preparation and research. The purpose of this commentary chapter was to discuss the unique contribution of each chapter to self-study research, and its implications. Built on these implications, as discussed earlier, I recommend the following two possible future directions for self-study research: (a) *connecting self-studies with specific aspects of reform recommendations* (i.e., scientific practices, social justice); and, (b) *positioning self-studies in conjunction with larger research programs* (i.e., a self-study of teacher educators teaching methods courses as part of a larger research program investigating preservice teachers' ideas about science teaching). Lastly, it is crucial to point out how despite the differences in the purposes, methods and approaches used in these self-studies, a consensus exists about the value of self-study research to examining teacher educators' learning and development. What is more prominent, perhaps, in the studies reviewed is how complex the conceptualization of self-study research is, and the recognition that there exist various methodological challenges and limitations, much like other research paradigms. Nonetheless, one thing is certain: self-study research plays an evolving role in science teacher education research as it offers tools for multi-angled explorations of science teacher educators' learning and development.

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Part IV
Self-Studies and Secondary Science Methods Courses

Chapter 13
Experiences with Activities Developing Pre-service Science Teacher Data Literacy

G. Michael Bowen, Anthony Bartley, Leo MacDonald, and Ann Sherman

Introduction

When inquiry investigations were first promoted for school science in the mid-1990s many pre-service teacher education "science methods" courses were premised on the assumption that an undergraduate background in science was sufficient for (pre-service) teachers to implement those inquiry activities. Yet, those of us teaching those courses often encountered difficulties promoting inquiry science to both new and experienced teachers. In Canada, the Council of Ministers of Education released the "Pan Canadian" framework documents for science curriculum in 1997 (CMEC, 1997) and that document was influential in promoting inquiry science in many provincial curricula.

Notably, the inquiry science described in provincial curricular documents is "open" inquiry (in contrast with the "guided" inquiry prevalent in the United States), and in our experience, most of our academic colleagues teach about engaging public school students with this type of inquiry in their science "methods" courses. Despite the instruction in methods courses focusing on inquiry investigations for the last

G.M. Bowen (✉)
Faculty of Education, Mt. Saint Vincent University, Halifax, Canada
e-mail: gmbowen@yahoo.com

A. Bartley
Lakehead University, Thunder Bay, Canada
e-mail: Anthony.bartley@lakeheadu.ca

L. MacDonald
St. Francis Xavier University, Antigonish, Canada
e-mail: lxmacdon@stfx.ca

A. Sherman
University of New Brunswick, Fredericton, Canada
e-mail: shermana@unb.ca

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decade and a half, conversations amongst our peers at conferences suggests that Canadian public school students appear to experience few, if any, science inquiry investigations in most middle and high schools (with some notable exceptions, such as those described in Jones, Kaplanis, Melville, & Bartley, 2009) impacting the science literacy skills they develop.

Hodson (1998) has described science literacy as having three areas of focus:

(i) 'Science' – referring mainly to what can be thought of as the "products" of science, such as laws, theories and inventions.
(ii) 'About Science' – including learning ideas about the nature of science and the methods used for scientific inquiry.
(iii) To 'Do Science' – referring to the expertise, confidence and motivation of scientists – much of it which appears to be tacit knowledge – which is required to develop and communicate knowledge in science and technology.

Generally it is recognized that schools tend to emphasize instruction in 'Science' and provide little education about the second and third categories. However, inquiry investigations, promoted in provincial curriculum documents, do focus on the other two categories, and one might expect that teachers should be teaching in those domains. Despite this, research suggests that teachers have "difficulty creating classrooms that are inquiry-based" (Crawford, 2007, p. 613) and that they are actually infrequently implemented (see Brown & Melear, 2006; Salish I Final Report, 1997[1]) despite mandates to do so.

Research into pre-service teacher's own competency with science inquiry identifies numerous issues ranging from difficulties asking inquiry-possible questions to representing and drawing conclusions from data, as well as the atheoretical nature with which student teacher participants often approached their inquiry tasks (see overview by Bowen & Bencze, 2008). In general, pre-service teachers had difficulty with almost all of the features identified by the National Research Council (1996) as characterizing inquiry instruction, including identifying researchable questions, designing and conducting experiments, developing explanations, thinking critically about the relationship between evidence and explanations, and communicating scientific procedures and explanations. This is perhaps for the understandable reason that "Most teachers have not had opportunities to learn science through inquiry or to conduct scientific inquiries themselves" (NRC, 2000, p. 87). Teachers' undergraduate education experiences in university science programs often tend to be lecture and confirmatory-laboratory activity-oriented (Woolnough & Allsop, 1985), thereby influencing their perspectives on teaching (Beisenherz & Dantonio, 1991, p. 44).

This general lack of inquiry science experiences, affects the belief system each pre-service teacher has about their own science teaching (Bryan, 2003; Guillame, 1995) and influences their confidence (Cheng, 2002). Bianchini, Johnston, Oram, and Cavazos (2003) describe the challenges faced by first-year science teachers as

[1] Although we are reporting on American data here, our own experiences support the argument that the Canadian condition is little different.

they try to teach in contemporary ways reporting that overcoming pre-conceived notions inquiry-based science teaching was, perhaps, their greatest challenge. Our own pre-service teachers generally find it difficult to describe successful and engaging science experiences they had with science inquiry investigations as students in school at any level to us.

Overall, this suggests that "science methods" courses need to serve a role with addressing this issue. The idea that it might be beneficial for pre-service teachers to engage in inquiry activities as part of their preparation to become teachers is not a new one. Duschl (1983, p. 753) recommended that pre-service teachers engage in "independent semester long science investigations or replications of previous investigations" but there are few reports of this happening.

All together this suggests that as science teacher educators we should provide inquiry science experiences within the context of our own pedagogy, which may in turn help pre-service teachers develop an understanding of inquiry from both the perspective of a learner of science as well as from the perspective of a teacher of science. In this chapter we report on three different examples of activities drawn from our own instructional "science methods" courses where we have attempted to model what was expected of the pre-service teachers in science classrooms while at the same time providing them, as students themselves, with experiences engaging in an inquiry environment. Our approach in these example activities are consistent with an experiential need identified by John Loughran:

> …in teacher preparation there is an acknowledgment of the need for student-teachers to be familiar with new teaching procedures and strategies, yet attempts to do so often flounder because these teaching approaches are 'delivered' through lectures, handouts and reference material as opposed to creating situations through which students genuinely learn about the teaching by experiencing it as both a learner and a teacher. (Loughran, 2001, p. 4)

Korthagen, Loughran, and Russell (2006) identified the need for pre-service teachers to "genuinely engage in experiencing the various aspects of teaching in an environment where [engagement in experience] is the focus, rather than in an environment where successful teaching and 'controlling' students is the dominant concern" (p. 1029). Each of the examples we have described here sought to offer an environment where pre-service teachers could immerse themselves in various aspects of teaching in a supportive and reflective inquiry-based context. However, keeping in mind Cheng's (2002) comments on the role of previous science experiences, we wanted our pre-service teachers to engage with science experiences that were inquiry-based investigations, where they were able to ask questions and experiment (reasonably) freely with the aim that they would feel confident enough to enact inquiry-based science investigation lessons as a significant part of their own teaching.

The activities described in this chapter represent ones we developed to address issues with other inquiry activities we tried and encountered problems with (such as those described in Bowen & Bartley, 2007; Bowen & Bencze, 2008). As our awareness of the problems student teachers had with inquiry activities developed we revised our classroom activities with the intent to more effectively engage pre-service teachers. The activities we describe in this paper are generally focused on the development of pre-service teachers' "*data literacy*" (see Bowen & Bartley, 2013) because the idea of "data" underlies the practice of science (Latour, 1987). In addition, current curricular directions in the United States have an increased emphasis on data literacy (see NRC, 2011) and, thus, we see working with data as fundamental to the science inquiry process.

In each of the following science inquiry examples we describe what we were hoping to accomplish with each activity, how the pre-service teachers engaged in it, what they accomplished while participating in the activity, and what each of us as science "methods" instructors learned from the activities. Example I discusses student teachers engaging in an introduction to self-directed inquiry using Jello (Bartley). Example II examines the outcomes of pre-service teachers sampling and counting grass in an uneven area (Bowen). Example III describes a three-part activity where pre-service teachers were engaged in "science fair" activities first producing a project of their own, then judging student projects in a local science fair, and finally engaging in a critical discussion about an academic publication critically discussing science fairs (MacDonald). As part of the discussion of these examples we highlight how our preservice science teacher students engaged in these different investigation activities and insights that we gleaned from their participation.

Data Methodology

While attending a Canadian conference[2] we (the authors) discussed the different approaches we used in our methods courses and the subsequent student learning. We decided that a paper discussing some of these methods might be useful for other "methods" instructors and that our collective experiences might provide insights into issues arising in science "methods" courses. In our discussions we realized that we had each kept written records as our recent science methods classes had progressed. Not only did we have copies and records of our student's assignments, we also had notes and records we had recorded by hand for individual classes. These were on our teaching outlines, in teaching diaries, or in emails we had exchanged with various others (including amongst the authors, with our students, or with other instructors or administrators). We essentially realized that we had a data set we could examine to determine the effectiveness of our individual teaching practices *in relation to each other's successes or failures* – particularly from the perspective of

[2] The Canadian community of science education professors is small enough that we each know a large segment of our total community and there are reasonably strong social bonds between a great number of us. This leads to socializing at our main conference that is markedly different than in meetings of other organizations such as NARST. For instance, at our largest professional gathering (the annual conference of the Canadian Society for the Study of Education, our equivalent of AERA) the Science Education Research Group might have 30 faculty members (of the 90 or so active ones in Canada) attending and we spend a lot of time socializing with each other, including over a research group dinner that, including graduate students, can easily exceed 30 participants.

activities which were about trying to teach our students about independent inquiry investigations that our discussions had revealed we were each having difficulty being successful with in our individual settings. Consequently, we decided to go away and each write about an example teaching activity that our peers might find useful in the conduct and planning of their own "science methods" courses which we then shared with each other. In our collective reading of these cases we gained insights into our own practices and those of others, but we also gained insights into broader issues of science teacher preparation through the juxtaposition of findings across the different cases. Subsequently, from our reading of the experiences of our peers in teaching inquiry science methods through experiential approaches, we decided to construct a conference proposal of these experiences[3] which we then presented in the next year of our conference.

Each instructor used the following resources to write about their curricular examples:

– the description (written and verbal) provided to students about the activity
– notes of comments recorded during classes with students
– notes of comments and student engagement recorded following the classes with students
– student work collected from the activity
– notes of comments following the return of graded student work
– notes drawn from class records and course outlines

The instructor of each example elaborated on the example providing the context of its use, the student engagement, and implications drawn from the student engagement.[4] As experienced instructors (each with 10+ years instructing "science methods") we each described scenarios with the intention both of improving our own practice as well as providing critical descriptions of classroom practice that may

[3] The four authors are reasonably senior science educators in Canada and are often amongst the most senior people (if not the most senior people) represented at the conference we previously described. As such, and given the large number of younger faculty hired recently in Canada, we felt some sense of obligation to our community to discuss the issues we were encountering in teaching inquiry science teaching approaches to our methods students for if we were having problems then junior faculty would be more likely to discuss their difficulties with others.

[4] We both note and acknowledge that we are not presenting "research" in the traditional sense but rather are describing, in the spirit of self-study and reflection (see Bullock & Russell, 2012), a form of self-study done by professionals who are working towards improving their own practices by critically examining and reflecting on those practices to gain insights into how to improve them while hoping that these efforts, conducted as rigorously as possible in our varied settings, may inform the practices of others in our field. As noted earlier, our data collection was not "intentional" while the class was progressing but reflected the notational practices we each typically engage in while teaching. The self-study from which this chapter emerged was a post-hoc endeavor following a realization of the difficulty we had teaching inquiry approaches in science to future high school teachers. We would argue that our post-hoc approach has advantages in that the classes as taught represent our "normal" practices uninfluenced by any supposition that our classes were "under study" of any sort, but it offers disadvantages in that data and information that might normally be collected in a self-study of a teaching environment are lacking.

engender discussions amongst our peers so that our collective practices may improve.

Interpretations of data records from the individual studies were strengthened through collaborations within our group. Bowen and Bartley had attended each of the activities done by the other in previous offerings of their courses and used that experience to examine the various records used by each of them to write their individual case studies. MacDonald's data was collected based on his class, but his interpretation of that data were checked by Sherman who had previously worked on that very sort of activity with previous students at his institution.

After we produced these three examples, we then collectively used them as a data source which we analyzed using an interaction analysis approach (Jordan & Henderson, 1995) drawing on grounded theory (Strauss & Corbin, 1990) as we conducted our interpretations of each other's work as we constructed insights gained from looking *across* the case studies. Collectively, we found that the examples we had individually provided gave us insights into issues that are found throughout science education and we write about these in the overall conclusions. Thus, inasmuch as our individual examples represent the data/information we individually collected on the activities in our classes at our different institutions, each example also then acted as a data source for our co-authors in drawing our overall final insights and conclusions. At the very end of the chapter we will discuss the influences this has had on the classes we now teach and what new activities some of us are trying either in addition to or to replace the issues we concluded were present more broadly than in just our own individual classes.

Example I: An Introduction to Investigations (Bartley)

Background

My approach to this investigation activity is informed by the work of Tamir (1991) who provides two illuminating tables (depicted below). In the table below Tamir describes the roles of scientists and technicians, and teachers and students by posing the question, "Who does what in the science laboratory?" (p. 16)

Activity	Scientist's lab	School lab
Identifying problem for investigation	Scientist	Textbook or teacher
Formulating hypotheses	Scientist	Textbook or teacher
Designing procedures and experiments	Scientist	Textbook or teacher
Collecting data	Technician	Student
Drawing conclusions	Scientist	Student or teacher

Tamir argues that student work will often correspond to that of a technician, representing a lower status and level of engagement than that of the scientist advocated for in the documents guiding science teaching and learning, e.g. *National*

Science Education Standards (National Research Council, 1996); *Science for All Americans* (AAAS, 1990) and in various provincial science education documents in Canada.

Tamir (1991) also categorized inquiry investigations according to the degree of openness of the problem choice, the experimental design and the choice of conclusions.

Levels of Inquiry in the Science Laboratory

Level of inquiry	Problems	Procedures	Conclusions
Level 0	Given	Given	Given
Level 1	Given	Given	Open
Level 2	Given	Open	Open
Level 3	Open	Open	Open

These levels represent different degrees of openness from Level 1 where problem and procedures are given and students only collect the data to Level 3 where students do everything themselves. Tamir describes situations where most teachers typically operate in levels 0 and 1, while levels 2 or 3 would offer students more authentic learning experiences; these higher levels would correspond to "open inquiry" types of investigation activities.

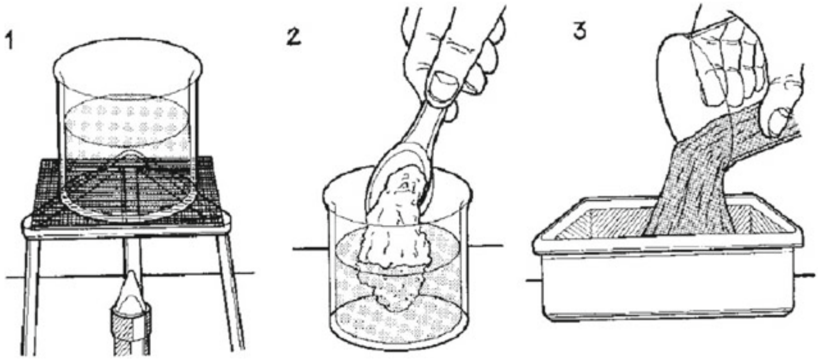
Context

The secondary physics and chemistry methods courses at Lakehead University (in Ontario) are taught in a single group. Over the last two decades instructional time for this course has varied from 54 to 81 h and is currently 72 h (20 % of the total program instructional time). Compared to many jurisdictions students in science methods classes at Lakehead often have strong science backgrounds (which might be considered "well-qualified") ranging from being in the final year of an honours science degree program to some with doctoral/post-doctoral experience. However, few students reported prior experiences with designing and performing investigations. In reference to Tamir's levels of science inquiry, most students had experience with Level 1 science investigations, some had experience with Level 2 investigations, while a few had some Level 3 investigation experiences (thesis work at honours (bachelors), masters or doctoral level). Apparently little has changed since Woolnough and Allsop (1985) wrote, "most science teachers have themselves been brought up on a diet of content dominated cookery book type practical work" (p. 80). My challenge was to enable pre-service teachers to experience level 2 or 3 investigations, and thereby feel able to engage their own future students in such activities (which most provincial curriculum documents call for at middle and high-school levels).

Gelatin is a powder. When mixed with water in the correct proportions if forms a solid jelly.

Instructions for mixing gelatin

1. Heat a measured amount of water but do not let the water boil. 2. The stir a weighed amount of gelatin. Stir continuously until all the gelatin has dissolved. 3. Pour the liquid into a container of your choice and leave the liquid to set. The liquid can set quite hard or soft depending how much gelatin is added to the water.



Problem

What is the smallest amount of gelatin needed to set a bath half full of water?
You must solve this problem by doing experiments with no more than three sachets of gelatin powder.
Here are a number of things to consider:
You need to make a tester to see if the mixture has set.
The bath cannot be put in the fridge.
Assume the bath is half full of water at room temperature.
How much water does the bath contain?

Fig. 13.1 Gelatin and the bath activity sheet (Ainley, Brown, Butler, Carrington, & Ellis, 1988)

The Activity

For this chapter I present a single activity (out of several I conduct like this over the school year). The first 20 or so minutes of the first class is spent in an ice-breaking activity in which participants introduce themselves to adjacent classmates and work together to melt ice cubes as rapidly as possible. This leads to a discussion of the science used for the ice cube melting activity and various other issues.

The follow-up activity – "Gelatin and the Bath" (See Fig. 13.1) – is usually presented in the second or third class of the course. Pre-service teachers are provided with three packets of Jello™ and are advised that they have 80 min this class, 45 min the next class, and 30 min the following class, 1 week later, to complete the activity.

Students are allowed any equipment available in the lab, and are provided with a broad range of balances (milligram to 2 kg ranges). In addition they are asked to consider how they would approach teaching this activity with 13-year old students, as this was a planned component of the activity. The activity involves trying to find the minimum amount of Jello that will "set" a tub half full of water and the "answer" will be in the form of packs or mass of Jello (which, therefore, is the variable of interest). During the activity the pre-service teachers initially need to establish criteria about what it means for the Jello to be "set". Because there are different definitions of "set", it is a variable (a covariate) that has a considerable effect upon the result, yet it is of no direct interest in their final claims of the amount of Jello needed. In essence, this is an activity related to the scientific practice of extrapolation of data from a known (how much Jello is needed in small amounts of water) to an unknown (how much Jello is needed in half a bathtub full of water).

Data and Discussion

Much of the activity sheet, and my introduction to the investigation, ensured that pre-service teachers were well aware that this was <u>not</u> a confirmatory experiment. However, some groups flirted briefly with solely analytical perspectives by arguing that the scaling model might/could not apply here.

If we only have three packs of Jello we cannot make the full size bath tub.

What if the Jello has to be close to a surface to set?

After about 15 min they perceived the problem as being sufficiently defined without any tensions concerning the size of the bathtub. However, their recognition that the problem did indeed have some approachable solution led them to move to the experiment.

Find out how big the bath tub is, say x Litres, then x/2 is the volume that we are working with.

Producing a model bathtub and scaling up led to some working with 100 mL beakers and 50 mL of water while others used 250 mL or 400 mL beakers with 200 mL of water.

The bigger sample is much better. We can get a better model of the bathtub than if we use small samples.

The small samples enable us to do many experiments. We can be more certain about our results with many experiments.

For some the definition of "set" was uncomplicated, as was its measurement.

*Our definition of **set** is when the Jello will support a coin such as a penny for at least a minute.*

*The Jello is **set** when we can turn the beaker upside down and the Jello does not fall out.*

For others, there was a necessity to seek authority for the definition of "set". The manufacturers of Jello™ provide a toll-free questions/concerns/help phone line. Each year, at least one group member contacts the company to elicit information regarding the company's definition of "**set**". Some years this has been fruitful, other years of little value other than comic relief as the person at the call centre has not taken the request for information about a definition of "set" as a serious question. One of the more valuable responses was:

> *The food technician on the phone told me that they carefully remove the Jello from the container and place it on a plate or similar flat surface. Then they cut the Jello with a sharp knife. If the cut line is straight and the knife blade is not wet, then the Jello is* ***set****.*

On being asked if it would be possible to compare results from one group to another, most groups concluded that such a question would require its own sub-set of experiments, and that had I needed such a comparison, it should have been built into the question. The provision of a solution concentration (g of Jello/litre of water) was deemed an appropriate starting point for later discussions.

I have 17 years of working with this activity and 1 year there was the unique result where none of the five groups were able to produce an answer to the question. Either all of the samples had set, or none of the samples had set. As an instructor it was a teachable moment: university science graduates had failed to complete an experiment deemed appropriate for middle school students and they wanted to explain what had happened. How was the 'teachable moment' addressed during class? Describe.

My experiences in working with around 110 groups on this activity have allowed me to enjoy many rich discussions about why this is not a trivial task. The stronger teams will usually set up five or six trials after the first session (varying mass of Jello per unit volume of water) and have some "set" and some not "set". Then for a second set of trials, the pre-service teachers will use samples with a concentration between the most dilute "set" and the most concentrated not "set", using up the remaining Jello™ for these trials.

Typical results come in around 80 packets of Jello™ (mass of each packet = 80 g) for a volume of about 150 L (≈40 US gallons). Follow-up conversations discuss "accuracy", "precision", and why both would be problematic given the latitude in the definitions of "set." At my prompting the discussion also involves whether providing a range of concentrations would be appropriate or feasible.

This activity is an activity particularly useful introduction to self-directed inquiry. The task demands careful analysis, much deliberation and calculation and a sense of humour. My experience is that students remember this activity and can discuss it well into their teaching careers.

One year my class was able to spend some time with two seventh grade classes to work through the activity. Having completed the activity, my pre-service teachers thought they had a good handle upon what might be the issues with real students in a school setting. The ensuing hour could be best described as a wonderful learning experience as they realized that not only was their own specialized science language beyond this audience, but that teaching students to think about their own ideas required patience and gentle tenacity. Timing was also an issue as the allocated 65 min passed very quickly. Questions of "fair test", dilution and "set" reappeared consistently with mixed levels of resolution. At the end of the class the school students thanked the pre-service teachers and left. We then held a debriefing sessions where there was a sense of amazement at the kinds of questions school students would come up with given an audience. For example: “What is the influence of shaking the packet before dilution?” or “How would you find the coolest location in the classroom for setting?” and “Could I define ‘set’ as strong enough for me to stand upon without splatting?” The second debriefing came after the teacher had spoken with the grade 7 classes about their experiences. In that debriefing the teacher made the primary suggestion that the pre-service teachers be less directing in their suggestions and suggested that they think more about the questions used to probe student comprehension. Given a week to reflect upon this we returned to support another class in the activity. While the ability and the experiences of the class were similar to the first group, the revised approach of the pre-service teachers led to a very different and more positive learning experience for all in the room.

Example II: Counting Grass (Bowen)

At the beginning of a fall semester middle school/secondary science methods course, in which most students have a university background in biology (as opposed to chemistry or physics) I have my post-baccalaureate B.Ed. students participate in a short inquiry investigation. I have them go outside to a bounded area of grass and address the following science “problem” which is framed as “authentic” for them: “On the designated patch of grass outside, with your partners (in teams of two or three), estimate the total number of blades/amount of grass in the area.” The students are also told that in the classroom they are to then “Provide a written step-by-step illustration of how your group calculated the total amount of grass in the patch.” with the goal of providing a “compelling and convincing” argument about how much grass is found in the area. Finally, after the data for each group has been collected, it is combined with that of previous years and students are asked, “Using the cumulative data set, choose and draw a graph that shows the most useful/interesting summary of the data that is possible. When you have completed your graph, write a paragraph to describe your interpretation of the data that you depicted in your graph.”

For this activity I have chosen a piece of land (approx. 11 m by 4 m) almost completely bounded by concrete curbing (with a small 2 m section that has rocks intruding on it from an adjacent area). There is a small worn “path” that crosses it diagonally, a stump, two trees, a hydro pole, and a small dirt patch. In addition, the grass is obviously “patchy” with higher densities in some areas and lower densities (mixed with other small plants) in others. Three sides are essentially straight, and one has a gentle arc. As a middle-school teacher I have successfully used a similar activity with grade 8 students (Note: their site had fewer complexities; no gentle arc, concrete around the complete area, and less “patchiness”).

For the pre-service teachers this is framed as an ‘authentic’ type of activity that a field scientist would do. They are provided examples of scientists such as ecologists monitoring long-term changes correlated with other factors (such as earthworm density, vertebrate herbivore density, or the addition of nutrients to the soil). The 'authenticity' is also embedded in students recognizing that (a) there is a finite amount of grass in the area, and (b) that neither I, nor anyone else, actually know what that finite amount of grass is. I provide the students with clipboards, blank paper, and measuring instruments (field tapes and metre sticks). Notably, all of the measuring instruments have both metric and imperial scales on them. [Canada adopted metric in 1974 and it is all that has been used in science and other classrooms since that time.]

My purposes in having my secondary science methods students engage in this activity are multi-fold. Firstly, a critique of another diagnostic/teaching exercise that I have used in the past (the Lost Field Notebook (LFN) exercise, see Roth, McGinn, & Bowen, 1998) is that the data is decontextualized for the students as it lies outside of experiences they have had. In the LFN activity students are provided a map of an "ecozone" (no scale is provided) with unevenly shaped areas that break up the ecozone. Within each area is a pair of numbers, one for bramble density, the other for light intensity. Students are asked to analyze and make a decision about the relationship between light intensity and bramble density. For individuals with a BSc in science responses are often quite poor, although science professors have indicated that they would expect a high level of response from anyone with a BSc degree (unpublished data). In order to address this data analysis issue (and address critiques that the decontextualized nature of the LFN activity contributed to the poor response), I developed the grass-counting activity as one that the type of data that field scientists would collect (i.e., it was "authentic") and was do-able in a 3-h class. The grass-counting exercise provides students a data set to work with that derives from their own first-hand experience because they themselves have collected it. Thus, it provides me a diagnostic on their overall data collection and representation skills (how they define variables, how attentive they are to detail, what units they use, what sampling regimes they use, their use of significant figures, etc.). I further use this activity as a starting point to discuss the various forms of inquiry (as depicted in Tamir's table), how one would evaluate investigation activities (particularly open-ended ones), what makes an activity "science", characteristics of science (i.e., the Nature of Science), student motivation (when they have input into the design of activities), and so forth. This is all described to the students in advance so that they understand that the activity is the foundation for later activities and discussions in their "methods" course.

Student Engagement: Reports

For this example I will discuss a summary of the methods (collection and analysis) used by 19 groups of students (41 students in total). Student participation outside was quite focused and generally enthusiastic. All students seemed engaged and interested, and they were encouraged to talk with each other if they had difficulty deciding how to do something. In general, this was encouraged to raise the standard

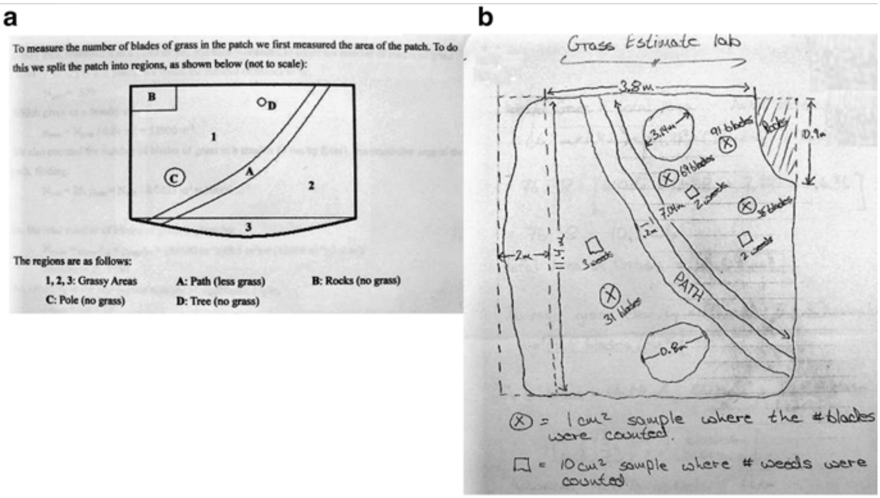


Fig. 13.2 Examples of sampling strategy maps. (**a**) Simple "subsection strategy" sampling strategy map showing three sampling areas in zones delineated by physical features. (**b**) Detailed "whole area" sampling strategy map showing "scale" and four sampling areas

of the work and to set the tone that would be encouraged throughout this and following semesters for engaging in class activities.

Of the 19 project reports, two general strategies were used for sampling. One strategy, the "whole area" strategy (Fig. 13.2) involved treating the entire area as "one sector" and randomly sampling within that sector, then extrapolating to the surface area of the entire sector. Eleven groups used this approach. To develop accurate estimates one would suspect a reasonably high number of samples would be needed (given that there was quite noticeable patchiness of grass in some places, with a high density of other small non-grass plants in some areas). Of these 11 groups, the arithmetic mean was 3.45 samples/total area (with a median of 3, and a range of 1–10 samples) with four groups collecting 1 or 2 samples and three groups doing 4 or more. These groups also "eyeballed" decisions around how to compensate for weeds, or grass patchiness. For instance "we decided to subtract 10 square feet from area to compensate for uneven grass growth", "Assuming ~6 % weeds", and "We estimated the number of weeds to be 1/3 of the area." typified statements about this.

The other strategy, the "subsection strategy", involved dividing the total area into subsections, and then making estimates within each of those areas. Eight groups used this strategy with two different approaches being utilized. In the first approach groups divided the area into zones on the basis of physical features (such as the path) or for geometric measuring/calculating purposes (for example, creating rectangles) (See Fig. 13.2a for an example). The problems with using this approach could be mitigated by higher sampling (which one group did; measuring 1 cm^2 of grass five times in <u>each</u> zone), but most groups only conducted one or two measures of grass density. The other approach to using a "subsection strategy" involved dividing the area into zones based on visible differences in grass density with sampling in each area – when using this approach sampling ranged from 1 to 11 samples per zone (note that the one sample/zone project sampled large areas, ~100 cm^2). Notably, the projects that divided the areas into zones on the basis of visible differences in grass density *also* sampled and counted larger areas of grass (in all cases but a few 25 cm^2 or higher per sample), whereas in the projects with a single zone 8 groups sampled 8 cm^2 or less.

When students were instructed to conduct their measurements in metric all but one group did so, however when that instruction was not given, five of eight groups did not use metric measuring. This was surprising because, according to curriculum guides and their own commentary, all of their instruction in schools (both public school and university) was done using the metric system and, notably, all commercial product sizes and signs in stores in Canada are also in metric and have been for 30+ years. The "default" practice of so many students being imperial measurement was thus quite surprising. However, even when students did use metric (13 groups did), there were quite a number of calculation errors when extrapolating from the sample size (such as # of blades of grass in 100 cm^2) to the number of blades of grass in a square metre. Four groups made errors when doing this calculation, usually neglecting to "square" the area in the extrapolation (such as multiplying the number of blades of grass by 10 instead of 100 when going from a 10×10 cm sample to 1 m^2).

Previous to the activity the role of inscriptions as being central in science to constructing compelling and convincing arguments was discussed. Despite the previous in-class discussion of the importance of visual representations in science, two groups did not provide a drawing to accompany their calculations and description. Of the 17 groups who did, 10 were essentially simple sketches of varying detail. Fifteen of the 17 included scales/measurements, only 9 labelled or included features on the graph (such as trees, rocky area, etc.), and only 4 included any indication of where samples of grass density were taken.

Student Engagement: Graphing the Year-to-Year Data

Twenty students were instructed: "Using the cumulative data set, draw a graph that shows the most useful/interesting summary of the data that is possible and provide an interpretation." Students could produce more than one graph if they chose. In that year, there were a total of 22 "grass estimates" (11 each from this and the previous year), including from their own data collection and estimates (which they watched entered in the table as they gave the numbers to me). As an instructor, this was quite instructive as the issues that had been present in the diagnostic Lost Field Notebook exercise were again played out but went further, indicating even more serious issues. Students appeared to have no conceptual framework guiding their choice of graphs. Overall students produced ten bar charts, one pie chart, one stem-and-leaf graph, and nine line graphs/scatterplots. The bar charts were often a compilation of the 2 years of data with ordered (but uneven) categories (see Fig. 13.3a). There was no bar chart showing the average # of blades of grass for each of the 2 years (which is

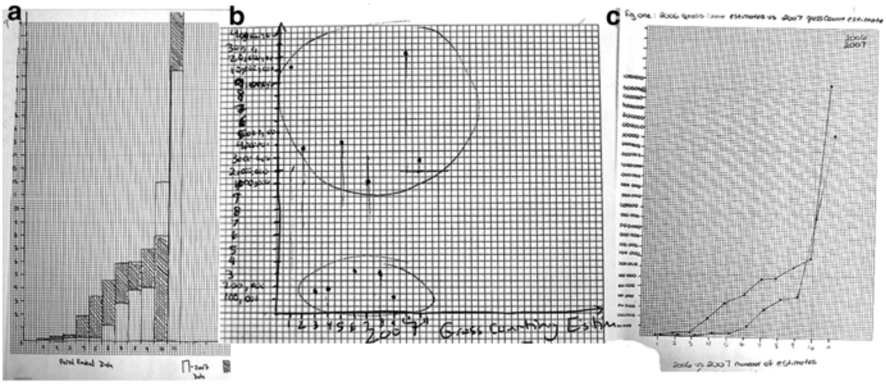


Fig. 13.3 Various graphical representations to show grass counts in two different years – (**a**, **b** and **c**) left-to-right respectively – note that each shows the x-axis having a count of "11" (which actually represents the total number of student groups in each year)

what I thought students would produce, and which would be the most sensible comparison from the data). The pie chart was a compilation of data from the 2 years (showing 22 "slices"). The line graphs/scatterplots were either (a) the 11 data categories ordered from smallest to largest and then plotted with a joining line (Fig. 13.3c), or (b) as with (a) but with "trend lines" drawn, or (c) entered in the order shown in the data table, sometimes broken into the 2 years, with the x-axis being the row # in the data table and the y-axis being the # of blades of grass (see Fig. 13.3b) and in several cases, a trend-line was drawn. In the majority of cases there were issues with the interpretive statement the students made about the graph. In general, the graphs the students produced indicated some serious issues in choice of graph (for example, a scatterplot is not possible, nor is there any "science" reason for an "ordered" line chart to be drawn particularly in order to compare the data across the 2 years, or to draw a "trend line").

Conclusions

An ongoing concern of mine has been data literacy issues in my secondary "science methods" students. Engaging in this short inquiry investigation with them, an activity that any science professor I have discussed the activity with believes should be well within the scope of someone with even a minor in science, highlights for me that we need to engage pre-service teachers in a "science methods" course (not a "science teaching methods" course) as part of their preparation to be a science teacher to help them develop their skills in the applied practices of engaging in science investigations. My student's difficulty with this activity, in both the sampling and the graphing, suggests to me that it would be difficult for most of these pre-service teachers to effectively engage their own students in any form of independent inquiry investigation activity. Anecdotally, over the years I have found the students who were most comfortable with (and most skilled at) data/investigation activities such as this one are also the ones who seemed more inclined to have their own students engage in science investigations when they became teachers…this highlights the importance of developing these data/investigation skills in their BEd program. If we really intend to have middle and high school students engage in activities that involve investigations where there is a variety of possible data collection and representation methods at play, then the data literacy of their teachers needs to be developed. Although I am satisfied with the role this "grass count" activity plays in other aspects of the "methods" course (such as discussions of inquiry, evaluation of inquiry, and the role that student control can have on motivation), even the other data-literacy oriented activities I conduct throughout the year to address data literacy issues may well be insufficient to address the depth of problems that I feel that this activity reveals. As a result of these findings (and others) I have become an advocate for a course to be offered in BEd programs that focuses on inquiry and data literacy through hands-on investigations (such as the elective documented by Melear, Goodlaxson, Warne, & Hickok, 2000).

Example III: The "Science Fair" Project (MacDonald)

This teaching example reports on an activity carried out at a teacher education institution in Nova Scotia with secondary level pre-service teachers. The example seeks to present aspects of the pre-service teachers' perspectives on science inquiry as revealed by their engagement in a three-part assignment – intended to both develop their understanding of inquiry reflecting the higher levels of Tamir's scale (1991) and reveal the way they engage in scientific inquiry – that was part of a "science methods" course. The three parts were: (1) pre-service teachers were asked to conduct their own inquiry investigation and present their findings at a university course-based science fair; (2) pre-service teachers were asked to participate as judges at a school-based science fair and describe in writing the projects they felt were the best exemplars of science inquiry; and (3) pre-service teachers were asked to read Bencze and Bowen (2009)[5] and make connections between this paper and the science fair in which they acted as a judge. The following is a synopsis of the assignment as provided to students:

[5] Bencze and Bowen (2009) concluded that for students, apart from positive outcomes regarding science literacy that are developed in science fair projects, there may be some significant issues about the fair that warrant critical review. For instance, it is apparent that there are issues of access, image, and recruitment associated with the fair such that participation in the fair appears to favour students from advantaged, resource-rich backgrounds and, in particular, offers particular advantages to corporate sponsors highlighting their connection to science. The latter frames science as an activity geared primarily to solving economic and monetary/business problems and not one which is more holistically about knowledge generation and developing a deeper understanding of our world.

This Assignment Has Three Parts as Follows:
(*1*) *You will carry out an extended open-ended science investigation. You may work together with a partner if you wish. You should choose a question to investigate and gather data over time* (*8 weeks are available*). *You should strive to formulate an original question about the everyday world around you that you can explore using easily accessible materials and equipment* (*most material and equipment requests can be accommodated using our existing science resources*). *You will present the findings of your investigation in a poster board* (*available in our resource centre*) *presentation as a part of an in-class science fair held near the end of this course. You should keep a journal that records your activities in this project over time. Your project will be evaluated using the Canada Wide Science Fair Evaluation Rubric* (Note: CWSF judging has changed since this activity).

(*2*) *In the second part of this assignment you will participate in a local science fair as a judge. The local Junior School will hold a science fair and everyone in our Science Education course has been invited to participate as judges. At the science fair you will be given a judging assignment that will involve you in interacting with several young people in short* (i.e. *10–15 min*) *discussions about their projects and using the school science fair rubric* (i.e. *Canada Wide Science Fair Evaluation Rubric*) *to evaluate projects. After the completion of the science fair*, *you should write a short essay* (e.g. *1–2 pages*) *in which you describe key aspects of the projects that impressed you as being good examples of science inquiry*.

(*3*) *After the completion of the science fair*, *you are asked to write a reflective essay in which you use specific examples from the science fair to respond to the arguments of* Bencze and Bowen (2009). *It will be important to make specific reference to cases from the science fair where you act as a judge as you respond to this paper. Try to respond to the following questions*: *What did/did not surprise you in the science fair*? *What would you change about the science fair*, *if you could change anything*? *Do you agree with the perspective toward science fairs presented by Bencze and Bowen?*

There were 50 pre-service teachers involved in this activity and all were students in a 2-year post–baccalaureate teacher preparation program. All of the participants had successfully completed a BSc degree at a Canadian university that involved them completing at least 30 credits of undergraduate university science coursework including lab-based science courses. Approximately half of the participants reported they had participated at least once in a middle-school and/or high-school based science fair as a student.

Table 13.1 Example "Science Fair Project" questions

Project question	Project type	Level
Does the color of food affect the way people taste it?	Experiment	1
What Tea Cozy material is the best insulator?	Experiment	2
What kinds of bacteria can we find on our hands?	Experiment	2
What kind of toothpaste works best?	Study	1
What kind of yeast works best?	Experiment	2
What kinds of bioluminescent sea creatures exist?	Study	1
How does the amount of borax in a slime solution affect its' viscosity?	Experiment	1
How does DNA extraction and gel electrophoresis work?	Study	2
What is the best environment for mealworms to thrive?	Experiment	1
How does chromatography work?	Study	1
What detergent works best?	Experiment	1
How does the weight of an object affect its tendency to slide?	Experiment	2
What is the staining impact of various materials on teeth?	Study	1
What are the uses of M'kmaq herbal medicines?	Study	1
How strong are eggshell supports?	Study	1

Inquiry Perspectives Revealed by Pre-service Teachers' Science Fair Investigations

The science fair projects carried out by the pre-service teachers were disappointing to me, as their professor, in the sense that they were not high level inquiry projects, based on the Canada Wide Science Fair Evaluation Rubric. As the professor, I rated all of the projects presented by the pre-service teachers in the science education course. Most of the projects were low level (i.e. level 1 or 2) on Tamir's scale whether they were studies or experiments. In short, none of the pre-service teachers in the class carried out a high level (i.e. level 3 or 4) inquiry project even though those had been presented to, discussed and modeled with the students previous to the assignment. A typical list of the questions investigated is presented below (Table 13.1).

This list of questions reveals that none of the pre-service teachers chose to investigate an original question (i.e. one that they did not know the answer to in advance). The pre-service teachers in this example seemed to choose one of two ways to engage in their own science fair inquiry activity. One category of students used the opportunity to recreate science fair projects they had found reported on the internet. This group rationalized their decision by saying that it was a valuable way for them to better understand a project they might encounter during their potential engagements with young people's school based science fair projects. The second category of students used the opportunity to refine an undergraduate university-based lab to "give it science fair qualities". This group rationalized their decision as being an opportunity to develop a resource that might be potentially useful in their future teaching. Revealed both through verbal comments and various written submissions, essentially none of the pre-service teachers felt that high level inquiry based thinking was an important or necessary component of their teacher education program.

The pre-service teachers who had some experience in university-based science inquiry (e.g. as research assistants) also reported that they did not consider high-level science inquiry to be especially important at this point in their development as teachers. Many of the pre-service teachers felt the amount of time and energy they would need to invest in a high-level inquiry project would be too much for a three credit science methods course as part of their B.Ed. experience. Pre-service teachers who described this belief tended to choose science fair projects based on university-based science labs they had completed as a part of their undergraduate degree (sometimes with small modifications).

Conversations held with the pre-service teachers after the completion of their science fair projects revealed that most of them did not consider themselves to have ever engaged in authentic science inquiry, either in school-based or university-based science experiences, so perhaps it should not be surprising that these pre-service teachers were not able to produce high level inquiry projects despite their science degrees.

Inquiry Perspectives Revealed by Pre-service Teachers' Experiences as Science Fair Judges

The pre-service teachers all reported they enjoyed their experiences as judges in the school-based science fair. The pre-service teachers visited three separate school science fairs displaying projects completed by students in grades 7–10. A portion of a typical response by pre-service teachers is shown as follows:

> *…To finish off this reflection I want to touch on a couple of the questions presented to us. I was surprised that no one did a presentation on something that I had never heard of before. Each topic was something that I knew what the result was going to be before I started. It did not surprise me on how well the students did on the presentations. Being involved in the school previously I had known the high expectations the teachers have for the students. If it was possible to change one thing about science fair I would want all the students to do something original. I was not able to see any innovations and I think this would be a perfect section for this part. However, I do not think that innovations and original ideas are the most important part of a science fair. Rather, I think that motivating students to want to do more science is the most important thing. The students that I talked to were all very excited to be participating in the science fair.*

This response is "typical" in that the pre-service teachers noticed that student projects were typically not original, they did not consider it an important consideration in the quality of the student projects. This suggests that their orientation was towards having students engage in more traditional "confirmatory" investigations rather than having them conduct more original investigations.

After reading the article by Bencze and Bowen (2009) and being asked to comment on it, virtually all of the pre-service teachers disagreed with the perspective presented in this article. Overall, they tended to dismiss the issues identified in the paper and chose to focus on what they perceived as significant benefits for school students during science fair engagements. For instance, one pre-service teacher wrote in his reflection:

> *The last thing that I want to talk about is the stressful and frustrating part mentioned by Benzce & Bowen (2009). Being in the classroom before this science fair was carried out, I was able to see that the students were given months for figuring out their topics and ideas and they had many deadlines along the way so they did not complete the activity in one night. The science fair provided an excellent opportunity for students to work in a hands-on way and display their multiple intelligences. Overall, I think that science fairs are great tools that allow the students to have some fun with science.*

All of the pre-service teachers highlighted the "fun" aspect of science fairs. I now suspect pre-service teachers are not fully ready to think about science fairs in a critical way. This suggests they need more experiences interacting with young people involved in science fair activities in order to develop a more critical eye about student participation in science fairs. My own experience as a science educator in Nova Scotia is that many teachers in schools tend to remove themselves from the science fair process (either as judges or as support people) because they do not feel qualified to support inquiry of any kind. Most school-based science fairs and regional science fairs select judges who are not active teachers. I think this suggests that school teachers also need to develop a deeper understanding of inquiry and need to become more involved in the nature of their students' thinking as the students engage in science fair activities.

Discussion and Implications from the "Science Fair" Activity

It seems that my pre-service teachers considered motivational features of science fairs to be the most important learning component of this kind of learning experience. All of the pre-service teachers engaged only in relatively low-level inquiry projects when asked to conduct their own investigations. In fact, all of these teachers reported that they did not consider their own performance as science investigators to be tightly connected to their future performance as teachers. In short, they seemed to be saying that one does not need to be able to *do* inquiry in order to *teach* inquiry effectively.

In their reports of what they noticed in their science fair judging experience, pre-service teachers tended to focus their attention on project features such as length of time, STSE connections, independence, and quality of the written and oral reports made by young people. While these features are useful to know about, none of these features focus on the level of inquiry displayed.

Finally, after reading Bencze and Bowen (2009), and reflecting on this piece of literature in the context of their school based science fair experiences, none of the students considered the issues described in this paper to be relevant. The pre-service teachers all tended to emphasize the "fun" and "hands-on" dimensions of science fair experiences for young people as being most important and tended to ignore more complex issues of privilege, power, and money that had been identified in the article.

I think this teaching example suggests that we need to rethink the way that a science fair experience for preservice teachers does or doesn't promote inquiry based learning. A science fair tends to be an experience that involves individuals in an almost completely independent activity, unlike much of the practice of science. While the promotion of inquiry based learning is a reasonable goal, it seems that more scaffolding, perhaps through guided-inquiry activities, is needed to help build a more complex and nuanced understanding of inquiry investigations, both with young people and with pre-service teachers, before being asked to engage in independent inquiry investigation activities.

The way the pre-service teachers involved perceived the importance of inquiry thinking as a part of their teacher development experiences remains a challenge. How can these pre-service teachers be encouraged to consider their own inquiries as important to their teaching? Perhaps rethinking the focus of the inquiry may be a useful way to move forward on this question. Rather than asking pre-service teachers to conduct original inquiries on science themes, perhaps teacher educators should ask them to conduct inquiries on topics they consider to be more relevant to their development as teachers. One way this might be addressed is to require teachers to conduct action research studies into their own practice during the field experience components of their teacher education program. Of course, this would require that pre-service teachers be introduced and educated in action research methodologies, a significant departure from the typical curriculum of many teacher education institutions in Canada.

Insights from the Cross-Case Examination

All of the examples reported pre-service teachers engaging (reasonably) enthusiastically in the various types of inquiry activities they were engaged in. The different investigation activities can be thought of as laying along a trajectory of complexity running from Bartley's example where students were expected to extrapolate, in some fashion, from known data to an unknown situation. Farther along that trajectory, in Bowen's example the students were provided a research question and were expected to develop a methodology, collect data and draw conclusions. Finally, at the terminus of that trajectory, MacDonald's students engaged in activities most resembling "authentic" science in that they were expected to engage in an open-inquiry activity, evaluate other science investigations, and then reflect on the benefits of those previous activities. From this we can see that the three different activities map onto Tamir's "Levels of Inquiry" scale (Tamir, 1991; described in Bartley's section) to facilitate a discussion about where "breakdowns" in student performance are found.

All three activities are ones which science faculty (i.e., professors of science) would expect graduates of their program to engage with successfully, in the case of MacDonald's activity at a high level on Tamir's (1991) scale (unpublished data). The example described by Bartley that examined the very beginning of data literacy, framing variables, deciding on criteria, and extrapolation from small to large samples, reported both considerable student enthusiasm and engagement, as well as satisfaction on the part of the instructor with the progress made with this as an introductory activity to introduce these concepts to his pre-service students. In Bartley's example, different approaches to solving the stipulated problem were acceptable, use of outside resources allowed, and collaboration and discussion across groups occurred – thus apart from other NOS perspectives (Lederman, 1992), the *social* nature of science communities were also conveyed (Latour, 1987; Latour & Woolgar, 1979). From a complexity perspective Bartley's example would appear less difficult than the other two examples because of the provision of the initial data (the ratio of water: jello at specific volumes) from which students could seemingly extrapolate to larger quantities.

The Bowen and MacDonald teaching examples both described student engagement in forms of 'authentic' inquiry (Level 2 and 3 respectively, Tamir (1991)) which were more complex than Bartley's because of the need to establish the preliminary relationships (from which, in Bowen's example, extrapolation could then occur). Both Bowen and MacDonald's examples reported on numerous issues with data literacy and inquiry that arose from their pre-service teacher student participation. In MacDonald's example there was an attitudinal issue in that the students themselves did not think that competency with inquiry/data literacy was relevant to their role as a teacher (this mirrors attitudes reported by Melear et al. (2000) who also engaged preservice science teachers in inquiry investigation activities in a course specifically focused on those), and this attitude may have influenced the depth of their engagement and the quality of their work. However, in contrast, the Bowen example described an activity where student time was essentially not limited so students had as much time as they wished for the activity to be conducted in the detail they desired and there was considerable engagement in the activity with most students participating enthusiastically and positively. Despite this, in the pre-service teacher grass count studies there were often low sampling rates, either or both of categorization of different zones by grass density and the counting of grass in small samples to be extrapolated upwards, and numerous other methodological issues. In this instance, it is hard to argue that there was a time or resource issue as the pre-service teachers had access to the internet in the classroom as well as resource books. Thus, a lack of time and resources can not be responsible for limiting the quality of their work, nor that their interest was lagging. In both the Bowen and MacDonald examples, one gets the sense that the pre-service students are under-challenging themselves *conceptually* from a science perspective, and often it seemed as if they weren't approaching the problems from a conceptual perspective at all; this might be understandable in MacDonald's example where a time limit was set, but less so in the case of Bowen's example where time restrictions were not imposed. Although it is arguable that explicit instruction could be used, in both cases there was a diagnostic aspect of the activity in that the instructors were attempting to determine what students would implement of their own accord. Both instructors engaged in explicit instruction in later activities but with apparently limited success at addressing the inquiry issues as demonstrated when students were, again, expected to engage in some investigation they themselves had designed. In some ways what really seems to limit many preservice science teachers in their own investigation efforts is their perspective that doing such activities is not something their own students will need to do nor should be expected to do under their direction as teachers. That they would have this perspective is not be all that surprising given their own experiences as students and the way in which science is presented in textbooks (Binns & Bell, 2015).

Studies reporting on issues with pre-service teachers' competencies with data literacy issues, some from authors of this paper, have often suggested that it is important to develop these competencies in methods courses and that perhaps even a separate course "on" inquiry is warranted. Claudia Melear and her colleagues at the University of Tennessee have conducted courses such as this for over a decade (see Bowen & Bencze, 2008 for a summary of this work, and other references therein) and have reported some success with this approach, although it was only a small subset of pre-service teachers in each Bachelor of Education program who participated in their course. However, in this chapter one of us has suggested an approach wherein competency with research practices, including data literacy, could be developed in pre-service teachers through the use of action research. There are differing views amongst the authors on this, as another of us (GMB) has been at two universities where action research was a part of the Bachelor of Education program and in both cases, he found considerable disinterest amongst the pre-service science teachers in participating in that type of research (with many being outright disdainful of that research approach when asked why they hadn't taken the action research course). At Bowen's current institution an attempt was made to implement action research as an activity in the BEd program-wide "seminar" course, and the comments made in their "methods" course by preservice science teachers about this activity were almost universally negative. This does not exclude including action research in a science "methods" course as an approach to address data literacy issues, but suggests that particular care must occur in designing such a course so that the pre-service science teachers engage in positive participation.

It is possible that the reasons for the negative outcomes, described by both Bowen and MacDonald, reside in why these pre-service teachers decided to go into teaching instead of staying in science – we speculate that perhaps many of these individuals are not really interested in research and related issues, such as dealing with abstractions, intangibles, unknowns and uncertainties, which are found embedded in science research. Recently, when his department was presented some of the findings of this study in a professional development session, a chemistry department head commented that it was only ever the weaker students in his department who didn't really seem interested in science who went into education programs so he didn't' find the findings all that surprising (unpublished data). If this is indeed more broadly the case, it would certainly help explain the relative disinterest in science inquiry investigations reported here by MacDonald (and others of us elsewhere).

Clearly, when you remember that these pre-service teachers are being certified to teach high school science, including International Baccalaureate courses and other senior courses, it is evident that there are insufficiencies in the competencies with data literacy that were revealed in one of the examples (Bowen's), and which were only beginning to be addressed in the other two examples. If we truly expect to have high school teachers teach inquiry-oriented courses, then at least in the Canadian context, where most of our science education students have attained 4-year BSc degrees, we need to adopt other approaches to help develop the associated data literacy skills. Whether that involves specialized science inquiry investigation courses in BEd programs, adoption of action research courses during the BEd degree, requirements of prerequisites such as honours thesis courses from the science degree or statistics courses, or some combination of all of these, there are issues with data literacy that science methods professors need to both better understand and develop better strategies to address. However, in this day and age of declining enrolments, when administrators are often less discriminating than in past about who is admitted to our programs, we recognize that we will certainly have challenges ahead of us in driving such an agenda.

It's worth noting that in this chapter we have only described three individual activities in our courses – courses which have other activities designed to address issues with conducting inquiry investigation activities and data literacy – the success of students in these described individual activities do not necessarily reflect their competencies with inquiry at the end of their programs. What we have done in this paper, we hope, is provided an indication of where the problems with inquiry begin with students so that our peers can better think of how to address these issues with their own students. In keeping with recommendations made for the need for "multiple experiences, spanning several semesters, in which potential teachers of science are routinely expected to engage in authentic science activity and the use of inscription…" (Lunsford, Melear, Roth, Perkins, & Hickok, 2007, p. 561) both Bartley and Bowen believe that other follow-up activities they engage in over at least two semesters lead to greater data literacy by the end of their programs, and a greater orientation towards engaging their own future students in inquiry investigations, than was evident at the end of these described example activities. In contrast with the inquiry-focused "Knowing and Teaching Science: Just Do It" (non-methods) course reported on by Melear (see Brown & Melear, 2006; Lunsford et al., 2007; Melear et al., 2000), which did not seemingly lead to much focus on the teaching of inquiry in their own courses, all of us believe that the integration of a series of inquiry activities <u>in</u> our methods courses leads to a stronger inclination towards doing higher-order inquiry investigations by our program's graduates in their own future classrooms (an area of future investigation for us).

Coda: Changes in Perspectives and Practices

In the beginning the four of us thought that our struggles were individual…that the student outcomes were based on our individual interactions, our particular pool of teacher candidates, the activities we designed, the way we enacted those activities. All too often conversations at conferences were not about teaching methods courses, not about what challenges we faced when teaching those courses, not about what we were experiencing with our students. In Bowen's case he experienced these issues with engagement in higher level inquiry activities at several of the institutions he worked at (some of which has been reported in other literature). Realizing that the challenges with inquiry are more than "just mine" provide a considerable incentive to work at resolving the issue. Our expectation as science "methods" instructors was that our students should easily be able to engage in inquiry activities at reasonably high levels and some of us (particularly Bowen, MacDonald and Sherman) over the years were quite surprised at the struggles our students had with those sorts of activities. We realized that our "assumption" – that students coming into education programs with BSc degrees should be able to do inquiry and so teaching them to teach it should be reasonably straightforward – was deeply flawed. Clearly our "methods" teaching had to address inquiry investigations in a more fundamental and basic fashion and for our students we have to start from the basic assumption that knowing about inquiry is not the same as being able to do inquiry.

All of us have subsequently worked at developing other activities to further our interests at improving data literacy and inquiry competency in our "methods" students…particularly hands-on activities combined with explicit instruction on inquiry. Shortly after completing this work Sherman and MacDonald both entered administrative roles so both teach "methods" much less frequently than previously (although there is much to be said for having an administrator who strongly supports science methods professors in engaging their pre-service students in inquiry activities, as sometimes there is considerable student resistance). With insights gained from this work Bowen and Bartley developed a series of activities on improving data literacy, tested with their methods courses, which they now conduct workshops on at the national conference of the National Science Teachers Association and elsewhere regionally. Recently those activities were developed into a book on data literacy (Bowen & Bartley, 2013) which is now used widely in science teacher professional development workshops and action research courses in the United States. Further "teacher professional" publications on these issues are also forthcoming.

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Chapter 14
Going Beyond the Status Quo: A Longitudinal Self-Study of a School Based Science Teacher Preparation Program

Nidaa Makki and Gary Holliday

Introduction

Improving the preparation of science and mathematics teachers is a national priority (National Academy of Sciences, 2010; White House Office of Science and Technology Policy, 2014), given the perceived shortage of qualified STEM teachers. To address these needs, many programs were developed to attract qualified STEM candidates to teaching in the hopes that it will improve the teaching and learning of science and mathematics in schools, and in turn, increase the STEM pipeline (Ledbetter, 2012). Moreover, teacher preparation programs are currently under scrutiny, if not attack, as they are being held responsible for the perceptions of failing schools (Greenberg, McKee, & Walsh, 2013; Levine, 2006). Some of these critiques focus on the disconnect between the realities of schools and the focus on theory in teacher education (Levine, 2006), which resulted in alternative teacher preparation programs such as residency programs to emerge (Urban Teacher Residency United, 2014), with various degrees of success (Sawchuk, 2014). Within traditional preparation programs, the Council for the Accreditation of Educator Preparation (CAEP) emphasizes clinical preparation. In Standard Two, the accreditation organization calls for partnerships with school districts to design in-depth clinical experiences for teacher candidates.

In this environment, we found ourselves with an opportunity to develop a new program to prepare mathematics and science teachers, with a focus on embedding them in schools for an extensive period of time. Knowing that practical experiences are essential for novice teacher learning, as science teacher educators, an important aspect of our practice was to establish and develop collaborations with classroom teachers to provide spaces where our teacher candidates can practice their teaching.

N. Makki (✉) • G. Holliday
Department of Curricular & Instructional Studies, The University of Akron, Akron, OH, USA
e-mail: nmakki@uakron.edu; gholliday@uakron.edu

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This self-study focuses on what we learned from the implementation of this program over 3 years, specifically in relation to our thinking about the relationship between science education faculty and teachers, and how the school experiences can be better integrated with coursework so that the experiences of teacher candidates in the program exemplify best practices in science education.

Given the current critique of teacher preparation programs, it is important to not lose sight of the proposition that extensive time in the classroom for a teacher candidate is essential, but is not the only factor that leads to success in teaching. The discourse on practical experiences can lead critics to discount pedagogical knowledge. Pinnegar and Hamilton (2009) suggest that self-study of teacher education practices begin with a provocation, which "can be a living contradiction or a puzzle or a wondering about where we want to be, what we know, and how we know it" (p. 105). The provocation for this work came from the complexities of the meaning of practical school experiences, and their relationships to the role of teacher educators at universities, especially in an environment where there are questions about the future of teacher education in the traditional context of colleges of education. Experience doesn't displace theory, but both are integral to the process of learning to teach. As Pinnegar and Hamilton explain: "theory and practice are both enacted in experience, and they are revealed as they bump against each other and potentially new theory and new practice merge" (p. 30).

To explicate these issues and unpack the various ways that "Experience" was being used, we focused our self-study on our individual selves, but also our collective selves as we studied the program as a whole, in relation to how we design meaningful practical experiences for our students. We wanted to study the ways in which a teacher preparation program supports innovative science teaching practices, rather than replicating traditional science teaching. Therefore, the research questions that we explored include:

1. In what ways can we, as science teacher educators, develop school-based experiences that promote inquiry teaching rather than replicate traditional methods?
2. In what ways can we learn and inform our practice while collaborating with teachers, specifically in learning environments that are supporting novice teacher learning?

Theoretical Background

Our practice (and reflection about our practice) was grounded in Dewey's notion of educative experiences, and the framework on critical reflective practice (Brookfield, 1995; Dewey, 1938/1997; Schön, 1983). Experience is a term used with various meanings in teacher education, but it has specific meanings in Dewey's philosophy. For Dewey (1938/1997), the purpose of education is to provide students with worthwhile experiences. These experiences need to be valuable on their own, in the present, as well as open the door to other worthwhile experiences. Not all experiences can be counted as "worthwhile". To understand this notion of experience more clearly, Wong and Pugh (2001) contrasted a Deweyan experience to an ordinary experience. An ordinary experience is mere activity, without a clear development or flow. It stops rather abruptly, by external interruptions or internal distractions and it does not achieve its full potential. On the contrary, a Deweyan experience is more involved. It is rather like a play, where there is anticipation, a sense of possibility, a fulfillment, and consummation. At the core of a Deweyan experience is the idea of consummation. "The individual looks forward to, imagines what may or may not be, and is surprised, disappointed, or fulfilled when consummation occurs" (Wong & Pugh, p. 321). In this view, learning science means not only engaging with thought, but also emotions and drama (Wong & Pugh, 2001).

Extending this framework to science teacher education, learning to teach can be conceived as engaging in "worthwhile experiences" that engage body and mind through "an unfolding drama of inquiry where one part leads to the next, where the activity is compelled by the anticipation of what might be" (Wong & Pugh, p. 321). Conceiving of worthwhile experiences in this manner transcends practice-as-learning-by-observing (and imitating) a seasoned teacher, to practice-as-acting on creative ideas as they unfold in the classroom.

We focused on designing a program that can involve teacher candidates in transformative experiences that are grounded in practice, but not just seeking to mimic it. It was essential that teacher learning of content and pedagogy occurs "through engagement in learning activity that "mirrors" the kind of experiences that reformers hope teachers would provide their students" (Davis, 2003, p. 6). We focused on studying how embedded school practical experiences "open the possibilities for creative pedagogies" (Britzman, 2003, p. 26), rather than on replicating what exists in classrooms.

Explicating the meanings of practical experiences is essential, as many programs are looking into increasing "experiences" in the classroom, which is exemplified in the Council for the Accreditation of Educator Preparation (CAEP) Standard Two – Clinical Partnerships and Practice. However, practical experience, while essential, is not an uncomplicated term. There is a perception among teacher candidates (and critics of teacher preparation programs) that time in the classroom will teach them everything they need to know about how to teach (Britzman, 2003). In our work, we questioned this assumption, through embedding requirements to challenge candidates to incorporate inquiry methods, and problem based learning approaches in the classroom, while also focusing on reflection in action (Schön, 1983).

In studying our own practice, we relied on the framework of critical reflection (Brookfield, 1995). Reflection is ubiquitous in education circles, but not all reflection is critical. Critical reflection attempts to understand how dynamics of power frame educational processes, and aims to "question assumptions and practices that seem to make our teaching lives easier but actually work against our best long-term interests" (Brookfield, p. 8). We engaged in critical reflection through conversations with colleagues about our practice, through examining our own assumptions, and by listening to our students' voices.

Methodology

The theoretical framework used in this research, and the focus on critical reflection of our own practice, lead seamlessly into self-study research. In particular, the reflective turn (Russell, 2012) was used to study our practices in how we prepare science teachers. We framed our study through collaboration, and reflections with other teacher educators, graduate students, and collaborative teachers in the field. This collaborative framing and reframing is essential in self-study research (Samaras & Freese, 2009) and allowed us to critique our assumptions and challenge ourselves to think differently about issues.

Setting

Pinnegar and Hamilton (2009) outline that the setting of self-study can be individual, collaborative, or programmatic. For the purposes of this study, the larger setting was programmatic- a graduate 1-year program that prepares recent STEM graduates and career changers for teaching in urban schools. The program begins in the summer with intensive coursework, followed by a full year in the classroom with a collaborative teacher, while taking courses related to STEM pedagogy. Faculty in the program worked closely with the teacher candidates and the collaborative teachers to ensure that the experiences are designed to support teacher learning. The program also provided formal mentoring and support during the first 3 years of teaching, which allowed us to maintain a relationship with our graduates.

At the beginning of the program, we brought the collaborative teachers from local high schools and the teacher candidates together for an interview day, where they interacted with each other and provided feedback on their preferences for placements. Throughout the day, faculty used the feedback and their observations from interacting with teachers and candidates to set up matching pairs. Once these were identified, the candidates spent a full year as interns with the collaborative teachers, leaving for two afternoons each week to take coursework at the university. We highly encouraged a co-teaching model rather than a student teaching model for the internship. For these two reasons, it was important that all those involved reflect upon how to pair the teacher candidate with the collaborative teacher during such an intensive year. Additionally, we set up several experiences for our candidates to observe innovative science teaching practices, such as visiting classrooms in STEM schools or other innovative classrooms, and attending professional development sessions.

There were several components in the program that were linked together, but we chose to focus in this self study on examining our (collective) practices in relation to setting up learning experiences in school settings that are most conducive to establishing worthwhile experiences as described above (Dewey, 1938/1997), and on connecting the coursework on science teaching and learning to the existing practices in the classroom. We operated with the assumption that we learn by participating in a community of practice (Lave & Wenger, 1991) and this was central to this study. The collaborative group included science educators, one math educator, and one STEM clinical faculty. In addition, curriculum specialists at partner school districts engaged with the group in planning and reflection. At various times, other faculty from the teacher preparation unit were also involved in planning experiences and in the reflective process. The make up of the group changed from the inception and planning phase, to the current year (year 4) of implementation due to changes in staffing, as well as changing responsibilities. For the purposes of this study, we focused on the process of learning and reflection that involved two science educators, math educator, and clinical faculty.

As a group, we met weekly to discuss our practices, both in teaching methods courses, and in working with teachers to engage the candidates in the most beneficial experiences. As we reflected and made changes to the program, we became increasingly focused not only on our teaching but also on how the practicum component of the program was an essential component of our practice of preparing teachers. The role of the clinical faculty was essential in bridging the two sets of experiences and providing connections between what we were learning about our teaching, and what we were learning about how our candidates experience the classroom settings. The clinical faculty attended the methods courses at the university and also visited candidates in their classrooms, observing and providing coaching on improving their teaching skills. She was also the liaison to the teachers in the classrooms who had a different perspective on what novice teachers needed to learn and do to become effective. While we collected data in the form of survey questions for the teachers, we also learned a good deal from the interactions of the clinical faculty with the teachers.

Data Collection

The data we collected to study the research questions came from three sources: faculty data, candidate data, and collaborative teacher data. The first set included individual faculty reflections and group reflections documented in meeting notes and email communications. Additionally, we collected data from our teacher candidates, which included survey data on their experiences in the program, work samples, course evaluations, and field teaching observation forms. Survey questions included items regarding aspects of the program that were most supportive of their learning, aspects needing improvement, as well as their experiences in various courses. Work samples included entry slips during coursework, reflections to prompts during their time in the classroom, and lesson plans that focused on student centered teaching strategies. For example, candidates attended workshops on Problem Based Learning and were required to design and implement PBL lessons in their classrooms.

Another source of data in this study included focus groups and informal interviews with the collaborative teachers and survey questions, which provided a different lens to study our practice, and enhanced triangulation of the data. Survey questions for the teachers included questions about their expectations of the candidates' pedagogical and content knowledge, the expertise that they feel the candidates bring to the classroom, areas of strengths and weakness, and questions about what teachers learned from the candidates. The informal interviews were conducted by faculty during observations and data was documented in meeting minutes or faculty reflection documents.

The timeline provided below clarifies the scope of data collection over the progression of the program:

Year 1: **Planning year**. During the first year of the program, a focus group was conducted with classroom teachers to gain input on the needs of novice teachers with a focus on schools as organizations, curriculum/content/instruction, technology, and professional development formats. Additionally, meeting notes and documentation from the planning committee provided us with data on our initial goals for the program, and how we approached setting up the program components (Cohort model, 1-year internship, Teacher/Teacher candidate interview selection process; Clinical faculty following the teacher candidates for the year).

Year 2: **Cohort one**. During the implementation of the program with the first cohort, we collected data from bi-monthly program faculty and staff meetings, journal entries from the authors, discussions with candidates about the program, visits and observations in classrooms, and a formal evaluation of the program (candidate surveys, teacher surveys, candidate outcomes).

Years 3–5: **Cohorts two through four**. Data collected included notes from bi-monthly program faculty and staff meetings, journal entries from authors, discussions with candidates, visits and observations during clinical, feedback from collaborative teachers, and a formal evaluation of the program.

Data Analysis

We analyzed the collected data inductively (Lincoln & Guba, 1984), looking for patterns throughout the various sources of data. Some of the data were already summarized from the program faculty meetings as we continuously examined and made changes to the program, and in yearly evaluation reports. We also re-examined data from our candidates to challenge and reframe our own reflection.

In addition, collaborations with other faculty members informed the data analysis to explicate the challenges and successes in implementing this program. We both read through faculty documents, candidate surveys and work samples, and teacher surveys. Themes were identified by the two authors individually, and then discussed with critical colleagues in the program for similarities and differences. Some themes were confirmed through the discussions, and others changed as a result of the examination of critical colleagues.

Feldman (2003) suggests that self-study researchers improve validity and quality of their research through exploring multiple representations of their data into the narratives. We addressed trustworthiness of our representation mainly through the use of critical colleagues, who provided different perspectives in looking at the same data throughout the program development and implementation. As researchers, we revisited the data in an iterative manner and continued to clarify our own reflections through this process. As teacher educators in the program, we had varied theoretical commitments that framed our work. For example, one colleague challenged us to question our own assumptions about race through a perspective of critical race theory. In addition, practitioners in the program challenged how we viewed our role as university educators. These various perspectives from critical colleagues helped challenge our assumptions and reframe our perceptions of our own practice.

Findings

As we delved into the data collected, we decided to write narratives from our personal reflections, to put in perspective how our selves changed during this examination. We present these narratives first before discussing the themes that emerged from analyzing the various data sources and what we learned from them to improve our practice.

Narrative-Nidaa

Presented with the opportunity to design a teacher preparation program in secondary science and mathematics, I was elated to participate with colleagues in a community of practice to re-envision a school based program and to study teacher learning. I expected the process to be a transformative experience, for myself as a science teacher educator, and for our program as we redefine how we prepare teachers. The possibilities were remarkable. The constraints, while very much present, seemed surmountable. I was also excited to work with collaborative teachers as partners. I was tired by the discourse that presented the theory/practice divide where university faculty complained about the lack of best practices in the classroom, and teachers complained that university faculty lacked grounding in practice. I assumed that working together with teachers, we can create opportunities for learning for everyone involved: teacher educators, teachers, and teacher candidates. After all, “critical teachers must be seen as critical learners too” (Brookfield, 1995, p. 206). We are all learning in the process- teacher educators learning how to improve their practice, teachers learning from the candidates how to approach STEM teaching, and how to mentor novice teachers, and teacher candidates learning how to become teachers of students who come from poverty.

Loughran (2007b) affirms that viewing the science teacher as learner cannot be separated from the teacher educator as learner. He further articulates that science teacher educators “challenge the taken-for granted in their practice” (p. 1059). Over several years of studying and revising the program, I wrestled with the tensions of the practical and the theoretical. Knowing that teacher educators are learners too, I found problematic the notion of adopting a “clinical model” without a critical stance to explicate the inherent meanings attributed to the value of experience- and the role of the teacher as critical learner. There seemed to be an assumption that I found problematic with the increased focus on a clinical model: first, the term brings baggage (clinical setting implying a deficit model- students as needing to be treated/fixed/cured…), and second, this stance implies the glorification of the value of experience.

Additionally, I found quite a bit of disconnect between the lives of the teacher candidates in the program, and the lives of their learners. Just as students learning science come to the classroom with their own preconceived ideas, teacher candidates engaging in different understandings of urban come with their own ideas of the world of students, teaching and learning. Many issues that surfaced in candidates’ reflections, questions, or concerns during the program focused on trying to impose order in what they perceived to be a chaotic environment. In unpacking some of these concerns, I came to understand that they are as much about cultural differences as the perceived lack of classroom order. This was an example of how “in schools, colorblindness often obscures, while simultaneously fostering, deficit thinking, which is usually linked to membership in a racial minority or low economic status group” (Watson, 2011, p. 24).

I also found ourselves (science and math educators) lacking in the area of supporting minority candidates as they navigated the program. It is documented that we have an underrepresentation of minority teachers in the US (Ingersoll & May, 2011), and as a program, we were able to recruit a few. However, providing the same level of support to the minority students as to everyone else was not enough. A concerted effort was needed, which led me to question the complexities of asking novice teachers to connect with urban students and support their learning, when we may not be as successful in reaching and supporting minority teachers, even after purposefully recruiting them into the program. By focusing on meeting expectations of the program, we ended up obscuring race and “speak about students without explicitly revealing racial bias and to pretend that skin color is not important” (Watson, 2011, p. 24).

What have I learned? Through the process of making my reflections public, and holding myself accountable to my colleagues, my practices were transformed as I reflected on what I do and why I do it. For example, my science methods course used to focus on teaching science using inquiry, but the candidates in my classroom had somewhat limited opportunities to implement these practices, as the field experiences were limited to few hours a week. Working with candidates in a “lived experience” model, they were able to voice concerns about applicability of ideas presented in class and challenge me to problem solve with them as they implemented those practices. I learned to value the perspectives that my students bring to the discussion and to use questions/disruptions of the given as opportunities for learning. More importantly, I grew to see my role as a learner and a problem solver, within a community of various perspectives, but who shares common goals, to build relationships with students so they can become scientifically literate.

Narrative-Gary

When I first arrived at the university, the program had been underway and the first cohort had been established. I knew little about the preparation and planning that occurred prior to my arrival but I quickly saw that the team was continually revisiting and revising the program. Monthly meetings (sometimes bi-monthly) and yearly reflections helped to fine-tune elements (such as supervision, mentoring, and professional development opportunities for the cohorts) and, I think, greatly improved upon a unique teacher preparation program. The collaborative nature of the university team and the collaborative teachers was especially enlightening. The program staff and faculty very much considered the feedback from the collaborating teachers, which quickly lead to changes in program components, and this seemed to make an impression on the teachers. Their opinions were valued and made impacts upon our own practice.

One thing that surprised me was that the teacher candidates at the beginning of the program did not seem to value the collaborative teachers as much as I thought they should. They seem to feel that they were they to help 'fix' the educational system and that the collaborative teachers were in need of help. This observation was noted at several points of the program and was addressed during the initial phases of following cohorts' programs. The idea that the collaborative teachers were mentors, experts, and resources, instead of being in need of help, began to be emphasized in the early coursework. This seemed to help change this mentality in the later cohorts. Another aspect that seemed to help was the close-knit university team. The clinical staff member would share observations with the faculty and candidate supervisors, allowing for a more unified approach throughout the program.

What have I learned? Such a program cannot survive without collaboration and effective communication. The collaborative teachers seemed to appreciate that their views and concerns were valued and contributed to the overall program. This was especially evident (to me) during the interview day for the fourth cohort. The large room was filled to capacity and the collaborative teachers from a number of schools and districts were eager to meet the new batch of teacher candidates. Careful consideration was taken when interviewing the candidates and when discussing where they should be placed. The teachers had a lot to say about each of the candidates and how they should be paired up for the upcoming teaching year. Over the years, the teachers became an integral part of the process and became more involved when interviewing all of the candidates. Their teaching experience and insight often gave the program staff and faculty another perspective. Also, having been a part of the program over the years, the returning collaborative teachers knew exactly what to expect during the clinical year and offered advice to the newer teachers. They have proved to be an extremely valuable asset.

Themes That Emerged

One of the assumptions that we made as teacher educators when we designed the program was that there needs to be seamless integration between theory and practice, between what is learned in our methods courses, and what is learned in a K-12 classroom under the supervision of a mentor teacher. However, when we examined the data collected, emerging themes suggested some tensions between best practices emphasized in methods courses, and the realities of teaching. While some candidates were able to successfully implement inquiry science in their classes, others reverted to traditional lecture style in their teaching. While this phenomenon is not new or peculiar to our program, it caused us to examine what we are doing in our courses and in our program and to question our assumptions about the integration between ideas explored in coursework and practical experiences. In this section, we begin by presenting some themes that emerged from our examination of candidate data, and proceed to how these findings informed our practice.

But It's All About Classroom Management

We framed our course assignments in ways to encourage applications of best practices. For example, we embedded the course assignments in applications in the classroom setting, such as requiring the candidates to develop and teach inquiry lessons, and to develop a problem based learning unit that they teach to their students. We wanted the classroom discussion to focus on implementing best practices, but it often turned to classroom management issues. In our reflections, we noted a concern for controlling the classroom surfacing in candidates' questions, and conversations about best practices often turned to conversations about control. This was also clear in survey responses. For example, one candidate responded to the question about aspects of the program that supported becoming an effective teacher:

> *Instruction wise I feel that I am doing well. The classroom management portion I am still struggling with and I do not feel that I had good support from the University in this area. I do not feel that our classes adequately prepared us for classroom management. I am still trying to find my way of discipline because the students know that I am not a disciplinarian and therefore laugh when I issue a punishment. {Candidate survey response}*
>
> *I am left trying to teach with the class not in control, because my mentor never handled her class. I feel stuck with no support or understanding from anyone. {Candidate survey response}*

Some of these concerns can be tied to the candidate's uncertainty about working in urban environments. This view is exemplified in this quote from a candidate:

> *I also learned a great deal about the state of public education in urban environments. I believe my students will be better for having been in my class, I'm not sure how much but I think I had them doing the type of assignments, lessons, and projects that will serve them in future classes. Finding ways to motivate the underachievers and the apathetic students was very very challenging. Also, I have learned that the culture in many schools, including mine, just isn't conducive to closing achievement gaps and getting students to value education enough to change their mental approach to school. {Candidate survey response}*

The turn of the classroom discussion to management and controlling students caused some frustrations for us. One of us resisted the turn of the discussion to how to control students. However, we realized as we examined the concerns of our students, that these concerns about order and control are not trivial. Rather than using theoretical work on rethinking what we mean by "managing the classroom", we began looking to use these incidences as problem solving activities. For example, we used an entry slip at the beginning of each class to make connections between the school experiences and course topics. As more of these entry slips focused on classroom management, we chose some questions weekly for class discussion, and encouraged our students to use readings, course activities, and discussions with mentor teachers to collectively problem solve the issues they brought up. While this strategy didn't resolve all the problems they identified, it allowed us to turn the discussions from venting activities to problem solving. Additionally, through discussions with critical colleagues, we explored with our students alternative perspectives. Rather than viewing issues of "lack of classroom control" as a problem of limited experience in the classroom, we were challenged to examine how the presentation of "classroom management concerns" obscure power relations in a classroom where students and teachers come from different cultural backgrounds.

Tensions Between Replicating Teacher-Centered Practices and Implementing Creative Pedagogies

One concern that emerged from our reflection, and that we saw the candidates express frequently, is the mismatch between the discussions of best practices and the observations and expectations in the classroom. This was definitely exasperated by the increase in the focus on testing that we are currently witnessing in schools. While this was not apparent for every classroom placement, it was nonetheless a concern, and it continued throughout the years of implementation. For example:

> *Many of [the candidates] are working with teachers who have the exact opposite viewpoints of the [program]. {Candidate survey response}*

The teachers also complained about having the candidates leave their classrooms for coursework and questioned the value of taking courses on the college campus, when it means that the candidates lose time in their classrooms. The teachers were questioning where the expertise/learning should be happening, which speaks to the issues of power in the relationships of faculty, collaborative teacher, and teacher candidate.

[They] seem bogged down with so much course work to fully give their attention to the classroom. {Collaborative Teacher survey response}

No classwork during this semester, it's too overwhelming with everything else that we need to do. {Candidate survey response}

The candidates were in a sense left with negotiating authority (Britzman, 2003), such that the tension between university expectations and classroom practice is really due to the challenge that they are visiting in someone's else classroom and are attempting to assert their teaching style, while also respecting a classroom culture that has been established. They felt a tension between expectations from faculty, and expectations from teachers. When the two expectations were aligned, the candidates flourished. When there was a mismatch, negotiations were often necessary in order to ensure candidate success.

As this issue unfolded in our reflections at the beginning of implementation of the program, we began offering professional development opportunities for both candidates and teachers, so that they were working together on common instructional approaches. We also acknowledged the demands that the program imposed on the candidates, and changed the framing of some of the assignments.

Relationship Building

The most positive aspect that was reflected in examining our practices in the program, was the essential role of building relationships with schools. One way this was emphasized was through the connections with the clinical faculty, who perceived herself as a bridge between what was learned in methods courses and what can be happening in the classroom. In this program, the clinical faculty member was a STEM educator who was also a career changer (from engineering) and she shared a similar background with the candidates. For example, one candidate mentioned:

I have learned the most from my interactions with [Clinical faculty], where she observes my work and provides direct, actionable feedback that I can apply quickly to improve my performance in the classroom. {Candidate survey response}

Visiting classrooms several days a week, and continuing the process over the full year, she was able to establish relationships with the teachers and provide an invaluable lens in weekly faculty meetings. It wasn't feasible to bring the teachers to our weekly meetings, but it seemed that their voice was represented, as well as the voice of the candidates. In several meetings, she questioned assumptions we made about what can be implemented in the classroom. While many programs have a role for a clinical faculty member who supervises candidates more closely, it is not always the case that that person is engaged in critical reflection with other faculty members. Building time for critical reflection was a powerful component to establish relationships and foster collaboration.

Teacher Candidates as Change Agents

One of the stated goals of our program was to prepare teacher leaders, who can be transformative agents in their buildings. Some teachers viewed the teacher candidates as an apprentice (or in some cases, a burden), while others found value in a career changer bringing that experience to the secondary classroom. For example, the clinical faculty member notes in one of her reflections: "*The collaborative teachers are using a model of* '*what I do with a student teacher*' *from what I observe in the field*." And a collaborative teacher stated:

> *It is a big responsibility having her there all the time. Yet, that is exactly what is needed to immerse her fully. So, it is not a complaint – it is just more time consuming on my part – during lunch, during my free period, etc. {Collaborative Teacher survey response}*

However, when the relationship worked, it resulted in very meaningful and innovative classroom experiences, as two teachers (novice/expert) collaborated on novel ideas. For example, several candidates designed and implemented problem based units that were successful in the classroom. The success of the collaboration was evident by comments from teachers that they learned new strategies from the candidates, or that they wouldn't have attempted an idea if they didn't have them in the classroom. We also saw evidence in comments during the candidate-teacher interview day, when teachers were disappointed when they didn't get a candidate as an intern for the year due to having a larger numbers of teachers than candidates. In one instance, one of our graduates from the first cohort served as a mentor for a new candidate. Together, they reinvented how the science curriculum was structured, so that it became more focused on mastery learning, and allowing each student to work at his or own pace, with the teacher in the classroom focusing their attention on students who need them the most, and allowing peers to help each other. We examined this specific collaboration in our reflection: is this an anomaly due to the personalities of the two individuals? Would having our own graduates serve as mentors lead to better collaboration possibly due to similar perspectives on best practices? This can be seen as an anomaly, as teacher development can be idiosyncratic (Bullough, 2008), but what can we learn from successful cases for future changes in the program?

A few ideas emerged from this reflection that we are hoping to use in the future. We learned from these examples that approaching the traditional student teaching experience as a collaboration/co-teaching model is very important, but that we need to work more closely with the teachers to reframe this experience. Some of our candidates are going to need a lot of support, and the mentor teachers will be focusing on helping them grow. Other candidates bring outside expertise and intense motivation, and can work as partners with their teachers. In these cases, we can begin to focus our collaboration on working towards K-12 student success. More importantly, we also changed our thinking from focusing on candidates as agents of change, to examining our role as capable of being an agent of change.

The process of critical reflection was instrumental in making revisions throughout the years of implementing the program. The themes listed above were the main drivers of some of the changes we made throughout the years. For example, while Cohort 1 was finishing their program, the team revisited the program expectations and coursework and decided to enhance the focus on pedagogical knowledge of STEM education. In addition, the team decided to provide more formative assessment opportunities in order to support the learning of the candidates. It also became clear that providing support for certification and employment opportunities earlier in the program would be beneficial to candidates. Ensuring successful clinical experiences required strengthening the support system with more site visits and concrete feedback.

These discussions continued while Cohort Two through Four progressed through the program. In particular, at the beginning, the summer course workload was restructured in order to improve candidates' learning experience. Providing more instructional materials or resources was another area for improvement. For example, professional development about Problem Based Learning was provided and resources were available in order to assist with the teaching of lessons. Since there were individuals from the various cohorts eventually obtained jobs as classroom teachers, there was the addition of virtual and onsite mentors for them as well.

Discussion

Loughran (2007a) affirms that self-study research requires evidence of transformation of practice, a need for interaction with colleagues and the literature, in addition to the need of researchers to interrogate assumptions and values. The process of engaging in self-study resulted in changes in our practices, with the collaborative reflection being a key driver of change. We also worked on challenging our assumptions about teaching and about designing components of the program. We outline below the main ideas that this self-study helped us bring to the forefront for ourselves and for others in our program. These issues are also important in the national discussions on preparing teachers.

Problematizing Experience

> *I know that even though she is anxious to please and learn – she doesn't have the comfort in front of the class. I have tried to help her with this, to encourage her – but I think it is just going to have to come with experience. {Teacher Survey Response}*

What does it mean to learn from experience? This was a theme that recurred throughout our study, and in our collective reflections on the program. Through various data sources, the theme of learning from experience emerged. Brookfield (1995) affirms, "Teachers have a choice either to work in ways that legitimize and reinforce the status quo or in ways that liberate and transform the possibilities people see in their lives" (p. 209).

This theme of transformation and possibilities applies to teacher candidates learning to teach, as well as to us, as science educators working with these candidates. Turning inwards, we examined how our own practice is legitimizing the status quo- that of viewing classroom experience as learning by osmosis- and how we can "work with the cultural and cognitive complexities represented by students' varying personalities, learning styles, genders, developmental levels, ideologies, and backgrounds" (p. 209). Through modifying requirements in our courses, we achieved some degree of success in challenging assumptions about "practical experience". More specifically, making concerted efforts to raise questions about the meaning of experience, and structure candidate reflections to explicitly question the practices they observe. We are also approaching the application of best practices as a collaborative effort. Rather than our candidates trying strategies (such as science inquiry, PBL, etc.) on their own, we are involving the teachers in implementing innovative approaches, through offering professional development activities to both groups.

Reflecting on the Meaning of "Urban"

The second theme that was front and central in our thinking about our practice was reflecting on the meaning of teaching in urban environment. Our candidates framing of the meaning of "urban" is not peculiar to the context of our program. In a study with novice teachers in urban schools, Watson (2011) found that while teachers expressed an interest in teaching in urban schools,

> They did not all necessarily want to teach who they defined as urban students. Those teachers who did not want to teach "typical" urban students desired to teach … "urban, but not too urban" students or in … an "urbanesque" school. These students were perceived as having cultural and symbolic resources that were more in line with those of suburban students. More specifically, these teachers wanted to teach students of color who exhibited their perceptions of middle-class-ness. (p. 31)

This anxiety about the environment where candidates were working can also be linked to their own background (which is also connected to race, gender, and class). In her reflection, the clinical faculty member noted that the candidates have been very successful in traditional environment. They were successful engineers, or chemists, or honors science graduates. They were able to succeed in traditional environment and therefore are having a hard time adjusting to a different culture. This is consistent with other research on STEM career changers (Grier & Johnston, 2012), which affirms that they contribute valuable experiences to the classroom, but also present challenges that are unique to this population.

This is an area that we still have more questions than answers. Turning the critical eye towards our practice, we are questioning how our program is serving the needs of minority candidates, who sometimes find the program requirements very challenging. As more calls for diversifying the teaching force (especially in the

STEM areas) are being made, we need to examine how our traditional teacher preparation programs are serving the needs of diverse candidates.

Establishing a Community of Educators-Learners

One of the questions that we began this study with focused on how we can work with practicing teachers to improve our own practice in preparing novice teachers. However, collaboration can bring tensions and challenges. For example, one of us experienced an encounter recently when a veteran teacher told a group of teacher candidates to forget everything they were taught in college, as it doesn't begin to prepare them for the realities of the classroom (the veteran teacher proceeded to apologize to me for making this comment in my presence, but he had to make the point!). We know this is a cliché, but we wanted to highlight this incident to frame and question our assumptions about collaboration. There are instances when collaborations work very well, but we also work with teachers who have very different ideas about good practices than we do. It would be easy to dismiss these teachers and move on to find new collaborators, but it is important to ask what we can learn from colleagues and teachers who have very different theoretical commitments than we do.

One of the approaches that we challenged ourselves to adopt was to shift the conversation to focus on problem solving. In other words, how do we use the various perspectives at the table-teacher educators, teachers, teacher candidates- to collaborate on investigating approaches to solve problems related to teaching and learning science in difficult classrooms. The example provided above with the teacher candidate and mentor teacher working together to rethink the science classrooms illustrates this approach, and while it is one instance, it offers a possibility of what can be accomplished with a fruitful collaboration.

Conclusion

What have we learned from this self-study about preparing teacher candidates in a school-based (clinical) model? As teacher education programs are being asked to move towards clinical models (CAEP), it is necessary to understand the types of experiences that lead to transformation, rather than replicating the status quo. Our goal for engaging in the process of self-study over the past 3 years was to explore how we can, as teacher educators, bridge the gap between the status quo and the possible. We began with questions such as what is the value of intensive school based experiences or internships? How much is enough? How do coursework build on school experiences? And how can experiences inform theory? Engaging in self-study allowed us to reframe the meanings of school based experiences, and taking a more critical stance on how these experiences socialize candidates into the roles of teachers. We also began to examine how we can see our role as agents of change in more practical ways.

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Chapter 15
Biology Student Teachers' Reflections in Eportfolios as a Trigger for Self-Study of a Teacher Educator

Lindsey Norma Conner

The Context of This Study

Student teachers in the Graduate Diploma programme for high school teaching at my university complete 10 weeks in three curriculum courses and 14 weeks of professional practice experience in schools as part of their broader 10-month preparation to become high school teachers. During this time they are expected to demonstrate evidence of reflection and this is assessed as part of their coursework. Jay and Johnson (2002) have stated that reflection was "the current grand idée in education and plays a central role in the preparation of many new teachers" (p. 73). While learning from experience through reflection is far from automatic, I wanted to promote sagacity where student teachers actively used reflection to understand what worked well and why- to gain insights into professional practice.

I had developed and taught this course for 12 years, followed by a 3-year gap (during a period of high administration load) then resumed teaching this course in a modified form with additional components such as students' developing reflective practice through an eportfolio. Therefore while I positioned myself as a "Knower" through my own teacher educator and high school teaching experience, I realised I didn't really use students' reflections on their experiences as a source for "knowing about my students to inform my practice". As a teacher educator I wanted to become more aware of areas of comfort and discomfort as experienced by my students, so that I could adjust my teaching to accommodate their issues and concerns. Challenging the relations of power and privilege (knowledge) has not always been the focus of self-study. Kuzmic (2002) argues that self-study has been marred by a failure to challenge boundaries and that self-study must take account of the lived realities, experiences and perspectives of students in teacher education. Therefore

L.N. Conner (✉)
University of Canterbury, Christchurch 8041, New Zealand
e-mail: lindsey.conner@canterbury.ac.nz

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positioning myself in relation to others allowed me to move beyond just focusing on "self" in that I used the insights of others as a source of self-learning. I questioned: How could I use students' reflections to gain insights into my own practice?

Therefore this chapter discusses how as a science/biology teacher educator in New Zealand, I used student teachers' reflections on pedagogy, practice (including the use of resources) and theories of learning and teaching in a pre-service biology curriculum (methods) course, as a trigger to inform my own development as a teacher educator. The main data sources were PSTs' reflections as posted in eportfolios, a student focus group session with a colleague and my own reflections.

Reflective Framing and Reframing

According to Schön (1983, 1987) framing is the process of identifying what a practitioner will attend to within a context. Then reframing of practice can occur in response to analyzing information including examples, understandings and actions in order to create a new way of 'seeing' the problem. Reframing turns the focus of the research back on the researcher to examine her or his framing of the question and seek alternative perspectives. Reframing lies in stark contrast to "action based on habit, tradition, or impulse" (Samaras & Freese, 2009, p. xiii) and therefore offers a way of approaching research that requires confronting our assumptions made in and about our teaching. In this way, reframing is not about coming up with a different solution but instead involves asking a different question.

Recently Conner and Sliwka (2014) have emphasised that teacher education courses are more likely to be effective if content is applied to appropriate learning contexts, when there are repeated opportunities for reflection, and when student teachers experience good modeling of practice by teacher educators and teachers in schools. Effective modeling by teacher educators (Goodlad, 1990) relates to Vygotsky's (1986) concept of relational imitation. As Goodlad wrote, "We recommend, then, that the responsible faculty plan not just a sequence of courses and field experiences, but deliberate demonstration of pedagogical procedures their students will be expected to use in the practice part of their preparation programs" (p. 291). I questioned whether I was effectively modeling the practices I wanted my students to demonstrate and whether I was making my deliberations (deliberate decisions about ways to teach) explicit enough so that students would see that I was "walking the talk".

While developing students' reflective practice is a learning outcome of the biology teacher education course, I was interested in how I could also use these reflections as a source to check my own assumptions about what they knew and were learning, and use this knowledge and potentially deeper understanding to inform my own reflections and future actions as a teacher educator of this course. This is not to say that I saw myself as the key determinant in what students learnt. Far from it as I subscribe to the idea that we are working with adult learners who have multiple capabilities and capacities to steer their own learning. However, my own experiences as a high school teacher and 18 years as a teacher educator, along with the roles and responsibilities that are associated with working with the education sector, confer a responsibility on me to make explicit my knowledge, experiences and any wisdom that might help beginning teachers. I also believe that teacher educators need to model how we become more "knowing about our learners" as part of the professional disposition of embracing continuous professional learning and basing changes to practice on information, rather than just hunches.

As previously stated, pre-service teachers as adult learners, can direct experiences to support their own learning (Dewey, 1938). However, they need examples and tools to help them reflect on their experiences as learners; and they may need support to examine what is working for them and what else they need to know, as they set and review goals and assume responsibility for their own development as active learners. Being familiar with what and how to teach is a necessary condition for teachers to support effective learning. This not only applies to enabling learning of content knowledge but also to enabling learning about the processes of learning and teaching. PSTs experiences of learning in school and teacher preparation programs tend to set the pattern for how they behave in their own classrooms (Belland, 2009).

Therefore it is important in teacher education courses to highlight the significance of reflection as a tool for identifying what prospective teachers are good at and what they need to work on. Their own reflection forms a key part in their professional development (Beck, Livne, & Bear, 2005; Buzzetto-More, 2010). By valuing reflection as part of this course and what was assessed, as well as valuing students reflections to inquire into my own teaching, I was attempting to model good practice and doubly valuing reflection as a process that they could use with their students in schools to enhance the key competencies of managing self and metacognition that are part of *The New Zealand Curriculum* (Ministry of Education, 2007).

The inclusion of reflective statements in eportfolios as a requirement for an assessment in an initial teacher education course not only places emphasis on reflection but also on the importance of knowing about and using eportfolios as a learning tool. This knowledge can be transferred to how teachers incorporate the use of eportfolios with their students in the high school classes they teach in the future (Hauge, 2006) and can help with the development of ICT skills more generally. Therefore there were content and process advantages in using students' eportfolio reflections as a source for my own self-study.

Developing Digital Expertise

Given the burgeoning variety and sophistication of educational software and digital tools in schools, PSTs need to have multiple opportunities to become aware of and experience a wide range of digital tools as they develop their knowledge, learn to teach using a diverse range of teaching and learning strategies and develop their expertise (Ertmer & Ottenbreit-Leftwich, 2010). Using technologies effectively requires developing a repertoire of complex digital literacies.[1] I wondered if I could combine this need and use it as a source for reflecting on how I utilized eportfolios for helping me and my students reflect on practice. I discuss this dual tension in the discussion section.

Eportfolios are now a well-established tool in initial teacher education that can provide beginning teachers with a vehicle or opportunity for supporting their ongoing professional learning (MacEntee & Garii, 2010). Eportfolios have been used to support students to connect to personal, internal and external examples of practice, resources, planning framewoks and reflective posts where they consider the relevance and application of their thinking and learning to teaching and learning. Thus the use of eportfolios can help prospective teachers to consider the wide array of teaching approaches including teaching using digital sources and indeed using eportfolios with their own students in subsequent teaching practices that occur as part of their qualification. Further the use of eportfolios can assist self-directed learning in what Conner (2014) has called *evaluative constructivism* where learning is an inquiry oriented, self-questioning activity through purposive and intentional processes for learning. Using reflective writing, PSTs can construct meaning from their previous and new experiences and develop their *adaptive expertise* (Hatano & Inagaki, 1986) where they consider alternative approaches, modify, adapt and adjust their teaching and apply these modifications to specific teaching and learning contexts (Darling, 2001).

The biology teacher preparation course was supported by an online moodle platform where learning intentions for each session and resources and questions were posted. While most students in the course were familiar with basic digital information processing skills, I was surprised that some students were not accustomed to using the moodle site to support their on-going learning through social forums. This was a reflection of the expectations for the program as well as for this course.

Graduates of initial teacher education programs in New Zealand must meet the Graduating Teacher Standards that include the requirement to "demonstrate proficiency in oral and written language (Māori and/or English), in numeracy and in ICT relevant to their professional role" (New Zealand Teachers Council, 2008). I made an assumption that my students would have considerable experience with a wide range of digital tools. However in a study of students' technology experiences, Bennett and Maton (2010) concluded that while many young people used a range of technology-based activities, their expertise was highly variable from being quite restricted in their digital practices, to pushing boundaries and being very creative in how they used tools. Bennett and Maton also pointed out that casual use of technology-based activities may not prepare students for academic practices or they may not transfer what they do in their private use to how they can use technologies in teaching. Therefore I had to challenge my assumptions about the levels of digital

[1] Digital literacy (Netsafe, 2010) is the ability to understand and fully participate in the digital world. According to NetSafe, a digital citizen is, along with other attributes, a confident and capable user of ICT who uses digital technologies to participate in educational, cultural, and economic activities and is literate in the language, symbols, and texts of these technologies.

expertise of my students especially about how they may be unaware of how digital tools can be used to learn more effectively.

Research Approach

As part of modelling of reflective learning and adaptive expertise, students in two senior biology curriculum courses for secondary teachers were expected to write five reflective statements in their eportfolios. They chose whether to share their reflections just with me or with the whole class. The instructions were:

1. Each student is to set up and create a Biology View in 'MyPortfolio'.[2] (See the 'how to' section for instructions)
2. As a key component of your **e-portfolio** you are to keep a '**reflections**' journal. This is an ongoing record of your thoughts as you reflect on the progress you are making. This could be about your own pedagogical content knowledge, or how certain lessons may have gone, or observations from the classroom.
3. There should be at least five reflections over the whole semester. As each one is written please share it with me so I can provide feedback. When on professional practice you will also keep a journal, and there may be some overlap in your reflections. This is not a problem.
4. At least **two examples of online resources** should be included where web 2.0 tools have been used. These will be covered in class and a *url* link can be inserted as a link. When this is done, please reflect on the use of this tool, and its possible use in the biology classroom. Examples include the use of wikis, quizlet, voicethread, animoto, or others as appropriate.
5. If possible, please include examples of student work (anon) or activities while on professional practice that show the use and application of different teaching strategies. These can be included as part of your reflections above, i.e. how well they went, what would you do differently next time etc. These examples could be written, or photos of student work (e.g. models, a photo of an experiment, an example of student produced work using an ICT application etc.). Ask permission first, but these examples of student work can help you when applying for positions later on and provide good evidence about student achievement.

All assignments for this course were uploaded to the PSTs' eportfolios which was the standard "myportfolio" website used by teachers and school students in the New Zealand education system (www.myportfolio.school.nz). Students were also provided with an on-line example during class time of five reflections that a student in a previous class had constructed.

Aspects of my pedagogy and the methods of this research were linked to the reflective cycle in models such as the teaching for better learning model (Aitken,

[2] http://myportfolio.school.nz/

Sinnema, & Meyer, 2013) that are an important part of developing as an effective teacher. I conducted this self-study over 2 years (two iterations of the same course).

As students entered their reflections in their eportfolios, I was sent an email notification. This enabled me to consider their reflections in an iterative way in relation to planning course experiences and what I emphasized during classes. Initially I focussed on tasks and activities that they found useful in a very technocratic way. On deeper content analysis of the writing (Fraenkel, Wallen, & Hyun, 2015), I identified key emotional aspects related to their experiences that I had not anticipated.

A colleague acted as a critical friend and conducted a focus group session with the students, which was audio recorded. Drawing on multiple sources and multiple perspectives in this way to gain feedback supported the credibility of the work, provided simple triangulation and also a context for critique of what I needed to change in my practice and how I viewed my own identity as a teacher educator. As Loughran (2002, pp. 243–244) asserts "reframing is much more difficult from an individual and personal perspective than when acting in collaboration with others." I needed to dig deeper into what beliefs I had about myself as a teacher educator and how "knowing" what my students were placing emphases o in their reflections enabled me to shift my pedagogy and how I positioned my identity as a teacher educator. Discussing this with my critical colleague enabled me to do this.

Analysis

Due to the complexity of the students' reflections, they were analysed using content analysis of the narratives (Fraenkel et al., 2015; Sarantakos, 2013) and coded to account for this complexity. Each reflection item was between several paragraphs to half a page and therefore contributed to multiple categories. I electronically coded the components or partial sentences as:

- strategies for learning about content
- reflection on pedagogy
- Evaluation of resources
- Observations of others teaching
- links to experiences as part of the university course
- links to their own teaching on professional practise
- links to evidence of school student learning for next practice

The collations of the coded items appear in Table 15.1. A t-test was used to compare the number of reflection items in each category for both classes to determine their similarity. There was a significant difference between the two classes [$p=0.05$] only for learning about pedagogy. The first class had a higher value for reflection on pedagogy (Table 15.1). Otherwise there was no significant difference between the two classes. I am not placing too much emphasis on this difference because of the relatively small sizes of the classes.

Table 15.1 PSTs' reflections as categorized from eportfolios

	Strategies for learning about content	Learning about pedagogy	Resources to support teaching	Reflection on other teacher	Links to university class	Links to their own teaching	Links to evidence of school student learning for next practice
PSTs in first class							
A	3	9	8	2	0	6	3
B	0	12	25	1	0	9	0
C	3	6	4	0	4	4	2
D	0	7	6	0	0	4	1
E	2	5	2	1	0	4	1
F	3	4	11	0	1	3	3
G	3	6	3	1	1	5	1
H	6	6	5	0	0	7	0
I	5	6	2	0	0	6	1
J	5	2	6	1	0	3	1
K	2	5	8	0	0	4	0
Mean #	2.9	6.2	7.3	0.6	0.6	5.0	1.2
PSTs in second class							
L	1	7	3	1	0	6	0
M	1	4	4	3	2	4	2
N	5	11	9	2	2	8	1
O	5	6	6	2	2	6	2
P	3	3	4	0	1	4	0
Q	2	5	4	1	0	4	1
R	2	7	6	1	1	4	2
S	3	4	4	2	1	4	1
Mean #	2.8	5.9	5.0	1.5	1.1	5.0	1.1
t- value comparing both classes	0.13	2.34	0.22	3.9	1.22	0	0.002

T_{17} (0.5) = 2.11

Ethical Considerations

My involvement in the biology course as part of my teaching meant that I had "insider" status when setting up the assignment and during the teaching of the course. I had to clarify my intentions and sought students' permission to use their reflective statements for analysis after they had received their grades for this course. Because I was also assessing the PSTs there were possible conflicts of interest. Not all students volunteered to be part of the study. It was important that the research project (nor participation in the project) did not influence student grades. However, I was trying to model teaching practice as *Teaching as Inquiry* (TAI) (Conner, 2015; Timperley, 2011) that they could potentially use as teachers in schools. I indicated that I was reflecting on my own teaching but using their outcomes as a basis for this reflection. They received letters outlining the extent of their involvement. Near the end of the course, I sought their permission to use their reflective statements and to participate in a focus group discussion that was facilitated by one of my colleagues who acted as a critical friend. There was also a formal written consent process as approved by the UC Educational Research and Human Ethics Committee.

Findings

While I was conscious of the range of things students might reflect on, it was important to let them chose with the provision that it related to biology teaching and met the requirements of the assignment. I modified this in the second class and emphasized several times that they could use a complex array of experiences that were based on their professional practice observations, what they had learnt in their preservice class and in their own time, and how these linked with their own development as a teacher. Their reflections were quite detailed and included e-links to the ideas they were reflecting on, graphics and digital resources, web supports and youtube videos, as required by the criteria for the assignment. This provided additional resources for me as the teacher of the course and for the other students in the class.

In the first iteration of the course, students mostly reflected on resources followed closely by statements about pedagogy (Table 15.1). Many of them made links to their own teaching but to varying degrees. The reflections came from a sample of 11 students from the first class and 8 students from the second class who gave consent for me to use their reflective statements.

Although the sample size of students is small, the data indicate that many students made links to their own teaching but to varying degrees. Students from both classes did not identify many strategies to help them bridge the gaps in their own content knowledge. This may have been because the course was designed for learning how to teach rather than for learning biology content per se but many students recognized the importance of being well prepared with resources to help the students they would teach learn content and that developing their own content knowledge helped them to be more effective teachers.

Students in both classes included very few reflections related to their professional practice experiences particularly on what their associate teachers in schools did. As well there were relatively few reflections on the teaching and learning experiences they had in this particular university class. This surprised me and therefore I tried to emphasize the range of aspects they could reflect on for the second class more often and indicated that they could post more than five reflections if they wanted to. Due to the small numbers of participants in each class, and the variation within each class, there is no significant difference in overall outcomes when comparing both classes, except for the reflections on pedagogy for the first class, indicating a level of consistency between outcomes for both classes. This was a disappointing outcome given that I thought I was emphasizing the types of reflections that could be made and thought I had mentioned them more often in the second iteration of the course. This action then, made little difference to the outcomes. Potentially this was because the students considered that posting their reflections was part of an assignment requirement and not part of their learning as such. This means that in the next iteration of the course I will present the eportfolio reflections as a mechanism or strategy that can help them to learn about being a biology teacher more explicitly. I will also change the assessment outline to indicate that they can reflect on as many items as they choose to and then they should select the five for the assignment at the end of the course.

Whilst categorizing the reflections was a useful exercise for me to see what students were considering most (and potentially valued more or found more challenging), their detailed comments about specific activities or how they adapted their teaching provided much more in-depth information. It was these in-depth comments that acted more as a trigger for changing my own practice. For this reason I have included some of their quotations in the next sections, as illustrations to indicate the sorts of comments they made and my responses to them.

Given that the assignment brief also indicated they should use evidence of students' work to support their reflections, the data in the last column in Table 15.1 indicate very little reflection on student evidence for informing teaching. PSTs who did this only used observational and anecdotal evidence rather than evidence of achievement or work samples/assessment outcomes of the students they were teaching. Therefore because of this and it's impending focus within schools for ongoing professional learning, I will add a focus on using student evidence of learning both within the next iteration of the course and give it more prominence in the assessment guidelines. The next section provides specific examples of their reflective statements and what they wrote about their developmental needs.

Strategies for Learning About Content

The reflection from students about how they might adjust their learning about content was disappointing. Nine students commented on strategies that would assist their learning of biology content knowledge. However the number of references to content knowledge overall was low compared with the other categories in the analysis of their reflections. Several students commented on how they needed to improve their content knowledge expertise as shown in the following example of a post in an eportfolio.

> Student A: I need to study hard so I know my stuff, and learn it to a point that I can recall knowledge quickly and easily.

Several others commented on ways to encourage school students to support each other with developing content knowledge and to use appropriate student engagement strategies to do this. Some examples below show students' awareness of the need to monitor learning and how important student engagement is in the learning process.

> Student C: I saw that students were actually learning the content I was teaching (I don't know that they weren't learning it before, but I doubt it. It was nice to know they *were* learning from my teaching). It goes to show the importance of being creative and finding ways to teach that your students respond to instead of sticking to the same old thing all day, every day.
>
> Student I: The more able students (conveniently half the class) would really enjoy teaching their peers one on one, and their peers seemed to enjoy learning from a more relevant perspective for a change. I was able to monitor the accuracy/enthusiasm of the teaching and was really impressed with how the material was being explained (*by the students themselves*). It also not only keeps the more academic students engaged, but also reinforces the understanding of the material greatly.
>
> Student A: I asked the students in Year 12 to create a poem, song, rap or colored storyboard that summarised DNA replication (I gave them a list of keywords that had to be included in the summary). They did this task in pairs, and had to present their finished song/rap/storyboard to the class in the final lesson. The level of engagement that I got from this task was huge – the students loved it! And the quality of the performances was great. All groups chose to do either a song or a rap, and they were so creative and summarised DNA replication really, really well. Not only this, but I heard them singing the songs they had created down the corridors and at lunchtime after they were finished.
>
> Student H: I did manage to learn the basic concepts, however I seemed to always lack the in-depth understanding that was needed to answer some of the student's questions. This definitely had an impact on my teaching… To help get around the problem, sometimes I would get students who really understood the concepts being explored to explain things to the class or individual students who were having trouble. This worked really well, because it gave those students who knew the content the opportunity to practice presenting their knowledge.

The examples of reflections above also indicate how the students were willing to try alternative ways of supporting learning and valued the success that this enabled.

The video creation activity in this class captured the PST's imagination and they thought they would use this activity and apply it to teaching in a range of biological contexts. Students' comments were positive affirmation of the utility and application of the activity but also that they had understood the value of transferring this idea to the teaching and learning contexts they would be designing in the future. As well this experience highlighted why it is important to be well prepared (another key point that I emphasize during class) as portrayed in the following comment by one of the students.

> Student O: This exercise involved pairing up with another student teacher to "wing it" as each of us we were filmed individually presenting what we knew about a skeleton (prop)

as if doing a presentation to a class of students. It was hilarious to say the least and a lot of fun (for me anyway) an on the spot realization of how we need to read and know what we are talking about before jumping in front of a class unprepared. When viewing the video footage, despite thinking I had put on an air of confidence (faked it), I saw how I looked when I didn't know what I was talking about, my facial expressions gave it away and it was so obvious that I didn't know what I was talking about in any great depth and just "winging it"…. It motivated me to read well about topics and look for interesting content to give me more confidence to teach and talk about the lesson content with genuine enthusiasm.

I try to emphasize pedagogical content knowledge, i.e. the ability to apply and adjust pedagogy and considerations about teaching in relation to specific topics or content areas. Therefore while I have previously viewed my own stance as being a "knower" of content and being a "knower" of pedagogy, due to these reflections I had to reconsider this stance. The comment above and similar comments from other students, indicated to me that students were considering appropriating pedagogy to specific content and that they were, in general conscious of the need to be well prepared. Their comments about the usefulness of some of the activities we did in class and their application of these activities in school classrooms indicated that they felt they were useful for helping school students to learn content knowledge. PSTs enjoyed them much as school students might. So what did these PSTs' reflections indicate about my practice and my stance? Perhaps I was not emphasizing the importance of understanding content knowledge enough.

Reflections on Pedagogy

All of the PSTs in this sample identified multiple aspects about their development of pedagogical knowledge and linked these to specific examples of digital resources, their benefits and some of the drawbacks or aspects of pedagogy to consider as well.

Student E: This free-to-use app literally does it all. Evernote lets you create notes and save them in different notebooks. The diverse text editor gives you a lot of freedom when creating the notes to ensure that you can add whatever you want in, making it a great lesson planner. Additionally, you can save the notes you make to different notebooks that you can title, allowing you to organize each of your classes separately.

Student J: Mindmeister can benefit my students in a variety of ways. My students can use it for effective note making and organisation. They can also use it for revision and it can be a collaborative experience because they can share it with their friends who can then also get a copy and edit it further. I can use Mindmeister for conceptual development of my unit plans and the topics I intend to cover each week. I can then share this information with my students that can be used by them in preparation and planning. I can use this as Diagnostic as well as Formative assessment as a quick review of the topics we learnt in class which can help in further development of concepts or reporting to their parents.

Student I: A downside to this is that it requires the Slowmation programme to be installed as well as that the process can be quite lengthy as I found when producing the Slowmation movie attached on Osmosis.

These comments signaled to me that they were considering the benefits, multiple uses and drawbacks of using particular technologies. Therefore the students had picked up on my indications of the importance of this. However, students in the focus group suggested they would have liked access to each others' comments during the course and not just at the end. Therefore I will suggest this as a possibility to the next class so they can learn more from each other. There are ethical considerations about sharing that they would need to agree to before this can happen, but there is scope within the eportfolio software to allow sharing with whomever students choose.

Some of the reflections on pedagogy were more general statements that indicated an awareness of the need to provide a range of learning experiences and for them as teachers to be creative in what kinds of experiences they provided. For example,

Student K: We as teachers need to address this issue and start making steps towards incorporating more hands on tasks in lessons. In biology this doesn't necessarily mean we have to start doing more dissections or bacterial streaking. What it means is that we have to start taking different approaches to presenting the same material.

Student E: Games and activities are perfect for formative assessment because the more students interact and share, the better they learn. Students can be learning and not even know it.

Student L: One person noted that not all students learn at the same pace as you are teaching, and while I didn't apply the "rewind me" method, I think it is a brilliant for students, not only to catch up because of absence, but also to refer back, reflect on their own understanding and to cement concepts.

Student E: In class we have been given multiple examples of how to use this pedagogy of learning and it allows the students to take control of their learning, be creative, and use critical thinking skills that are necessary in all subjects but also very beneficial to biology.

As part of the modeling of good practice, there were times in this class where I specifically made use of strategies and explained why they might be useful, such as the "rewind me" strategy of reflecting on class sessions in a forum post or indicating questioning protocols for scaffolding critical thinking. Some of these appeared in the PSTs' reflective statements as indicated below.

Student A: They had to think about the process in order to verbalize what they were doing (by talking through the steps as they moved through them with the model of DNA) so that by the end of it they were each able to write a really good summary of the steps of protein synthesis. I think that getting students to talk through their model is a really vital part of the process, whether it's just to a partner or to the class. If they just made the model, they're not really engaging with the content; they need to show that they understand how the model works, and explaining it out loud is a great way to achieve this.

Student E: Because I do not have the most experience in the labs and facilitating activities, I found that the activities we did as a class helped my understanding of how labs work and how to organize them. It will be very helpful to be able to go on our (biology) group page and use the lab activities that have been posted.

Student K: I do like the idea from class of making a video to present to the class as (school) students aren't always confident with getting up in front of the class.

These statements were somewhat affirming that the activities they identified had shown examples of pedagogy and perhaps how the approaches could be transferred to multiple contexts. The most common activity that was commented on by the PSTs in the second iteration of the class was the rat dissection. During this practical activity we discussed the ethics of doing dissections with school students and how teachers introduce the ethic of care and regard for animals was very important. This obviously provoked students to think about these issues carefully as illustrated by the following student's comment. This particular student was so engaged because she had not undertaken an animal dissection ever before, that she took photos of her student partner as he undertook the dissection and then posted the photos on a shared space within her eportfolio so that the whole class could access them. She wrote,

> Student O: Personally I felt quite ill at the thought of dissecting a rodent and the smell was quite revolting therefore I would expect students to be well within their reasonable grounds to not want to participate in this activity. However upon overcoming my own aversion to the procedure, I began to think about how the activity in itself brings about questions of ethics and the respect for life of all living creatures…..Sometimes emotive or research based content does not grab the attention of adolescents particularly when it comes to critical analysis of ethics and human interaction with the earth environment. However participating or even looking at a dissection of a dead animal for any great length of time does provide thinking and learning opportunities over and above simply looking at specific internal organs of a creature. If I was teaching (this) I would consider setting the students a small research assignment about ethical considerations, animal welfare, or something connected to different perspectives about respect for all life on the planet in contemporary society.

It was interesting that students in general, realized the increased ways digital resources, digital assessments and using a range of interactive tools could support learning. The students mentioned in class several times and one student commented in his eportfolio that sometimes they were actively discouraged to use digital tools when they were on professional practice in schools. I was dismayed by this and will indicate in the future that as newly graduating teachers, they can lead the way.

> Student L: While student-centred learning was still in its infancy at both my schools (for professional practice) and the use of electronic media in some cases non-existent (due to older teachers holding on to [un]-proven and ingrained methods?) I was in one instance verbally discouraged from using electronic media and digital resources by one of my associates. I found that very strange as our training focuses heavily on the use of electronic resources as an indispensable and invaluable aid to enhance learning for all students.

I was pleased though that the student considered her "training focuses heavily on the use of electronic resources", affirming my emphasis on this. This student had also picked up on the equity value of using digital resources that I had been mentioned briefly in class. Such aspects as enlarging text, turning on text to voice modes or being able to replay video or look at content online at any time are advantages for many students, especially who have English as a second language. I will continue to emphasize this equity message associated with using digital resources.

During the course, I tried to model how to use websites to compare planning and to evaluate resources. This has proved to be useful to students as they can see the benefits for accessing this information to support their future teaching as exemplified by the following quote from an eportfolio. There were comments about websites replicated by other students in different ways.

> Student O: As a beginning teacher I would use this website (TKI[3]) as a guide when designing my own lesson plans, and compare the effectiveness of new ideas relative to learning outcomes to what information this website outlines as key learning points.

The student teacher's comments indicated that the use of the eportfolio for recording their reflective statements resulted in substantial gains for them as learners. This especially applied to identifying and critiquing resources and considering pedagogical approaches and how these applied to their own teaching. Learning from each other was a core element that was facilitated by sharing their reflections but that could be enhanced further by emphasizing the benefit of sharing more so in class. As student B wrote about the use of eportfolios:

> Student B: I will also be making full use of the sharing system that myPortfolio offers users. This has been very useful as I can see others' resources and plans and with permission be able to use them in my teaching, and if I feel like it making adjustments to those to suit the class I am teaching.

Students B's comments also reflect the idea that teaching in the New Zealand context expects teachers to choose what they do from a range of resources and use their professional judgment and expertise to adapt resources and ideas to meet the needs of their learners. Students in this class had grasped this idea well.

Student L wrote a whole page about his use of reflection as a learning tool. The quote below indicates his growing awareness of how student backgrounds should be taken into account when planning sessions for level of interest, difficulty and quantity of activities.

> Student L: What I found about my own personal reflections and those of my associates were that they were actually a good starting point when preparing the next lesson, as I now had a much clearer idea of what worked well during a lesson and what didn't work well.

I was surprised though that not more students reflected on reflection as a learning tool. Thje requirement to post five reflections as part of a summative assessment, placed value on this activity as a process for learning and as a model they could use with their students in schools. Naturally, there was variation as to the extent and depth that students reflected on their own teaching, aspects of teaching and learning that they observed during the course sessions and observations of their associate teachers in schools. The students' reflective statements acted as a trigger to help me identify what activities and aspects of the university course they found useful. It turned out that the eportfolio itself was one of the most useful experiences as indicated by the following comments from the discussion with a critical friend during the focus group at the end of the second course.

> Student M: One really good thing about it is that it is ongoing (beyond the course).
> Student O: It encourages us to share our resources more easily.
> Student L: I agree with having the reflections all in one place .. I don't know, it's nice to have it all laid out.

[3] Te Kite Ipurangi website https://www.tki.org.nz/

Student N: Myportfolio is "data kind" in that you can embed links and videos.
Student P: I liked the structure with groups, personal page, you could share pages or it (pages) could be made private.
Student Q: In a practical sense you don't have to print everything out.
Student S: You can edit things. You know compared with "dropbox" where once you hand things in, it's gone.
Student R: It's a good way to get feedback.

One student thought that eportfolios could replace the student management system used for all courses, whereas another student thought that the student course site just needed reducing and managing and others agreed. This has triggered me to revise the organization of the course link in the student management system and I have since rearranged the topics, sessions and resources to be more modularized and systematic.

Several students indicated in the focus group interview, that they needed more assistance with getting started to create their pages in eportfolio. This indicated that my assumptions about their existing ICT expertise were incorrect. In future I will give much more direct instruction to develop their capabilities to use eportfolios.

Discussion

My self-study indicated aspects of my teaching that were much wider than my initial scope of considering whether e-portfolios were useful and whether I could use then to investigate my own teaching. In retrospect, I was using the students' reflections in e-portfolios as a "catch all" for gaining insights into potential tensions and problems within my practice. In this discussion I first consider what students reflection indicated about the use of eportfolios, as this was my original intention. Then I discuss how the reflections themselves acted as triggers for a much wider consideration of the activities we undertook in this class and how my identity is gradually shifting from a "knower" stance to one of modeling "knowing about my students".

Use of Eportfolios

Using eportfolios and sharing these reflections amongst the participants in the class leveraged their experiential and situated learning and social learning that made it useful which has been determined as two significant factors that can support students' learning, motivation and retention of content (Chen, Calinger, Howard, & Oskorus, 2010). It also enabled them to participate in a student-centered learning activity since eportfolios are individualized and customizable. This allowed the PSTs to choose what to write about, in their own time, and therefore was self-directed. That is, the student teachers were given control over the content and links that they chose to make, rather than prescribing the topic for reflection.

Some reflections indicated they were able to consider how they would apply the use of resources or pedagogies in multiple contexts, but in many statements this was not evident. However, many of these students related their biology teaching to experiences they had with years 9 or 10 classes when they had taught biology topics with these classes. It also seemed important as, Knight et al. (2006) have indicated, that while they were choosing what to reflect on, they indicated why they selected particular approaches, resources or experiences and how they used examples or pedagogy to illustrate their deeper learning and transference to other contexts or next practice. When student teachers are consciously aware of how they can appropriate content and pedagogy, they are more likely to enhance their *adaptive expertise* (Darling, 2001). Therefore I will continue to emphasize the importance of considering why they might use particular resources and how they can adapt them appropriately to accommodate the needs of their students.

Several students had not used eportfolios previously so through having this experience they would be more likely to use them with their own classes in high schools in the future. Having to learn about the functionality of myportfolio coupled with their comments about other ICT tools and resources enhanced their awareness of access and use of digital resources and on-line interactive activities. The eportfolios also provided a tool and easily accessible space for sharing their ideas with the other class participants, further enhancing their social learning opportunities.

The timing of the writing of the reflective statements as part of the course was also important. As it was scheduled, the course has two 5-week teaching blocks punctuated by 7 weeks of professional practice in schools. The students in this class did not write their reflective statements until well after their professional practice in schools, even though I had indicated orally that they could do this in relation to our activities in class and went through the assignment orally with them prior to their professional practice in schools. Therefore there was a social learning opportunity during their professional practice that was not well leveraged as indicated by Evans and Powell (2007). There is also scope for allowing students to extend beyond the five required reflections, especially given the power of sharing their reflections and how this can support professional learning socially (Hauge, 2006). It would be interesting to allow students to post as many reflections as they liked and to ascertain whether this would help to address to some extent what Orland-Blank (2005) calls "what remains untold". That is through repeated reflective practice, PSTs may become more confident and willing to share what has not worked and their learning from these experiences more. In the future I will encourage students to create reflective statements throughout the course, then choose which ones they use for evidence for the summative assessment. As it stood, students generally only produced the minimum number required (5) for the assessment except where formative feedback to two students indicated they had not met the requirement for the assignment.

Other advantages of using eportfolios more generally included: their total mobility, they are easily shared with anyone, anywhere, facilitate shared learning, reproducible, improve ICT skills, provide support for the development of future teacher actions, enable a personal approach to learning and development as a teacher, provide evidence and examples of development (Barrett, 2000). They can also include multimedia and embedded files, as well as enhance the development of new learning and make connections to prior learning. Therefore there is wide scope to explore how the use of eportfolios in initial teacher education programs can be incorporated into course design to support the development of ICT capabilities (Chen et al., 2010) and for assessing PSTs' progress towards becoming a reflective practitioner (Cooper & Love, 2007) through showcasing evidence of learning (Delandshere & Arens, 2003; Denner, Norman, Salzman, Pankratz, & Evans, 2004).

I will definitely use and recommend the use of eportfolios in the future since they acted as a source for posting reflections, a source of evidence for the learning outcomes for the class and as a repository of ideas they could use in their teaching. An additional advantage is that students are able to access their posts and the shared pages including their lesson planning assignments, when they are employed as teachers. They can also develop them further to help provide evidence for their teacher registration requirements.

The analysis of students' reflections informed and triggered changes to my practise as a teacher educator. For example, in the second iteration of this self-study, I realized that the purpose of using eportfolios could have been clearer and therefore revised the approach to the assignment. I tried to be more deliberate about explaining why we were doing activities throughout the course (i.e. I indicated the purpose of activities more as I was trying to model how effective teaching makes the purpose clear and used talk aloud reflections (Berry, 2007)). I prompted spontaneous student teacher reflection, both oral and written during classes to provide them with multiple opportunities for reflection and will continue to do this in the future to assist the development of reflective practice. A point of interest will be to see how often they use eportfolios to keep their reflections when they are encouraged to record them more frequently.

In the first class students' reflective paragraphs did not identify many strategies to bridge their gaps in content knowledge, so in the second iteration, I developed an on-line formative self-paced quiz for them to self identify their content knowledge needs. This strategy may have led to the second group of students being slightly more reflective about how to learn content knowledge. Students were also invited during the second class to suggest content areas that we could focus on multiple times and the course sessions were adjusted to accommodate these suggestions.

From "Knower" to "Knowing" More About My Student' Experiences

Through discussion with my critical friend, I came to realise that my own identity as a teacher educator was that of "Knower" where because of my 7 years teaching in schools and 18 years as a teacher educator, I thought I knew what prospective teachers needed to know to become a biology teacher (content knowledge and pedagogical knowledge). However, the reflections and focus group discussion indicated, that if I was serious about meeting the needs of my students, I needed to find out more about my students' prior knowledge and experiences during my teaching. My awareness of the need to check in with students, particularly for animal dissections and pre-empting lack of prior knowledge and skills related to ICT has been heightened.

While we have criteria for selecting students into the programme and therefore some assumptions can be made about their knowledge and skills, the sobering thought is that all students are different and therefore finding out about my students' needs will be ongoing. To reduce the daunting nature of this realisation, potentially students can be assisted to self-identify their specific needs more directly, such as the self-directed formative quizzes that I trialled in the second iteration of the course.

As a result of analysing my students' reflections, I have changed my practices directly but also changed my positioning as a teacher educator. I have changed the organisation of the online student management support site for this course to create modules so that students can access these at any time and check which content or activities they would like to experience in class. In this way, I hope to model student-centred learning in that the PSTs will be able to determine through the use of the student management link, what we do in class time and what they do in their own time.

Since we are working with adult learners and we are also supposed to be modelling student-centred learning based on students' needs, modifying the course in this way and allowing the students to choose what we do, may address their needs better. This of course needs to be set in the context of the course learning outcomes and what students are required to demonstrate to pass the course. Potentially though, allowing this flexibility might free up some session time, where previously I thought I had to "cover things" because it was important for student teachers to "know" them. As a teacher educator it has become more important for me to help them identify (know) what they need as beginning teachers.

Limitations of This Study

While the eportfolio reflections were useful "triggers" for self-study there were some limitations due to the e-portfolio acting as a contribution to assessment for the course, whereby mostly students only submitted the required five reflections. Because some students identified they had a low level of digital literacy, I will make a deliberate effort to check on students' e-skills more thoroughly in the future and appropriate the level of instruction accordingly.

Other limitations were related to capturing students' thoughts as they occurred and that these thoughts probably change over time. As Orland-Barak (2005) has discussed, eportfolios provide a snapshot of thinking while much remains untold. The focus group discussion conducted by a colleague about what they found useful and what they thought would enhance the use of eportfolios confirmed some of the aspects related to my teaching but also provided valuable information about further modifications and applications for this pre-service teacher education course.

Conclusion

My intention to reflect on my own practice by using students' reflections as triggers was designed to inform my practices so that PSTs' educational experiences would be enhanced as discussed by Maclean and Poole (2010). I made assumptions about students' technical expertise that they would be able to intuitively use eportfolios. As a teacher educator, I need to continuously check on students' existing knowledge, skills and progress and development more often. I had assumed that they all had a reasonable capability and some experience in using online systems, which was not necessarily true for all students. While they were given opportunities to ask for help, perhaps in a small class, they did not want to acknowledge their need for help as it would indicate a deficiency to the other students.

While the PSTs appreciated becoming familiar with eportfolios as part of this senior biology curriculum course, they were only beginning to realize the power of them for supporting their own learning. I am now realizing the benefit and the window into their learning and experiences that they provided for me. There are possibilities for supporting PSTs' learning using multiple forms of reflection to assist their development as teachers and to inform teacher educators' practices. In particular, there is scope for student teachers to be guided in developing a more mature eportfolio as described by Challis (2005) and for teacher educators to utilize and identify the developmental needs of their students during courses through their electronic posts.

The implications of the findings of this study for my teaching are to keep using PSTs reflections as part of this assignment to inform my understandings of my students' needs and development and therefore what adjustments I might need to make as a teacher educator. Specific changes to my practice include:

1. Developing a more detailed tutorial on how to set up pages in eportfolio and check on students ICT skills
2. Promoting the use of eportfolios in more courses within the overall initial teacher education program
3. Within the course, I could be even more explicit about how eportfolios could be used to support learning
4. More time could be provided within tutorial time for students to write reflections on what they have learnt in class sessions
5. Indicate to the student teachers, multiple ways for observing, collecting and providing evidence of students' learning as a source for their reflection as teachers who need to know what their students need

6. Find additional ways to identify students' needs and respond accordingly
7. Redesign on-line support modules so that students have more flexibility in identifying their needs and can have input into what is covered during class time and what they can do in their own time.

This research study was not designed to transform myself but rather to refine what I emphasised in classes. In the process of doing this self-study, I have changed my positioning to become more aware of the need to identify PSTs' concerns and needs. Their reflections in eportfolios were only one way of doing this. Face-to-face discussions, individual conferencing with students and providing feedback to students both orally and for assignment work helped students to benchmark their development and also provided me with indications of what else I needed to focus on. The PSTs valued being able to use a tool (myportfolio) that is also used in schools and they were considering how they could use this tool more effectively with students they would teach. This self-study through reflecting on PSTs reflections, triggered my own changes in pedagogy and practice as well as my positioning as a teacher educator. As a result of this study, my own identity is shifting from that of "knower" (about teaching biology) to the importance "knowing" more about what my students are thinking and what their needs are, so these can be addressed more directly.

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Chapter 16
Response to Section IV: Self-Studies and Secondary Science Methods Courses

Gillian Roehrig

Pinnegar (1998) defined self-study as "a methodology for studying professional practice settings" (p. 33). This set of chapters demonstrates the range of practice settings that self-study can illuminate, from a focus on inquiry activities within a science methods course (Bowen, Bartley, MacDonald, & Sherman) to a programmatic analysis of a clinical preparation model (Makki & Holliday). Similarly, these chapters explore a range of knowledge and skills that we as a profession expect of our preservice science teachers (PSTs), such as the development of PSTs' data literacy through engaging in inquiry learning (Bowen, Bartley, MacDonald, & Sherman) to the development of PSTs as reflective practitioners (Connor).

Samaras and Freese (2009) distinguish between action research, which focuses on our students and what they learned and self-study that additionally includes, "a very important aspect of the study—the self, the role we played in the research, and what we learned and how we subsequently changed (p. 12)." They argue that this personal focus and reference involves *study of the self* and *study by the self*. Most evident in these chapters, is the notion of *study by the self*. Bowen et al conclude their chapter by discussing the role of such inquiry activities on developing PSTs' data literacy and the how as a result of their self-study they have modified activities and developed a series of inquiry activities to address the issue of data literacy. The notion of self in this study is as designer of inquiry activities and promoter of data literacy. Connor shares both the changes in the design of her e-portfolio intervention and explores her assumptions about her students and the importance of starting from where her students are. In many ways, her analysis mirrors the reflective practice that she wants to develop within her students. Makki and Holliday, in taking a more

G. Roehrig (✉)
University of Minnesota, St. Paul, MN, USA
e-mail: roehr013@umn.edu

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critical stance in their self-study, embody the notion of study of the self, and indeed the broader endeavor of teacher preparation, as they explore the role of experience in science teacher preparation.

The three chapters tackle two prevalent issues within science teacher preparation programs: (i) developing the knowledge and dispositions for inquiry teaching and (ii) the divide between teacher preparation coursework and clinical experience. As Bowen et al describe in their chapter, the science education literature clearly documents the limited enactment of inquiry-based teaching in classrooms. They point to the limited experiences of PSTs with inquiry in their undergraduate science courses and attempt to remediate within their science methods courses. I would argue that while Makki and Holliday explicitly reach out to and collaborate with their K-12 partner schools, we as science teacher educators also need to reach out and partner with our colleagues in science departments within our institutions. Active learning is becoming the norm for students in undergraduate science classrooms, our PSTs are no longer learning science by sitting passively in a large lecture hall and completing verification laboratory exercises. Indeed, at the University of Minnesota, all biology students (majors and non-majors) have an authentic research experience. We need to reframe our thinking about how we develop PSTs' knowledge and dispositions towards inquiry-based teaching from a deficit model of PSTs' learning experiences in undergraduate science courses towards a collaborative approach that bridges science educators across the divide between Colleges of Science and Colleges of Education. PSTs are now coming to our teacher preparation programs with learning experiences designed from constructivist frameworks within active learning classrooms and authentic research experiences. We need to reframe our understanding of the prior experiences of our PSTs and how to build on these experiences to improve the implementation of inquiry-based instruction in secondary science classrooms.

The theory-practice gap is evident to different extents in each of the three chapters. In focusing her self-study on developing her PSTs as reflective practitioners, Connor also reveals her PSTs' problems with reflecting on their professional practice and connecting their learning about digital resources to teaching and learning. The structure of the teacher preparation program with two 5-week teaching blocks separated by 7 weeks of professional practice in schools cements this divide for PSTs. Such structural separation of university coursework and clinical placements reinforces the gap for PSTs, as seen in the case of Connor's study through their reflective focus on the activities within the university course. The PSTs treated the e-portfolio as an assignment to be completed before the end of the course, rather than an on-going learning tool. In spite of encouragement to reflect continually, the e-portfolio became a summative assessment as opposed to a formative assessment bridging the theory-practice gap. Bowen et al provide a glimpse into the power of connecting learning from university coursework and the clinical setting when a cohort of PSTs had an opportunity to implement the inquiry activity from their methods course in a local middle school classroom.

The development of successful school partnerships for improving science teacher preparation is important and difficult work. Makki and Holliday provide important insights for science teacher educators about this work. The program structure was designed to promote collaboration, for example, encouraging co-teaching, hiring a fulltime clinical faculty member, and involving teachers in decisions about placements for PSTs. Through their critical reflective lens, Makki and Holliday illustrate that as science teacher educators we should not have a singular focus on inquiry. As we strive to prepare PSTs in urban settings and to diversify our science teaching pool, we need to think more deeply about "the meaning of urban" and how to support teacher learning in urban settings. Teacher candidates needs an understanding of urban cultures, as well as the pedagogy and skills to implement a meaningful curriculum (Gay, 2002). Without more explicit support for learning to teach in urban settings, we will continue the phenomena of "the revolving door" where up to 50 % of teachers leave the profession within their first 5 years of teaching (Smith & Ingersoll, 2004). This attrition is notably higher in urban districts (Ingersoll & Perda, 2009). Indeed, there are now over 200,000 first year teachers as compared to 65,000 first-year teachers about 25 years ago, with a quarter of the current teaching force having 5 years or less of experience (Ingersoll, 2012). Wong (2003) argues that it takes at least 5 years to develop an effective teacher, so these high attrition rates in urban schools mean that urban students rarely experience the same quality of teaching as their suburban counterparts. Self-study is one mechanism to reframe science teacher education in urban settings in collaboration with partners who bring new ideas to the table. It is through "dialogue and collaboration with other teacher educators and students, the researcher can frame and reframe a problem or situation (Samaras & Freese, 2009, p. 8) or in the words of Makki and Holliday, to "shift the conversation to focus on problem solving .., [using] the various perspectives at the table – teacher educators, teachers, teacher candidate – to collaborate on investigating approaches to solve problems related to teaching and learning science in difficult classrooms."

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Part V
Self-Studies and the Preparation of Future Science Teacher Educators

Chapter 17
Finding the Means to Initiate and Sustain a Teacher Educator's Pedagogical Content Knowledge (PCK) Development in Science Education

Anne Hume

Introduction

There is a temptation to believe that an expert classroom teacher automatically becomes an expert teacher educator. However, Abell, Park Rogers, Hanuscin, Lee, and Gagnon (2009) argue that individual science teacher educators possess and utilise a unique pedagogical content knowledge (PCK), which is different to that they may possess as an expert science teacher. Like all forms of PCK, such knowledge is highly specific to the learners and teaching context and can only be built up over time and experience (Lee, Brown, Luft, & Roehrig, 2007). It requires long-term, ongoing professional learning, not only to establish expertise but also maintain its dynamic dimension.

The narrative in this chapter traces the personal continuum of professional and academic learning I have been experiencing since my move from classroom science teacher to teacher educator. It takes the form of a meta-study in which I highlight the role purposeful action research into my own teaching at tertiary (university) level has played in my learning journey. I look retrsospectively at this research to establish the nature of my current self-identity as a teacher educator and how it has evolved. My purpose in explicating this process of 'self-development' is the hope that others entering teacher education might see parallels with their own experiences, gaining insights that can ultimately help their own career advancement.

A. Hume (✉)
TEMS Education Research Centre, University of Waikato, Hamilton, New Zealand
e-mail: annehume@waikato.ac.nz

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Methodology

This meta-study uses the signature features of a research approach called self-study, as identified by Vanassche and Kelchtermans (2015) in their systematic review of the literature in the field of the Self-Study of Teacher Education practice from 1990 to 2012. The methodology I employ is characterised by four features: a focus on my own practice; the use of qualitative research methods; collaborative interactions with my academic colleagues; and validation of my findings based on trustworthiness. The data for the meta-study comes from research articles I have published over a 10-year period. These articles record how I addressed specific pedagogical issues arising in my day-to-day teaching role as a teacher educator through action research into my practice. To identify key themes in the growth and nature of my professional knowledge as a teacher educator, I use components of the construct pedagogical content knowledge (PCK) as an analytical framework (Magnusson, Krajcik, & Borko, 1999; Shulman, 1987). These five components come specifically from the model of PCK proposed by Magnusson et al. (1999) – see below. I have included some qualifying statements with each component to indicate how they serve as a means for monitoring my PCK development as a teacher educator throughout this narrative. (Note: I provide more detail about the PCK concept later when using this same model to monitor the PCK development of my students for science teaching). The five components of PCK are:

(a) *orientations toward science education teaching* – includes a teacher educator's beliefs and ways of viewing how science education should be taught and how these views guide pedagogical decision-making. These orientations are typically reflected in the approach a teacher educator uses when teaching particular content
(b) *knowledge of science education curriculum* – includes knowing what specific concepts and skills to teach in a particular science education topic, and when and why. Such knowledge involves understanding of curriculum goals, outcomes across particular courses and grades/levels and awareness of curriculum resources available at various grade levels to support teaching and learning of that topic.
(c) *knowledge of students' understanding of science teaching* – includes beliefs about and insights into what pre-requisite knowledge, abilities, and skills student teachers need to learn about teaching particular science education topics. It is also about knowing how students vary in their approaches to learning how to teach particular topics, misconceptions and beliefs they may often hold and which science education concepts and ideas are difficult for student teachers to learn.
(d) *knowledge of instructional strategies* – includes beliefs and understanding of which specific strategies are most useful to use when teaching particular concepts and/or skills within certain science education topics.

(e) *knowledge of assessment* – includes beliefs and understanding of which aspects of student learning are important to assess within a learning episode or unit, and how such assessment is best carried out i.e., what methods of methods of assessment are appropriate for determining the learning that has occurred in given topics.

Aspects of this model are woven into the chapter when and where they are most relevant to the emerging picture of my self-identity – in places where it may be not be apparent in the text, I refer to the relevant component using italics and brackets.

A significant contribution to the trustworthiness of my findings comes in the form of published exemplars (i.e., my research publications), which provide evidence of how the particular personal practices I investigated work and impacted on my PCK. In many instances, collaboration with colleagues contributed to the credibility of my research. The trustworthiness of this meta-study, however, ultimately lies in the degree to which other researchers in the self-study field find my research findings in synergy with and applicable to their own situations.

Findings

Background to My University Career

Prior to my university career I had been a science teacher in primary and secondary schools for over 25 years, followed by 4 years with the New Zealand Education Review Office (ERO) where I evaluated pre-tertiary (i.e., early childhood, primary and secondary) education in schools. These years gave me extensive first-hand experience of classroom science teaching and learning. During this time I was also a member of national curriculum writing and examining teams in science, including the *Science in the New Zealand curriculum* (MOE, 1993) and the National Certificate of Educational Achievement (NCEA) Expert Panel in Science. In addition I gained a Master's degree in education and at the end of my first year of University teaching managed to complete a science education doctorate. Although an added pressure in my first year of tertiary teaching, my doctoral study was an important contributor to my budding PCK as a science teacher educator. This piece of research had no explicit elements related to the development of science teacher educators, but from this scholarship crystallised some key concepts of teaching and learning that apply across most learning contexts, including teacher education.

My doctoral study concerned the reality of classroom-based inquiry learning in science, from the perspectives of high school students and their teachers, under the New Zealand national curriculum (Ministry of Education, 1993). That curriculum was intent on promoting students' knowledge and capabilities in authentic scientific inquiry (as practiced by scientists), but my study revealed that students were acquiring a narrow view of scientific inquiry in their learning where the thinking was mechanistic and superficial rather than creative and critical (Hume & Coll, 2008).

This student-experienced curriculum was a direct result of curriculum decisions made by their classroom teachers and science departments in response to the assessment requirements of a high stakes national qualification. Students were exposed to programme content that limited the range of methods that scientists use to fair testing. Pedagogies were substantially didactic in nature, including planning templates and exemplar assessment schedules that tended to reduce student learning about experimental design to an exercise in 'following the rules' as they engaged in closed rather than open investigations.

In hindsight, I realise this formal study, early in my tertiary career, provides an important starting point for this meta-study into my self-identity development as a teacher educator. It facilitated the integration of my personal science teaching and learning experiences as a practitioner with findings from both my own scholarship and the wider science education research community. For example, my doctoral findings convinced me about the worth of scientific literacy as a curriculum goal and that authentic science learning experiences should lie at the heart of pedagogy (*orientations toward science education teaching*). Also certain seminal papers I encountered in my doctoral research strongly influenced the pedagogical approach I was to develop for my pre-service science education courses (see later).

My First Year as a Science Teacher Educator

With this experience behind me I was feeling reasonably confident of my ability to take on my new career as teacher educator and education researcher. Obviously any new position requires a period of transition where you learn different procedures and gain institutional knowledge; however, the reality of the tertiary sector proved to be far more complex than I had anticipated. My confidence quickly dissipated as uncertainty about the precise nature of my new role began to grow. Naively I had assumed the teaching component of my position to be a straightforward matter, and simply a continuation of my practice as a secondary teacher. That assumption was very quickly challenged when I was presented with the documentation outlining the courses in my tertiary teaching programme. My first reaction was surprise and a polite request, "Where is the rest?"

My surprised response to the university teaching guidelines must be seen in the light of my previous experience as a teacher and reviewer in schools. Our schooling environment in New Zealand is underpinned by national curriculum and qualification policy that is detailed in carefully structured curriculum documents and assessment specifications. Secondary schools in turn typically have detailed guidelines for teachers in the form of schemes of work and resources aligned with national policy. In contrast, my first impression of university curriculum policy and guidelines was one of disbelief at how broad and vague they were! The short paragraphs in the University calendar describing each paper and the course outlines together provided little more than a brief summary of the course content, a list of learning outcomes assessment requirements and a reference list. After frantically searching for more information on the specifics came the realisation that the specifics were my responsibility – I recall the unnerving experience of becoming a novice again! Suddenly in an unfamiliar context I was struggling with decision-making about learning content, pedagogical approaches, resource materials and modes of assessment for courses with rather esoteric goals and student cohorts I had never taught before. With less than 1 month before teaching was to begin the task of course design seemed almost overwhelming, compounded by the fact I was in my final year of my doctorate! I had some big curriculum design decisions to make in a very short period of time! As it turned out many factors, both past and present, had strong influences on how those decisions were made.

Influences on My Curriculum Design from the Past and Present

Fortunately in that first year I was only required to teach two courses – one preparing post-graduate student teachers for secondary science teaching (which I sole-taught) and the other introducing first year undergraduate primary student teachers to science teaching (co-teaching i.e., teaching four out of seven parallel classes). The learning outcomes of both courses indicated that I needed to:

1. familarise students with the structure and requirements of the *Science in the New Zealand Curriculum* (Ministry of Education, 1993), including how to use this national policy document to plan effective classroom science lessons and units of work;
2. promote constructivist views of teaching and learning;
3. give recognition to the diversity of students entering the course;
4. encourage the reflection and evaluation of teaching and learning processes; and
5. promote safe laboratory practice and management.

Reflecting on these outcomes I began to appreciate that I was no longer teaching science per say, but rather I was teaching people *how to teach science* (*knowledge of science education curriculum*) What is more, my prior teaching experience and doctoral study actually gave me deep understanding of what these learning outcomes entailed and the intricate professional knowledge that underpins their mastery. The task for me was to devise instructional strategies in lecture/workshop sessions that provided authentic learning experiences i.e., activities that mirrored teachers' day-to-day lives in classrooms (*knowledge of instructional strategies*). Thus in the month before teaching I started the process of planning for the first lectures and workshops by breaking down the rather broad learning outcomes into more specific learning goals, selecting appropriate content and designing learning activities that might be suitable for groups of students about which I knew very little. A month later I had the first few weeks of workshops mapped out but little more, as I was also trying to put time and thought into the last year of my doctoral study – not the ideal situation to be in when starting a new academic career!

I began that first year with no real conception of how a science teacher education class should function and felt quite isolated. I had sole responsibility for the secondary science paper, but was fortunate to have another colleague in a similar situation to me. She was beginning her full-time career as a teacher educator in primary science and senior biology and had some previous experience teaching in teacher education. We were able to co-plan in the primary science course, and although we did not team teach as we were assigned separate classes, this experience did help me with instructional and assessment strategies that could be translated into my practice in the secondary course. I settled into a pattern of planning teaching sessions a week ahead, selecting what content I thought applicable from my existing knowledge to the task of teaching student teachers how to teach science, while at the same time processing the incoming information about the new educational context. Looking back, these instructional decisions involved synthesis of a tentative form of PCK, which was very soon put to the test. Through that first year, using a 'trial and error' form of pedagogical reasoning and action, I began to accumulate some of the knowledge underpinning the components of an expert's PCK in science teacher education. However, I was acquiring a rudimentary form of PCK through a haphazard and at times quite stressful means, particularly when certain of my pedagogical decisions did not produce the learning I had anticipated and/or hoped for. For example, setting the students planning tasks without sufficient recognition on my part of the pre-requisite pedagogical skills and knowledge they would require to carry out such professional activity with any degree of success would be one instance of a decision I needed to rethink to improve my PCK (notably, *knowledge of learners' characteristics*).

Despite this uncertainty, these 'errors of judgment' contributed to my growing knowledge of the learners in front of me and I found myself drawing increasingly on their specific learning needs for direction in my course design. As I discovered there were distinct differences between groups of student teachers when it came to the educational context for which I was preparing them i.e., for primary and secondary schooling (*knowledge of learners' characteristics*).

Growing Awareness of My Students' Learning Needs

The emerging learning needs of my primary student teachers typically turned out to be dispositional (becoming motivated and interested in science) and content-related (building their science content and curriculum knowledge, and their PCK). These needs stemmed largely from their lack of science content knowledge and feelings of low self-efficacy about their ability to teach science. Many showed disinterest in science and reported school experiences that had put them "off science". The literature reflects similar trends (e.g., Hipkins & Bolstad, 2008; Kenny, 2010; Nilsson & van Driel, 2010).

My secondary science student teachers on the other hand arrived in the 1-year programme with science degrees and varied backgrounds, some as former scientists or in science-related careers and some straight from university. As I discovered, they came with a wide range of prior experiences and views on the teaching and learning of science within the class. Reflecting back on my own science teaching career, I remember my impressions of such student teachers as they engaged in their first classroom teaching experiences. Despite their science qualifications they seemed unsure in their science knowledge, over-crammed lessons with content pitched at levels way above their students' capabilities to comprehend and overused transmissive modes of teaching. I witnessed their frustrations and at times denial that the problem may lie in their teaching. Loughran, Mulhall, and Berry (2008) report these novices often lack a deep conceptual understanding of science and display disjointed and muddled ideas about particular science topics. They are unable to focus on ensuring that their students develop the key ideas that are needed for science understanding and to appreciate that 'less is more' (Gess-Newsome, 1999).

When first observing and critiquing my secondary student teachers on teaching practice in real classrooms as a university field supervisor, I became aware many of them found adapting to a pedagogical role in real classrooms difficult. It's my belief these students were experiencing for the first time an educational programme with a professional orientation rather than a focus on mastery of a knowledge domain, which did create tensions. For example, some struggled to understand why their students appeared unmotivated and found science difficult, especially when they themselves had been successful learners in science and enjoyed it. These experiences taught me that my secondary student teachers' learning needs were primarily content-related, pedagogical (especially PCK), and learner-related in terms of developing their capacity to perform successfully as teachers of science (*knowledge of learners' characteristics*).

The Role of a Tertiary Teaching Qualification in Promoting My PCK Development

Six months into my first year I began to receive support from the University in the form of a series of professional development sessions that all new academic staff were required to attend as part of our induction into university teaching. These cross-faculty workshops dealt with generic aspects of teaching University courses where participants had the opportunity to discuss the content as it applied to their discipline area, exchange ideas and receive feedback from course members and the facilitator. The discussions were immensely valuable for me in identifying the differences between teaching in the university and school contexts and some of the issues that I needed to give careful thought to, like: teaching and learning goals that encompassed the notion of scholarship and the autonomous learner; the content of my courses; and appropriate teaching and assessment methods for a university learning environment.

It was during this induction programme that I was made aware of a qualification known as the Post-Graduate Certificate in Tertiary Teaching (PGCertTT). This University of Waikato qualification was designed to encourage both emerging and experienced tertiary teachers to purposefully draw on scholarship to assist in the design of teaching and learning initiatives. The qualification targeted the improvement of teaching practice by helping lecturers to conceptualise their pedagogical philosophies and goals more clearly i.e., develop a self-identity as a tertiary educator (teacher educator in my case). Study for this qualification involved research into your own practice, which had instant appeal for me because I could see ways to combine research (a requirement of my academic position) with my teaching – tertiary staff undertaking this qualification were actively encouraged to publish their findings. So after completing my doctorate, I enrolled and began formally engaging in scholarship to enhance my tertiary teaching.

Shaping My Pedagogical Practice Through Scholarship

In the PGCertTT workshops our lecturers encouraged us to be reflective practitioners and our keeping of personal reflective journals was promoted. These journals became data sources for subsequent professional tasks and assessments. My first learning task for the PGCertTT required me to identify examples of how scholarship was shaping my pedagogical practice [Note: For a full account of my response to this task see Hume (2008)]. I chose first to detail the influence a paper by Nuthall (1997) was having on my practice. In this paper Nuthall brought together three closely inter-related perspectives on learning that were shaping educational thinking and development in the late twentieth century in the hope that this amalgamation would facilitate advances in pedagogy and learning outcomes for students. He argued these three perspectives on learning – constructivist, sociocultural and linguistic – have a synergy that encapsulates classroom life and if considered together have the potential for improved classroom practice. I explored his views of learning in greater depth as applied to science teacher education along with the work of other authors (e.g., Barnett & Hodson, 2001; Leach & Scott, 2003; Skamp, 2004), and in my paper for the PGCertTT discussed the manner in which these perspectives on learning were being manifested in my tertiary pedagogy.

Nuthall's paper had provided me with a more holistic understanding of how science learning occurs, so when beginning work on my own design of the secondary science education course I realised some of the existing learning outcomes needed rethinking. In particular, a learning outcome that promoted constructivist approaches in the course needed to be more inclusive of the other perspectives supporting my philosophy on the teaching and learning of science. Thus I modified this outcome to read that on completion of this course students will be able to "*apply constructivist and sociocultural approaches to the teaching and learning of science*". I chose not to formally include the linguistic perspective at this stage simply because of my own fledging knowledge in this field. I believed I could introduce elements of this view within the other two approaches where and when I felt it appropriate, for example, as a component of scientific literacy (*knowledge of science education curriculum*), and as an integral feature of my pedagogy for teacher education (*knowledge of instructional strategies*).

To infiltrate more scholarship into the course I also introduced a series of small professional tasks (about eight in total) for the students that are assessed on a 3-point scale of achieved, merit and excellence. These tasks usually involve analysis and interpretation of professional readings related to various topics in the course. For example, in one task they were to locate a research paper dealing with the teaching of scientific inquiry and share the major message of the paper with others in small groups in class. Key emerging ideas were in turn shared with the whole class in report backs. Students commented in course evaluations on how worthwhile they found this activity for raising their awareness and deepening their understanding of particular issues in this area of teaching and learning. This strategy proved very effective for monitoring my students' learning progress, especially when I later introduced reflective writing that targeted some of these tasks (*knowledge of assessment*).

Other scholarship to have a strong influence on the nature of my course design was again a seminal paper, this time concerning a foundation for teaching reform. The paper "*Knowledge and teaching*: *foundations of the new reform*" (Shulman, 1987) was informed by philosophy, psychology and a growing body of knowledge gained from case studies of the practice of young and experienced teachers. In seeking to promote teaching that emphasises comprehension and reasoning, transformation and reflection Shulman observed that good teachers utilise a complex knowledge base gained from a range of sources or "domains of scholarship and experience" (Shulman, 1987, p. 5) for understanding. To deal with the complexity of the knowledge base good teachers draw upon Shulman proposed a number of categories. These categories include:

- content knowledge;
- general pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organisation that appear to transcend subject matter;
- curriculum knowledge, with particular grasp of the materials and programs that serve as "tools of the trade" for teachers;
- pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their special form of professional understanding;
- knowledge of learners and their characteristics;
- knowledge of educational contexts, ranging from workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures; and
- knowledge of educational ends, purposes, and values, and their philosophical and historical grounds. (p. 8)

I introduced Shulman's paper early in the secondary science course to provide students with a sense of direction for the course. It seemed to me that the students taking this course were beginning a process of enculturation where they would be progressively learning and expanding upon their categories of knowledge as depicted as depicted above (*orientations towards teaching science education*).

Over time this Shulman framework became my planning tool for designing the course content and structure and a reflection tool for students to monitor their learning progress in the course.

My First Piece of Action Research

A second task for the PGCertTT required me to research a teaching and learning initiative I had introduced into my teaching, for which I chose use an action research design known as *practical action research* (Creswell, 2005, p. 9). This form of action research I conducted within an interpretivist paradigm using a case study approach (Bryman, 2008; Cohen, Manion, & Morrison, 2007). It involves a dynamic, flexible and iterative methodology that allowed me as researcher to spiral back and forth between reflections about the problem, data collection and action. The spiral of generic steps can be entered at any point and time appropriate to the problem under investigation. [Note: For a full account of the steps in the model as it applied to my first initiative I refer the reader to two papers published out of this study i.e., Hume (2008, 2009)]. There are few restrictions on data gathering methods in the practical action research design, so 'fitness for purpose' informs decision-making around data collection (Cohen et al., 2007) and collaboration with other researchers or mentors is a characteristic feature. Data collection in my first research project included personal field notes (my journal reflective notes), students' reflective journals, and interviews. A thematic approach (Braun & Clarke, 2006) proved to be most appropriate for data analysis. Fellow members of the PGCertTT course and the course leader mentored me through this research process for my first initiative, with the course leader also acted as a co-researcher when she interviewed the student teachers on completion of their course.

The teaching and learning initiative under investigation in this first action research project involved the use of student reflective journals. These journals were to serve two purposes: as a metacognitive tool for the student teachers; and a means of providing me feedback about their learning in my workshops and on their teaching practice in schools. The first analysis of the student teachers' reflective accounts yielded somewhat disappointing findings in that their comments tended to be descriptive and lacked depth of thought. However, from their comments (or lack of comments) I was alerted to elements of the course content that needed reconsideration, or in some cases adding to the course content, such as assessment for qualifications. I used this information to help design the workshop sessions and tasks for the remainder of the course (knowledge of science education curriculum).

Enhancing an Instructional Strategy

Despite the sketchy nature of these early student journals I was encouraged by insights I was gaining from my own professional and academic learning to continue their use in the course. In the research literature I found strong evidence that a more structured approach to the teaching of reflective writing can promote greater understanding of learning how to learn in a given discipline area (Moore, 2005). In the context of teacher education it has been found that intentional targeting and scaffolding of reflective skills embedded in authentic learning experiences supports higher quality thinking about teaching and learning (e.g., Bain, Mills, Ballantyne, & Packer, 2002; Moon, 1999). So over the next few years, to encourage my students to engage in purposeful and regular reflection, I progressively set in place guidelines for journal keeping and various means by which students could recognize and measure their learning progress. All these incremental steps I evaluated through ongoing action research. Support for students' reflective capabilities involved the use of 'Shulman's Framework' (see Fig. 17.1 below), which was my diagrammatic representation of the knowledge base for teaching concept (Shulman, 1987).

A pro-active approach on my part, including overt reference to Shulman's framework in workshops when appropriate and in the assessment criteria for their journals to 'remind' students of its role in their reflection, brought some success as student comments began to focus more on the effectiveness of workshop and classroom activities for learning rather than descriptive detail. As I delved further into the literature on journal writing though, it became clear that reflection was a far more complex and multifaceted activity than I had first thought (e.g., Dart, Boulton-Lewis, Brownlee, & McCrindle, 1998) and I was really only scratching the surface in relation to my own understanding of the nature of reflection and devising pedagogies for acquiring reflective capabilities. For example, as I began to appreciate subtleties like differences between the 'focus' of reflection (the nature of the event, observation or issue being reported) and the 'level' of reflection (the degree to which the student

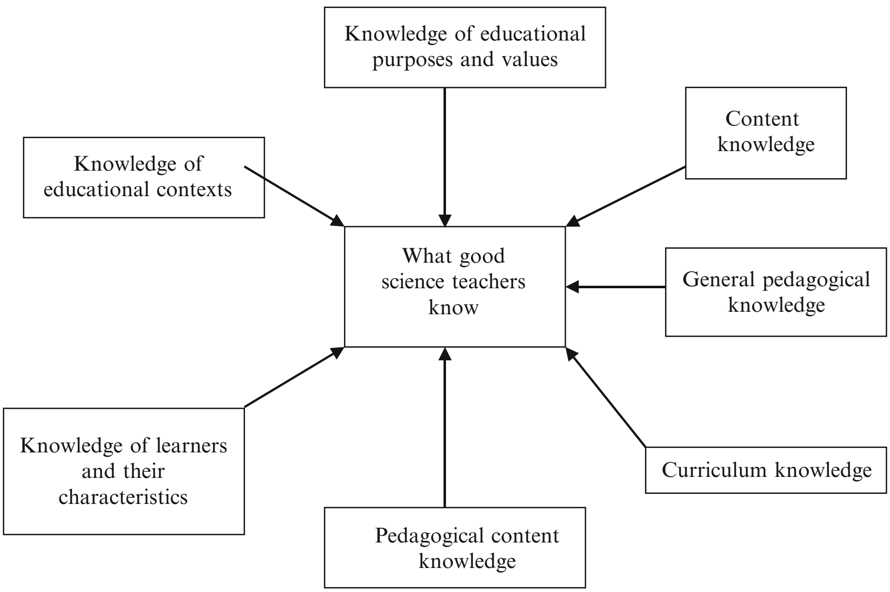

Fig. 17.1 Shulman's framework (After Shulman 1987)

has worked with the subject of reflection and the level of analysis/reflection reached) (Bain, Ballantyne, Packer, & Mills, 1999), I grasped that my ability to detect and discriminate quality in reflective writing needed honing and my students had had little/no experience of what good reflective writing actually looked like or practice in doing it!. I had also overestimated my students' understanding of the ideas that underpin the Shulman framework and therefore their ability to relate these concepts to their classroom and school experiences as novice teachers.

These findings were fed back into my teaching in ways that I believe led both directly and indirectly to a deepening of my PCK for the secondary science programme. For example, I began explicitly sharing the pedagogical reasoning behind my own teaching in the workshops with my student teachers in ways in ways that modeled the reflective thinking I wanted my students to engage in (*knowledge of instructional strategies*). I also introduced the Bain et al. (1999) levels of reflective thinking schedule to the student teachers to help them gauge the quality of their metacognitive thinking. To give them opportunities to practice their reflective skills I provided learning activities in workshops designed to challenge their pre-conceived ideas or expose them to new ideas, after which they were required to write reflectively on their learning. All students were given written feedback and feed forward comments on their writing in relation to the Bain et al. levels and with students' permission I shared samples of their writing, which I believe exemplified higher/deeper levels of reflection with the whole class (*knowledge of assessment*).

Over a relatively short time the overall quality of my students' reflections improved considerably and became a valuable source of insight, along with data from their end-of-course interviews, about the effectiveness of different pedagogical strategies I had employed in the course e.g., the use of controversial statements about science for extracting views on the nature of science in the postbox strategy (participants 'post' their anonymous views in a box sitting next to the statement); concept mapping; and collaboratively designing, performing and reporting fair test investigations. Here in her reflective comments my student Mary (pseudonym) gives me assurance that the sharing of the student teachers' views in the postbox strategy enhances their understanding of the nature of science.

> I felt that the post-box technique is a very useful tool for opening up my way of thinking about science. During the process I was more aware of my views and able to discuss and listen to others' point of views. In some cases I was able to 'see' things in a different way such as the statement of science is an unbiased, value free activity. The way I saw this statement was quite different from others as many saw this as value of life etc. … It was helpful to see different views and I felt overall was very effective. (Hume, 2009, p. 254)

(See Hume 2009 for a fuller account of my research into reflection journals).

My Emerging Philosophy of Teaching

The last PGCertTT task helped me to reflect upon and articulate another of my evolving PCK components, namely my *orientations towards teaching science education*. We were asked to compile teaching portfolios – one a personal portfolio tracing our teaching careers in ways that illustrated how events and experience had shaped our beliefs about teaching and learning and influenced our pedagogical approaches; and the other a career portfolio that might be used alongside a curriculum vitae for promotional purposes or job applications. The career portfolio was to include a personal teaching philosophy. The exercise of formulating my teaching philosophy proved very beneficial in bringing coherence to my teaching of the science education course – I can see now I was rationalizing my decisions about course content, pedagogies and assessment methods through their alignment with my underpinning teaching beliefs and goals related to science teacher education. Here is an extract from my teaching philosophy from my career portfolio that documents my emerging *orientations towards teaching science education*:

> Currently, as an educator of pre-service student teachers in science, I am aware that I have the added pedagogical challenge of teaching students how to teach. My teaching involves inducting students into a professional role that draws upon an extensive knowledge base gained from a range of sources or "domains of scholarship and experience" (Shulman, 1987, p. 5) such as discipline(s) content knowledge, educational research, educational contexts and materials and perhaps most importantly classroom experience. I need to instill in my students the understanding that teaching is a skilled and purposeful activity requiring a form of 'pedagogical reasoning' (Shulman, 1987), which is an acquired, often tacit professional capability that comes from the wisdom of practice. To provide learning environments that enable novice teachers to gain these insights into the nature of teaching is no easy matter. Consequently in my teaching I have sought to 'lay bare' my own pedagogical reasoning in ways that illustrate the thoughts processes I employ as I teach and in so doing exemplify/model strategies that the students can begin to utilize in their own learning of how to teach. (Personal career portfolio, 2008)

In summary, my involvement in the PGCertTT programme, in particular the action research aspect, gave me the means for ongoing development of my PCK over the following years. It also helped to establish my self-identity as a science teacher educator by providing the raw material for publications (one international and two national journal articles) and the wherewithal to identify new opportunities for action research and future publications in the hiatus period after my doctoral study. Research into my own tertiary teaching became my prime research agenda with the focus turning to my other teaching programmes, namely chemistry and primary science education. In the latter part of this chapter I shall recount how the purposefully planned and researched introduction of interventions into these programmes produced improved outcomes for my students and publications that bolstered my academic career and sense of self-identity.

PCK as a Focus for My Research Agenda

When I was handed the chemistry course to teach in my fourth year, I was far better placed to develop the PCK of an expert chemistry teacher educator than I had been 3 years earlier. For one thing I had deepened understanding of what PCK for chemistry teaching and for chemistry teacher education might encompass, particularly through application of the PCK model of Magnusson et al. (1999) in my pedagogy.

Assessing my PCK for science teacher education at that stage of my tertiary career, I can see now that my articulation of my orientations towards science teacher education was happening with greater conviction and clarity and my knowledge of the university education sector and its practices was more in depth. In all my courses I had heightened awareness of my learners and the range of experiences and beliefs about teaching science that they potentially brought to their learning about how to teach science. I had devised a repertoire of instructional and assessment strategies in secondary science education that fortunately translated readily into the chemistry course. This underlying knowledge gave me a much firmer base on which to begin developing my PCK for chemistry teacher education. More importantly, my growing competence, interest and confidence in researching my own practice drove me to look for more research opportunities. It was not long before my next project was underway as I focused in on one component of my PCK for teaching the chemistry education course that did need consolidation i.e., my own curriculum knowledge for chemistry education.

Content Representation (CoRe) Design

In my academic reading and attendance at science education conferences I came across the work of Loughran, Berry, and Mulhall (2006, 2008), who were using Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs) to explore experienced science teachers' PCK. A CoRe (as originally developed) was a framework for portraying the collective overview of expert teachers' PCK related to the teaching of a particular science topic. Each CoRe diagram has a set of related PaP-eRs exemplify the collective PCK of a group of expert science teachers for particular science topics and groups of learners. Loughran et al. were aiming to use CoRes and PaP-eRs as tools in teacher education for revealing the largely tacit professional knowledge of experienced and capable teachers. Their work to date had produced these resources for a selection of junior secondary science topics. It occurred to me that CoRe design for specific chemistry content (topics) and particular groups of students could be a potentially useful instructional strategy for my chemistry student teachers as a means of building a foundation for their future PCK – a form of hypothetical PCK that they could test when planning and teaching the topic for the first time. My research aim was to determine what role CoRe design might play in the initial PCK development of my student teachers. Collaborating with my students might also grant me space to sharpen up my PCK for senior chemistry education too!

CoRe design proved to be a complex task for the student teachers and I because we needed to draw heavily on our knowledge of current curriculum content, assessment for qualifications and teaching experience. Given I had not taught the topic for 7 years and the students were novice teachers, we struggled initially. The process entailed the identification of key ideas to be learned in a specific topic (we chose Year 12 Redox chemistry), accompanied by an analysis that includes: a justification for choosing each of the key ideas; difficulties students may encounter learning these ideas; related misconceptions students may hold; appropriate instructional sequences and strategies for the intended learning; and finally the means for monitoring the learning. To complete this design task requires thorough familiarisation with the content to be taught, the sources of that content and the rationale for that content choice. Working with students to help them complete their CoRes enabled me to re-familiarise and/or update my knowledge of current national curriculum statements, qualifications requirements, common chemistry misconceptions, and sources of appropriate instructional strategies such as text, electronic resources and the Internet (*knowledge of curriculum for science teacher education*). As well, the systematic gathering and interpretation of data from sources such as my workshop observations and reflections (recorded as field notes in my reflection journal), students' reflective journals and artefacts (their finished CoRes) produced convincing evidence that the students were building sound foundational PCK through CoRe design (Hume & Berry, 2010). The students themselves firmly believed in their professional growth when interviewed on completion of the course. I found the act of researching CoRe design had simultaneously deepened my knowledge of what curricular content I needed to teach in this course and allowed me to synthesise new PCK.

Armed with CoRe design data I visited Amanda Berry in Australia to seek her help with data analysis on my first sabbatical overseas in 2009. Amanda was one of the original CoRe and PaP-eRs research team and our collaboration, based on findings from my research into CoRe design as a professional learning tool, has since produced two papers (Hume & Berry, 2010, 2013) and a number of international conference presentations. With her support I extended this research the following year by involving associate teachers (school-based mentors) who work with my chemistry student teachers on their pre-service teaching practice in schools.

This second phase of CoRe study was carried out with a new cohort of student teachers. As in the earlier phase, student teachers in the course first prepared a series of chemistry CoRes in collaboration with one another in small groups during university workshop activities. However, this time each student teacher prepared an additional CoRe for use on the second of their two teaching practices. Each student teacher was required to contact their prospective associate teacher in advance to determine which topic(s) he/she would be allocated for their senior chemistry teaching, and one of these topics became the subject of their individually constructed CoRe. Once draft CoRes were completed, the associate teachers were invited by each student teacher to view their respective CoRe and discuss how the CoRe content might relate to teaching the required topic on teaching practice. During these discussions additions and/or modifications to the CoRes were agreed upon and the students then planned and taught a series of lessons based on these collaborative CoRes supported by the associate teacher. On completion of the teaching my student teachers wrote an evaluation of the collaborative CoRe design experience (including the initial collaborative task and initial unit design and enactment), which they submitted to me as an assessed course task. Full informed consent was obtained from the associate teachers to be involved in this research.

The student teachers' CoRes, planning documents, evaluations and post-interviews confirmed again that CoRe design was very useful in establishing their foundational PCK and the added opportunity to enact and evaluate their tentative PCK in real classroom situations an added boost to their professional learning. Their comments also revealed that they valued the use of CoRes as a focus for authentic professional discussion with their associate teachers and the involvement of their associate teachers in CoRe design: particularly their interest and preparedness to share their expertise and provide support as they enacted their CoRes in classrooms (Hume, 2013). From the data we were able to infer that the CoRe design task appeared to give these associates the opportunity to engage in deeper aspects of modeling and mentoring through purposeful pedagogical discussion, allowing student teachers access to the knowledge of experienced classroom practitioner. Issues, such as the rationale for curriculum design decisions, could be aired, explained and debated during processes of critical reflection, which are so often missing in the practicum experience for expert teachers and student teachers (Sanders, Dowson, & Sinclair, 2005). In some instances the draft CoRes served as points of reference for both parties as student teachers start to test their own tentative PCK in classrooms with real students under the guidance of their associates – something not possible in my university course. Working together, as an extension of my course work, the associate teachers helped the student teachers to develop PCK by providing ongoing credible feedback, advice and feedforward comments stemming from the draft CoRe content and their own professional knowledge. I gained a real sense of working in partnership with professional mentors to provide improved learning opportunities for my student teachers – an extension of my academic teaching role [For full accounts of my CoRe design research see the Hume and Berry (2010, 2013) papers].

Addressing Ethical Issues

In the second phase of CoRe investigation, my collaborator Amanda carried out the post-interviews, on my behalf, as part of a new strategy to help minimize researcher bias (Erickson, 1998) and to address ethical issues, which I was being challenged on from some quarters within my faculty. From the outset, in preparing applications for university ethics approval to carry out my action research, I had to consider the ethics surrounding research into my own practice. This extract from my 2007 ethics application shows an example of a key issue I considered i.e., the potential for conflict between my role as teacher and researcher and harm to the participants, and how I sought to address it.

> An ethical issue that I will address concerns my position as the course lecturer and possible conflict of interest situations that I may find myself in since I am also the researcher. As the course lecturer I am required to assess the student teachers' progress and achievement of the course aims and objectives. The journals are one source of assessment evidence that I use in my judgements of the participants' level of success in the course. In these journals the

> student teachers are required to reflect on their experiences, both on practicum and in course workshops, using a metacognitive framework centred on Shulman's (1987) knowledge bases for good teachers. The quality of these reflections in relation to the framework was assessed in an ongoing, formative manner during the course and will contribute to an overall summative judgement I make at the end of the course. I was open with the students that their reflections would assist me to plan sessions and tasks for them during the remainder of the course. Thus I believe the potential for student teachers to perceive this evidence as detrimental to their progress in the course, since it was being used for assessment, was minimised because they were able to witness my responses to their reflections in subsequent programme planning and delivery.
>
> The fact that I am requesting student teachers' permission to use their journals retrospectively, that is, after assessments for the course have been finalised, contributes to the credibility of the data. It also helps avoid the conflict of interest situation that could arise when the same data is used for assessment purposes and for research. The interviews will also be held after assessments for the course are finalised.

A very experienced researcher in education at my university suggested the requesting of informed consent retrospectively as a way to minimize the potential for harm, and my ethics approval was granted. However, several years later in follow up applications, members of the Faculty Ethics Committee questioned my keeping of a personal reflections journal during the research, in that students were unaware I was recording my thoughts at that time for research purposes. I was reluctant to change the timing of seeking informed consent since it might compromise the credibility of my data and potentially increase the perception by the participants of researcher coercion and bias (Erickson, 1998). I made a point of raising the issue in our faculty at a number of forums various forums for discussion. Most academic staff were supportive of my stance, but key people on the Ethics Committee were staunch in their view that I needed to inform students <u>before</u> I wrote anything reflective that my notes were going to be a data source for research. Thus I made the decision to drop my personal reflections as a data source, but maintained inviting the student teachers to participate in the research after all assessment and grades for the course were finalised. Ethics approval was granted! My reflective thoughts are now gathered and sorted during my long morning swims! It was not ideal, as personal reflective journals provide rich data for the self-study researcher, but a necessary compromise in my situation to ensure the findings of my action research were credible and safety of my students.

Focus group interviews in all subsequent projects were carried out by interested fellow researchers whenever possible (e.g. Hume & Berry, 2013; Hume & Buntting, 2014; Hume & Young-Loveridge, 2011). My rationale was that student teachers might feel more comfortable with a neutral interviewer rather than their teacher, and therefore more open and honest in their conversations. Also the experience and skills of my colleagues, like Amanda, might provide more insights into the student teachers' views on their learning and my pedagogical effectiveness. In all instances my rationale was justified, although at times I must admit to feelings of disquiet and unease when I felt my practices and aspirations were being questioned, both by my colleagues and my students. These 'criticisms' ranged from: questions in interviews that strayed off the planned schedule (Hume & Young-Loveridge, 2011; Hume & Berry, 2010); to different interpretations of conceptual frameworks, such as PCK (Hume & Berry, 2010); to new perspectives on data (Hume & Buntting, 2014); and evaluative comments from students that were not always favourable. I've learned to live with these unsettling feelings because each critique has inevitably led to reflection on my part. Frequently the result has been a rethink of what I am trying to achieve in my pedagogy and why, and a refining of my PCK.

CoRe Use Elsewhere

After the success of CoRe design in the chemistry programme I wondered about its use with primary science teacher trainees. Could it be a tool for building their limited science content knowledge and promoting feelings of self-efficacy for the teaching of science? My concerns lay in the intellectual demands of CoRe design, but I decided to trial it in a second year science option paper where the students had experienced some classroom teaching and they had shown motivation to learn about science teaching by making their course choice. We were also fortunate enough to have access to an innovative web-based resource known as *The Science Learning Hub* (*SLH*) [www.sciencelearn.org.nz], which was developed by teachers and education researchers in collaboration with New Zealand scientists to provide insights into contemporary science research in New Zealand. The project is primarily intended to enhance the science understandings of Year 2–10 teachers. A key feature is the presentation of multimedia content in collections of 'contexts', for example, *Satellites*, *Toxins*, *Light and Sight*, *Rockets*, *The Noisy Reef*, *Super Sense*, *Hidden Taonga*, etc. Each context includes identification and explanation of key science concepts underpinning the context; detailed story-telling about contemporary New Zealand research, presented through text, video and animation; a question bank for initiating teacher and student thinking; profiles of people involved in the work; and examples of teaching and learning activities.

In the past my primary students teachers had dabbled with the SLH, but as it transpired my experiment with CoRe design resulted in a purposeful and planned approach for the primary students to access and navigate the Hub. It's fair to say the students did not find CoRe design easy the first time around and I had to carefully scaffold the process – the risk of alienating the student teachers was very real as they struggled with the concepts but I was confident from my earlier experiences that these challenges would ultimately result in better learning. The benefits came later as they developed science unit plans based on their CoRes and made far better use of the resources the SLH offered. This 'pre-planning' tool, as we termed CoRe design, in conjunction with the SLH provided the primary student teachers with focus and a powerful means for building their professional knowledge for teaching science (Hume, 2013; Hume & Buntting, 2014).

Introducing Role Play into My Pedagogical Repertoire

The last piece of action research I would like to share again involved the second year primary student teachers (Hume, 2011, 2012). As in all my science education programmes, I was attempting to enculturate them into reform-oriented communities of practice (Putnam & Borko, 2000; Wenger, 1998) that exemplify quality learner-centred science teaching and inquiry-based learning (orientations towards teaching science education). Ideally my primary student teachers would experience this apprenticeship model in real classrooms working alongside master science teachers whilst out on teaching practice. Unfortunately, this model is problematic because in reality science has low status in New Zealand primary schools (Bull, Gilbert, Barwick, Hipkins, & Baker, 2010), teachers lack confidence in teaching science and models of exemplary science teaching are therefore not easy to find. There were, however, very good models of inquiry-based learning in science available in the form of professional learning programmes and accompanying resources.

One such example was the resource known as *Primary Connections*: *linking science with literacy* (Australian Academy of Science, 2005) whose stated purpose is "to improve learning outcomes in science and literacy through a sophisticated professional learning programme supported with rich curriculum resources that will improve teachers' knowledge of science and science teaching and thereby improve teachers' confidence and competence for teaching science and the literacies needed for learning science" (p. 1). This resource has at its core a teaching and learning model known as the 5Es, which is closely aligned to the pedagogical approaches and learning goals of the New Zealand Curriculum (2007). This model (see Fig. 17.2 below) 'is based on an inquiry and investigative approach in which students work from questions to undertake investigations and construct explanations. … Assessment is integrated with teaching and learning" (Australian Academy of Science, 2005, p. 2).

Phase	Focus
Engage	Engage students and elicit prior knowledge. *Diagnostic assessment.*
Explore	Provide hands-on experience of the phenomenon.
Explain	Develop science explanations for experiences and representations of developing understandings. *Formative assessment.*
Elaborate	Extend understandings to a new context or make connections to additional concepts through student-planned investigations. *Summative assessment of the investigating outcome.*
Evaluate	Re-represent understandings, reflect on learning journey and collect evidence about achievement of conceptual outcomes. *Summative assessment of conceptual outcomes.*

Fig. 17.2 The *Primary Connections* teaching and learning model

In the literature around developing student teachers' pedagogy and PCK, Lloyd et al. (1998) suggest that lecturers model how subject knowledge and pedagogical knowledge can be amalgamated into PCK in their own teaching. Magnusson et al. (1999) also advocated observing, analysing and reflecting on others' teaching as a means of appreciating/developing PCK. "It could well be argued that teacher educators need to provide opportunities for student-teachers to examine, elaborate, and integrate new knowledge and beliefs about teaching and learning into their existing knowledge and beliefs." (p. 1285).

Thus, I began thinking about creating create a community of learning myself using this resource that simulated a real-life community of practice i.e., classroom science teaching and learning where my students personally experienced learner-centred pedagogy from both the perspective of the teacher and the learner in a role-play. So in a series of eight 2-h workshops I played the role of a primary teacher role teaching a unit called "It's Electrifying" to Year 7 students (11–12 year olds) played by the student teachers. I made sure that plenty of reflective data was generated by the student teachers about the nature of their PCK development as they experienced my role-play pedagogy. For example, as part of their role in the simulation the student teachers were required to keep science journals (a reflective tool used in the Primary Connections approach) as a record of their learning.

While the initial emphasis was on building their topic-specific PCK in the area of electrical circuits, there were also planned opportunities within the workshops for the student teachers to evaluate and reflect on the pedagogy after each role-play episode, that is, their learning of science as the 'students' and their learning about the teaching that supported this learning. In these reflective sessions I helped the students become aware of the nature of their emerging PCK in ways that the student teachers could generalise to other science topics, drawing attention to components of their emerging PCK as described by Magnusson et al. (1999). At the conclusion of the role-play the student teachers were required to write an evaluation of the Primary Connections programme in terms of its suitability for the New Zealand context, as part of their course assessment (more concrete evidence of their PCK development).

Findings from my action research investigation (Hume, 2011) showed the collaborative reflective opportunities had helped my student teachers gain insights into the thinking and basis upon which experienced science teachers might make decisions about their inquiry-based pedagogy for particular science topics/concepts. It also appeared that the personal exposure to inquiry-based pedagogy informed by quality curriculum material in my classroom simulation, and later to an evaluative exercise of the curriculum material, had resulted in my student teachers developing the beginning of reform-oriented PCK. Here also was another instance of my PCK growth (more specifically, *knowledge of instructional strategies*) as I chose to continue this 'experiment' in the course over the following years, fine-tuning aspects that did/did not contribute to desirable PCK development of my student teachers.

Conclusion

I hope this self-study meta-study has given you, the reader, ideas about how research into an individuals' own tertiary teaching can build a sense of self-identify and confidence, particularly during the transition from teacher to teacher educator. The exercise of carrying out the meta-study has been quite cathartic as I looked back on my tertiary career. It's obvious to me now that a number of catalysts kick-started my self-identity development, including: my doctoral study; timely advice and tips from several supportive colleagues both in and outside my university; and participation in a University-wide teaching network whose leadership encouraged me to start and complete a Post-graduate Diploma of Tertiary Teaching. These catalysts provided direction and the means by which to face the challenges of a new career.

My initiation into tertiary teaching did not involve a process of carefully scaffolded induction, but rather one of 'jumping in at the deep end'. It could have been disastrous and at times, if I am truthful, it was quite dispiriting. In retrospect, addressing and resolving some of the issues these early challenges raised was of immense value to my long-term professional learning. It is paradoxical that the challenges placed certain imperatives on the nature of my professional learning, but they also gave me freedom to develop my self-identity in ways that were personally empowering. As a final note, do not underestimate the contribution this scholarly approach can make to your curriculum vitae by way of publications!

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Chapter 18
Trash or Treasure? Re-conceptualizing My Ruins as a Tool for Re-imagining the Nature of Science Teacher Education

Maria F.G. Wallace

Introduction

> *I resisted the path of becoming a teacher. My family and friends, except my mother and father of course, said time and time again, "Why don't you just become a teacher"? Time and time again I responded, "Because that is what I am expected to do". Ironically, my life and simultaneously becoming a teacher occurred out of a path of resistance.*

The purpose of this chapter is to demonstrate ways in which the ontologies of science teachers and science teacher educators are often trapped by prevailing epistemologies. While this self-study was technically conducted during one of the most tenuous times in my doctoral program, it is imperative to acknowledge the becoming (Deleuze & Guattari, 1987) nature of my insights and sense of self examined in this chapter.

As a current doctoral student studying science education and curriculum theory, I actively work to find peace in the ruins of American society. For me, this requires a critical negotiation of ruins influencing American education, yet created by American culture: (a) concepts of rationality; (b) power, resistance, and freedom; (c) knowledge and truth; and (d) the subject (St. Pierre & Pillow, 1999). My critical examination of ways these societal ruins have impacted my subjectivity as a future science teacher educator transforms my inquiry from merely one of enhancing my professional practice into an ethical endeavor. For this self-study and influence from my critical friends, I was challenged to critically engage my onto-epistemological (Barad, 2007) becoming-science teacher educator positionality within complex American ruins shaping the American educational system. More specifically, the objective of this self-study is to depict ways in which the preparation of science teacher educators, and also science teachers, is implicitly and explicitly shaped by

M.F.G. Wallace (✉)
Louisiana State University, Baton Rouge, LA, USA
e-mail: mmaria2@lsu.edu

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dominant structures and discourses of science education. Through this self-study, I engage a critical counter-narrative of development, preparation, and normative conceptions of becoming a future science teacher educator. Asking and exploring difficult questions is often not perceived as a positive and/or solutions-oriented outlook on education, however, I contend that continuous efforts to seek "solutions" or idealistic forms of education, can limit pre-service and in-service educators' sense of self. Furthermore, educators might easily skip over the depths to which capitalistic underpinnings remain engrained in the American education system.

For these reasons I aim to re-conceptualize My Ruins as treasures that aid me in re-imagining the nature of science teacher educator preparation while I prepare for my future work as a science teacher educator. Over my first year and half of doctoral education, I attempted to embrace and make sense of my professional preparation only to realize that it is truly an onto-epistemological (Barad, 2007) endeavor. Without purposefully rummaging each of My Ruins, I recognize the severe implications for my future students (science teachers) and daily interactions that make up my lived reality. This critical autobiographical inquiry, in part, also models the intersection of my three recommendations for future science teacher educator preparation: (1) shifting traditional notions of identity to onto-epistemological becoming; (2) embrace the use of *critical* autobiographical inquiry; and (3) explicitly expose the scientism plaguing education.

Each ruin arose from the pain of recognizing a society built by unquestioned human conditioning in a standardized education system. I aim to disrupt, or resist, this inherent tradition in science teacher educator preparation by exploring ways in which dominant epistemologies influence prevailing assumptions regarding science teacher educator preparation. Similar to bell hooks, "I came to theory because I was hurting–the pain within me was so intense … I came to theory desperate, wanting to comprehend–to grasp what was happening around and within me" (1994, p. 58). This feeling of pain, irritation, and disappointment evolved as I encountered unfamiliar moments, texts, and people while preparing to become a science teacher educator. So here, in this chapter, I set out with the intention of finding peace in the rummaging of My Ruins as a tool for re-imagining how others (science teacher educators) can prepare one to become a science teacher.

Background

Self-study research is increasingly prominent in the field of research on teachers and teaching. As self-study research continues to develop, I assert that it is imperative to conceptualize each piece of scholarly literature as also culturally, politically, and historically situated. Just as teacher self-studies are driven by personal context, the ways in which researchers come to know the practice of self-study continues to be shaped. In the sections that follow, I provide additional background regarding the self-study tradition. Moreover, through my own self-study I strive to demonstrate ways in which science teacher educators can also begin *Thinking with Theory* (Jackson & Mazzei, 2012).

Self-study research originated out of three overarching paradigms framing teacher education: (1) teacher inquiry, (2) reflective practice, and (3) action research (Samaras & Freese, 2009). Each of these themes signal an interesting methodological, ontological, and epistemological shift in research on teaching. Instead of "Teachers primarily [seeing] their responsibility as implementing what researchers told them was valid in their classrooms" (Samaras & Freese, 2009, p. 3), they were re-centered as holding critical knowledge of their students and classroom. Generally speaking, teachers formally and informally examine their practice regularly. The aim of self-study research is to capture and systematize this inherent process to a more rigorous degree. More specifically, Carr and Kemmis (1986) emphasize the connection between action research and the self-study tradition by finding strategic ways to systematize personal problem solving. These foundations to self-study research lead the way for its very nature of analyses and purposes: (a) open, collaborative, and reframed practice (Barnes, 1998); (b) paradoxical through the involvement of critical friends (LaBoskey, 2004; Loughran, 2007; Loughran & Northfield, 1998; Whitehead, 2004); (c) postmodern in nature (Cochran-Smith & Lytle, 2004; Wilcox, Watson, & Paterson, 2004); (d) multiple and multifaceted (Samaras & Freese, 2006). Throughout each of these major tenets of self-study research, Samaras and Freese contend that while self-study research begins privately and personally, it is also public (p. 8). From Samaras and Freese (2006) description, I extend the public nature and practice of self-study inquiry into an ethical one.

Self-study research ignited a movement from merely the reflective practitioner into a common narrative of teacher-led research (Schön, 1987; Zeichner & Liston, 1996). Building off of the reflective practitioner paradigm, the use of self-study research is progressing among teacher educators in an attempt to gain critical insights and capture many of the taken-for-granted aspects of becoming and being a teacher. Resultantly, the methodological processes guiding self-study research challenge teachers to engage inquiry related to their own practice more systematically (LaBoskey, 1994; Russell & Munby, 1992; Zeichner & Liston, 1987).

For my self-study, I draw particularly on Feldman, Paugh, and Mills (2004) description of purpose-driven inquiry, "the collection and analysis of data are used to guide the development of a plan of action or to articulate a critical analysis of the individual and institutional barriers that are shaping their lives" (p. 953). However, my self-study also demonstrates the ways in which dismantling confining structures of traditional Cartesism can serve as a generative space for re-conceptualizing how science teacher educators and researchers' come to "know" their practice and subjectivities. Feldman (2002) continues to frame this self-study by emphasizing the use of real-life experiences to "problematize their selves" with the intention of re-conceptualizing their beliefs and practices (Samaras & Freese, 2009, p. 5). Hamilton and Pinnegar (1998) further influence my self-study by defining self-study as, "the study of one's self, one's actions, one's ideas, as well as the 'not self'" (p. 238). This self-study demonstrates the inherent relationship between Hamilton and Pinnegar's (1998) and Feldman et al.'s (2004) definitions as "autobiographical, historical, cultural, and political and takes a thoughtful look at texts read, experiences had, people known and ideas considered" (Hamilton & Pinnegar, 1998, p. 236). It is through problematization that researchers and future science teacher educators can carve out new spaces for re-imagining the nature of science teacher educator preparation and while also extending the self-study research paradigm.

Theoretical Framework

Researchers, teacher educators, and classroom teachers often overlook the implications structural ruins and decisions have on research findings as well as teacher preparation. By choosing to take up a feminist post-structuralist perspective I negotiate dominant discourses as "items for sale" to dive beyond the surface of the traditional objectified language seeking implications, results, or findings. Bove describes the concerns of post-structuralists as being driven by a different set of questions: "How does discourse function? Where is it to be found? How does it get produced and regulated? What are its social effects? How does it exist? (as cited in St. Pierre, 2000). From these overarching questions, I narrow the context of this study slightly to the field of science education and also use a post-structural form of analysis. Additionally, post-structuralists thrive on re-examining the "known" by bringing forth further questions. It is through this perspective I present my "results" and analyses. Moreover, I contend that teachers, specifically science teachers and teacher educators, are better positioned for their poignant work ahead when they deconstruct the grand narrative of selecting the "right solution" or "right instructional method", and intentionally work to scrutinize, negotiate, and dissect pedagogical content in ways that expose power/knowledge structures.

Situating the Study

The path to employing a feminist post-structural theoretical framework was inadvertent, yet appropriate. My ability to understand and recognize the power and importance of feminist post-structuralism arose from a life-changing course in my second semester of doctoral preparation called "Traditions of Inquiry". I was thrown into a group book project for my final paper where we were to explore St. Pierre and Pillow's (2000) compilation of personal essays entitled, *Working the Ruins*: *Feminist Poststructural Theory and Methods in Education*. Then several weeks later in a midst of frustration, confusion, and sadness, the professor prompted another life-changing endeavor. She asked, "What are your ruins"? So here, in this space I cautiously, yet diligently share My Ruins with the objective of exposing new terrain for the preparation of future science teacher educators.

Across and within many platforms ideas are presented linearly, yet this approach underrepresents the creative cognitive and soulful journey I took to identify My Ruins. Similarly, my self-reflexive inquiry leads me through many unexpected mental bifurcations resulting in three blurry demarcations I call My Ruins: (a) science as almighty and how the perception of scientific method influences the nature of science teacher preparation; (b) traditions in American culture and their influence on teacher preparation; and (c) tension with the "women in STEM" movement.

Throughout the chapter I have organized this dynamic pursuit similar to the structure of a garage sale. Hermann (2011) describes how garage sales often serve as an American rite of passage signaling a major shift in life orientation; physically and psychologically. Over the past two years my mind and heart feels increasing similar to exploring neighborhood garage sales. I wonder if this feeling is ultimately the rite of passage to earning a doctoral degree? When I first started this journey, I sought out a specific item, a doctoral degree, not anticipating the level of difficulty present when negotiating the enduring implications of each thought. This internal bargaining led to a painful, yet necessary, ontological and epistemological revolution to re-conceptualize my experiences from trash to treasure. Over the course of my first year, I experienced and continue to struggle with understanding my own identity as an educational researcher/future science teacher educator in relation to each "item for sale". During my initial month of the doctoral program, I claimed that I "thought and wanted to conduct research practically"; however, at the close of my first semester I articulated an emotional dilemma around the popular "women in STEM" movement, then in my 11th month I experienced an inadvertent epistemological shudder (Charteris, 2014). Each epistemological and ontological dilemma has relentlessly driven me to engage in a critical and complex autobiographical inquiry to inform my future work with all persons, that is scientists/teachers/students/humans.

Before examining the data (moments in my life and doctoral preparation) I must clarify that there is some degree of difficulty using the language of science teacher preparation and that this concern, in and of itself, is also a necessary topic needing address in the complicated conversation of science teacher preparation. For example, framing the definition of "science teacher educator" and "pre-service science teacher" preparation is difficult because they are not inherently two different processes of becoming an educator, since I see a need for critical autobiographical inquiry for both degrees of preparation. When we use the term "science teacher *educator*", this implies that future science teachers come *without* some form of information that us, as science teacher *educators*, must have and give to our "students". For me, these relationships are a matter of exposing one's ability to already know and then collectively negotiate the understanding among all participants in the preparation process. Each student is a teacher and every teacher is a student. Autobiographical inquiry draws this symbiotic relationship out of all participants in science teacher preparation. Furthermore, without acknowledging our ontological experiences we inherently eliminate our primary approach to knowing. In this self-study the terminology, discourse, and the unspoken message play an important role in constructing the emerging path leading me to become a science teacher educator/student.

Methodology

The methods used in this study draw on the post-structural process of reflexivity and use of rhizomatic analysis (Gough, 2006). Higgins (2014) describes rhizomatic analysis as working "against the reductionism of conventional coding methods through productively putting to work a network of connectivities and relationships between theories, practices, data, ethics, and other bodies of knowledge and being that are always already becoming" (p. 157). In my critical analysis I draw on three influential cultural experiences that underpin the tensions I explore in my preparation as a future science teacher educator. It is in these in-between sites that I methodologically *get lost* (Lather, 2007) in the data. Rhizomatic analysis (Gough, 2006) and *getting lost* (Lather, 2007) is not a matter of "losing one's way (i.e. losing sense of where one is and where one might go) but rather as losing *the* way (i.e. losing sense of there being *a* way that is singular and definite)" (Higgins, 2014, p. 157). I intentionally interlay data and my analysis together to demonstrate the inherent messiness of critically examining oneself. To make sense of the data is rarely ever linear and by *getting lost* in the data I open up new ways of being with and knowing the data. As Loughran (2007) states, "there is no one way, or correct way, of doing self-study. Rather how a self-study might be done depends on what is sought to be better understood" (p. 15).

This self-study was conducted intentionally and inadvertently. Over the course of my first year and a half of doctoral education I organized my course notes into two primary sections: (a) notes on the material being discussed; and (b) my attempt to negotiate the relationship of the material to my subjective culture. For example, the data presented is the result of a compounded set of frustrations discussed in a two-month long Summer course. This time and space became a formal site of analysis and community of critical friends. However, it is imperative to note the critical friends in this formal classroom space expanded beyond this particular class and onto the outdoor benches found around campus. In these critical conversations, my critical friends, consistent classmates and formal doctoral education, my sense making was implicitly and explicitly guided.

Each of my classmates' responses to and mediation of my seemingly nonsensical worries and questions were also influenced by their personal cultures of the self. From prior teaching experiences in the United States and China, to Eastern wisdom traditions, African philosophies, and diverse racial and gender experiences, my classmates served as mediators to my self-reflexive study. These individuals and my coursework play a role in my intrinsic negotiation of self and practice. Below I have included an example of my raw annotations from a class where I first exposed my deep underlying tension:

> *Maria's annotation*: *Is the tension in your heart or your mind? Supposedly, the heart has neurons…. Can the neurons in one's heart create synapses?*
>
> *Maria*: *How and what does science privilege?*

Maria's annotation: tension in scientific method
Material annotations: The process of experiencing things in the in-between spaces (Gattamer)
Material annotations: Dewey is kind of "in-between".
Material annotations: Creation is the result of influence.
Material annotations: It's through our social interactions that we move from being a person to a human.
Material annotations: Western epistemologies are privileged, but now there is shift to understand and utilize Eastern epistemologies.
Maria's annotations: What epistemologies or whose epistemologies are being left out? Why?
Material annotations: The Chinese approach to "knowing" is through meditation.
Material annotations: Scientific method is the method of thinking-Dewey
Maria: Can culture be taught and if so, is it ethical?
Maria: How are the pathways of meaning-making different for pre-service, traditionally certified teachers in their induction phase and alt. cert teachers in their induction phase?
Maria: So what do we call "learners" and "teachers"? What should we call "learning"?
Maria: By assuming that teachers have to love helping, does society further impose the idea that students are without?
Maria: Experience is not only about experience in the profession. It bounded by life/informal experience.
Material annotation: Maxine Greene- "making the familiar strange"
Maria: culture is problematic
Material annotations: Culture is not orientalism and orientalism is not culture, relationships and experiences may define "culture"…is "culture" even such a concept? So then are traditions problematic? If so, is it because tradition constructs culture?
Maria: Is subjectivity one's own culture?
Maria: Does "culture" just build/construct more boundaries to limit "outsiders"?
Material annotations: consider culture as intra-active process rather than a product

While this particular exchange appears messy and disconnected at times it is in the moments between my annotations that also play an important role in my analysis. Furthermore, much, if not all of the literature I cite in this chapter is the textual preparation embedded in my doctoral program. Beyond my critical friends, I contend that scholarly work about science education, curriculum, and the social construction of knowledge also inherently serve as a critical friend throughout my self-study. Given the dynamic and emergent nature of our interactions, my critical friends and I continue to challenge each other to think deeply about our practice and being. It is in these conversations that our subjectivities become.

Scientifically speaking, my mind, body, and heart serve as the medium for which an "intervention" is applied; that is, my preparation to become a science teacher educator and more broadly my continuous growth as an educator. However, the outcome is not quantifiable and will never be complete. Rather, I provide a glimpse into the nature of this negotiation through a "variety of methods such as personal history, narrative inquiry, [and] memory work" (LaBoskey, 2004; Samaras & Freese, 2006). Moreover, like Pinnegar (1998) I engage in self-study as "methodologically unique" (p. 31).

My Conditioned Self: Before Doctoral Education Happened to and Within Me

The place where I fell in love with science was not in a classroom; it was on the farm. Interestingly, this same farm was on the campus of my urban high school. Here is where I began boldly and intentionally resisting dominant stereotypes associated with people participating in agriculture organizations, activities, and conversations. Each morning, I set out on a mission to challenge the normative images of "farmer", "hick", or "redneck" by blurring the social lines of traditional high school cliques. I was a female leader in the one of the largest agriculture organizations in Texas who woke up early each morning to feed two 300-lb show hogs, while dressed in a skirt and rubber steel toed boots (later switching to matching heels). I attended traditionally prescribed public high school courses and agriscience courses as my electives during the day. Afterschool, I participated in track and field events adjacent to my hog barn. During track practice, smells of manure, cries of young boars becoming barrows, and stirred up dust following large trucks were common occurrences. Weekends consisted of hog barn visits, livestock shows, track meets, and agronomy (soil science) and agri-business marketing competitions around the country.

The first moment where my required science courses and extracurricular science opportunities collided was during my senior year of high school. As a senior, I had the opportunity to choose a fourth year science course or other elective, so I chose "Environmental Science". From the first day of class, that course was different. My teacher began by asking us what we (six students) hoped to get out of the class and she as our teacher. As a group of seven, we discussed and decided how we wanted the course to be taught. The two most significant decisions we made were to engage in science projects outside our classroom and to read books related to science. That was the first opportunity, of my traditional science courses, to discuss and participate in science as a process of inquiry. However, little did I know at the close of the semester I would be asked to leave the course, because I, unlike my classmates, passed the state science test. I was told the second semester of the course would become focused on standardized test preparation, so the teacher thought my time would be better spent elsewhere. The next semester I enrolled in "Agriculture Mechanics" where I learned, alongside many men, how to construct, design, and develop pieces of agriculture equipment.

My connection to agriculture extended beyond high school, yet was redirected after choosing to attend a small liberal arts college in Mississippi, while many of my classmates chose to go the large public agriculture university in Texas. This decision, alongside all the rest, was life changing. Here is where I continued to resist and disrupt dominant stereotypes by choosing to major in Geology. As a member of the cross-country team and campus sorority, I was fascinated by the ability to depict, imagine, and construct historical information about the ever-changing, yet contradictorily consistent planet supporting all known humanity. Furthermore, a geological lens forced me to consider how single events, found in present time periods, are always situated within much larger geologic timescale. From my courses, undergraduate research, teaching opportunities, and regular fieldwork, I learned very quickly that Geology was and continues to be about *doing* science. Reciting complex scientific terminology, independent thinking, and sterility are not at the core of knowing science or being a scientist. My experiences in a small liberal arts Geology program, no more than five students in my classes, lead me to share these same aspects of science with others as I intended to become a science teacher after graduation.

Once again I tentatively made the unpopular decision of attending my alma mater's rival, also a liberal arts university, for my Masters of Arts in Teaching. There is where I began to recognize teaching as a messy, complicated, and an extremely thoughtful endeavor. I graduated with a desire to disrupt stereotypical views of teachers, normative decisions made by teachers, and create a community of scientists on the constant verge of discovery! I, unlike many of the Teach for America Corps colleagues at my school, had a very clear understanding that the work we do as teachers is difficult and emotionally challenging; yet, in my years as a K-12 science teacher I did not fathom the depth to which these repercussions originated. The first time I felt clear tension in my science teacher identity was linked to instructional alignment with standardized testing expectations. I shared my concerns with administration as I continued teaching science based on my prior experiences in the sciences and family upbringing. Through love, joy, and curiosity my students became enthralled with science; however, this was not good enough for my school district. I was told by my administration halfway through my first year of teaching that if my instruction did not produce higher test scores on the regular district benchmarks, my contract would not be renewed for the following year. So, like many new teachers, I was presented with a very important question; do I reject my formal and informal preparation of becoming a science teacher and conform to the demands of those in power? This question underpinned everything I did as a teacher. What am I willing to give up? Do I have to give up part or all of my ideologies defining science teaching in order to become a science teacher? How do my decisions and those made by my administration directly affect my students, who were not worried about a contract renewal, but rather being a lover of learning and science? How are the decisions of the adults around my students ultimately shaping future perceptions of learning, knowing, and teaching science? I expected the job and decisions to be difficult, but I was not prepared to negotiate the democratic implications my choices had on the present and future realities of American society. I was not prepared to mask, even change, my ideologies about what it means to "know" science, create science "knowers", and "effectively" teach science. Once I learned how to successfully mask and adopt my district and school's definitions of "effective teacher", I became recognized as Teacher of the Month multiple times, a top science teacher in my school district (one of the largest in the country), and earned merit based pay as a recognition for my "achievements".

One Saturday Morning

Before starting my first year teaching, I set out on an adventure; looking for garage sales in my childhood neighborhood. My mission was to find and buy gently used books, lots of them, to begin building a classroom library at my first school. After much reconnaissance, I ran across what I thought was a gold mine, the home of a retiring teacher! The driveway was covered with several large containers of books, bookshelves, and easels! How could I have gotten so lucky? The books were only twenty-five cents each, so naturally I started piling up as many books before they started toppling over. It did not take long before the homeowner, the retiring teacher, walked over to me and asked if I was a teacher, then we exchanged stories. I was beginning my journey as a formal educator while she was ending hers and reluctantly selling her own classroom library. She offered the entire set of books, at least 3,000, for thirty dollars! In addition to the books I walked away with outdated bookshelves and easels for my classroom for only five dollars! The value of this informal business exchange extends far beyond the money I saved; the experience has remained within others and me several years later. Since leaving the garage sale this moment has diffused throughout the country: books have been given to students and used to provide additional context in lessons, the shelves received a fresh coat of paint, and the moment has been reciprocated in ways that span beyond a classroom library.

Garage sales, like this story, demonstrate how a moment, object, or an encounter with a stranger can influence the work we do as educators. Each experience takes form as an "item for sale" challenging us to constantly negotiate our subjectivities as teachers/humans/students/researchers. My journey to becoming a science teacher educator is no different.

Becoming-Results

Item for Sale: The Scientific Method as Almighty

During my second semester of doctoral education I was charged with reading Ellen Lagemann's book, *An Elusive Science*: *The Troubling History of Education Research* (2000), which is also the site of many personal onto-epistemological quandaries. Early in my doctoral career, this book began to expose America's problematic and multifaceted education system. I must admit I knew there were problems with our system, but the ways in which power, violence (in the Foucauldian sense), and science infiltrated every decision was extremely disturbing to me.

Lagemann's (2000) premise suggested the work of education researchers, curriculum theorists, and educators were ultimately to the demise of the scientific method and field of science. Underpinning her work is the ideological competition between the "victor", Edward L. Thorndike (Behavioral Psychologist), and "failure", John Dewey (Philosopher). Further, early educationists, like Thorndike, attempted to increase the level of respect and independence of teaching by attempting "to emulate their brethren in the 'hard' sciences" (Lagemann, 2000, p. xii). However, all the while, antieducationist like George Bernard Shaw and many still today state, "he or she who can, does; he or she who cannot, teaches" (Lagemann, 2000, p. xiii) or reduces the profession of teaching to "women's work". These foundational attempts to create a science of education have resulted in an oppressive reductionist system. The aspect concerning and perplexing me most is when curriculum theorists/doctoral students/educators/educational researchers chalk many of these issues, or ruins of American culture, up to the scientific method. Since earning my Bachelors degree in a science, being a science teacher, and marrying a scientist this notion struck me as surprising and discomforting. Is science perceived as superior because the nature of learning is ultimately the nature of the scientific method, or the process of coming to know and understanding a scientific concept? For me, I define the scientific method as a non-linear creative process/approach to understanding all things. In all learning endeavors we make sense of experience and knowledge as we interact with it, as it emerges.

Each aspect of coming to know is based on my meanings constructed from my personal experiences. "Knowing" the nature of "science" is no different. Long before studying agri-science in high school, Geology in college, teaching science in public schools, and now studying science education in graduate school I knew, felt, and participated in the scientific method. When I was nine years old, I was diagnosed with a rare form of cancer. Over the past eighteen years, I witnessed the inquiry, planning, collaboration, discovery, and failures of the scientific "method" as a cancer patient. My doctors are some of the most recognized scientists in the world. From my diagnosis, their nature of science has become part of my own. Throughout my entire life I have seen these doctors' repeatedly acknowledge that no two patients with my disease are the same. From this stance, my doctors selflessly collaborated all while learning from failed treatment plans. The nature of my earliest appointments with my first specialist, whom still examines me today, remains constant as my life and career continues to become. Due to relocating across the country I had the opportunity to be literally studied by dermatologists and radiation oncologists shaping the field of study on my form of cancer. In July of 2015, I received potentially my last dose of radiation. Typically when people think of radiation or cancer treatments, the process is reduced to a standardized prescribed procedure, or "method". However, this is not my experience; one treatment entails a separate day of specialized team planning and preparation for my body. As I lay on the magnetic resonance imaging (MRI) machine, I watched, felt, and contributed to my own treatment planning. The radiation oncologist, physicists, radiation therapists, nurses, dermatologists, and medical students framed their plan around one central question; "Does this work for you"? Naturally, as an individual with many feminist poststructuralist tendencies, I deconstructed the inherent underlying meanings of this question during each of my twelve sets of radiation treatments over the past three and a half years. "Does this work for you" implies an essential acknowledgement of the implicit, yet extremely important, work of all scientists/humans as subjective, perspectival, and communal. Without these conditions there is no science. There is no knowing.

This component of my autobiographical inquiry is absolutely necessary as it underpins my philosophical views concerning the nature of science. The essence of my medical team's preparation is a prime example of the nature in which we come to know science, or all "things". There is no simple yes or no answer to the question of science as "almighty"; rather, the point of this negotiation is to consider the normative conditions in which the discourse, of scientists/teachers/students/humans/researchers, has constructed the field to be perceived as almighty.

Item for Sale: Tradition or Standardization?

Is the notion of tradition for better or worse? Why do people cling to tradition and how does this attachment perpetuate further oppression? Could tradition be considered the ultimate form of oppression, because of its ability to inherit ideologies with limited questioning or contemplation? Many people often hear the phrase, "well that's the way we have always done it" and "if it isn't broke, don't fix it". These phrases often portray the comfort people find in tradition; however, this lack of questioning often leaves large amounts, groups and individuals, of people to accept a type of cultural conditioning. Within each culture there are traditions that ultimately define a community. This group inevitably bleeds into others, thus extending the tradition and cultural norms to outsiders. In a critical sense, this form of social tradition, or indoctrination, is terrifying. Alternatively, the notion can also be seen as an opportunity. Yet, educators must be cautious when presented with the implicit decision to simply accept and embrace the "positive" and/or normative characteristics of tradition. Elizabeth St. Pierre states,

> We have constructed the world as it is through language and cultural practice, and we can also deconstruct and reconstruct it. There are many structures that simply do not exist prior to naming and are not essential or absolute but are created and maintained every day by people. (2000, p. 483)

Butler (1995) contends the underpinnings of this world are contingent, not necessary, not absolute, and therefore open to change. St. Pierre continues, "In fact, if we believe [Butler], then we are all responsible for those structures and the damage they do" (2000, p. 483).

Today's current emphasis on standardized tests, grade level expectations, and teacher evaluation, to name a few, have distinct ties to cultural traditions, or cultural conditioning, in America. Winfield and Dikotter push this connection even farther:

> Operating within a power differential defined by class, race, gender, and a narrowly defined conception of "normality," "eugenics was a fundamental aspect of some of the most important cultural and social movements of the twentieth century, intimately linked to ideologies of 'race,' nations, and sex, inextricably meshed with population control, social hygiene, state hospitals, and the welfare state" (Dikotter, as cited in Winfield, 2009) and, I would add, education. (Winfield, 2010, p. 143)

Winfield's description is particularly disturbing when working in the field of science education. In what ways are science teachers, science teacher educators, and scientists perpetuating standards of "normality"? By centering teacher preparation on the right method or best approach to implementing science as inquiry, how might science teacher educators implicitly perpetuate gendered "racialized scientism" (Winfield, 2010, p. 143)? The historical origins of the American education system have framed today's education as reductionist and at times dehumanizing. While this notion continues to support my struggle with the idea of tradition by further demarcating a multifaceted set of caste systems, it also provides the prospect to distort these inequitable lines. Science teacher educator preparation has the critical opportunity and space to be at the center of this distortion.

Item for Sale: Strategic Efforts to De-gender STEM

The concept of tradition parallels a topic I have struggled with since middle school. My mother, a feminist businesswoman, emphasized the associated ideals of powerful women throughout my life. Also integrated in this upbringing, I watched my mother lead other women and young girls through entrepreneurship, lead women business owners associations, and continue to see her awarded for foraging a path for other women leaders in my hometown. By purposefully raising awareness of women or underrepresented groups (the oppressed) is society, suggesting that they *need* assistance and must be lifted up? This is seen particularly in STEM education and university program assessment. By creating groups/associations/clubs of the oppressed, is society and participants in such organizations in some way perpetuating further oppression? Moreover, are the oppressed participating in their own oppression? Alternatively, if individuals (for example, myself being a woman connected to the sciences) choose not engage in such organized groups or challenge problematic representations in the media, they are often perceived as complicit in this culturally and historically embedded oppression. Biesta (2013), drawing on the work of Ranciere, provides some solace in re-conceptualizing an alternative route towards intrinsic and extrinsic emancipation. He states,

> One of Ranciere's central insights is that as long as we project equality into the future and see it as something that has to be brought about through particular interventions and activities that aim to overcome existing inequality—such as the education of the masses or the integral pedagogicization of society—we will never reach equality but will simply reproduce inequality. (Biesta,2013, p. 96)

From this, science educators should also consider alternative points of entry into the complicated conversation of science education. Biesta and Ranciere suggest rethinking or conceptualizing *learning as a process of unknowing* is the form of praxis needed.

Identity in Tension

Over my first 2 years as a doctoral student, I have come to acknowledge my involvement in a sorority, athletics, agri-business marketing competitions, neighborhood public schools, receiving high quality medical care, and career endeavors are all products of a hegemonic and oppressive society. While these ruins will remain within me, I am now in a frame of mind that allows me to embrace, deconstruct, and imagine the process of unlearning imposed ideologies in the context of science education.

At my first national conference presentation, I get asked, "Are you a teacher educator or curriculum theorist"? However, at that same conference I heard another scholar say, "I do not think people do enough curriculum theorizing". The discourse surrounding my doctoral program and scholarly pursuits constantly influences how I negotiate my identity-in-practice (Wenger, 1998). My response to the aforementioned either/or question is with another question. Why can't I be both? Questions framed in such a binary, continue to normalize the profession/art/science of teaching. Frankly, the perspective of a critical curriculum theorist is the preparation I lacked when entering the classroom as a third, fourth, fifth, and sixth grade science teacher.

My process of becoming a science teacher educator combined with that of a curriculum theorist is what happens when we begin re-conceptualizing the notion of identity. Eaton (2015) further questions dominant representations of identity, "What makes it possible for us as educators, to believe we can, or should, 'control' identity? What would it mean for us to relinquish such control, to see identity not as 'outcome', but as a continuous process" (p. 279). Drawing on Deleuze, Marble (2014) shares two ways we can view teacher preparation: as a becoming-teacher and the process of becoming a teacher. Furthermore, Ansell Pearson (1997) describes the uncomfortable feeling when reading the work of Deleuze by stating: "To enter the labyrinth of his thought one must have courage for the forbidden where the strange and unfamiliar things of the future are more familiar than the so-called reality of the present" (pp. 2–3). I contend this is not just an emotion felt when reading Deleuze, but also through the intentional excavation and negotiation seen in my items for sale. For this reason, it becomes imperative to ask aspiring science teacher educators to construct, in relationship to critical scholarly literature and life experiences, a counter narrative of their self is to also move beyond confining epistemologies and intentionally traverse one's ontological.

Discussion and Implications for Science Teacher Educator Preparation

Points of "Entry"

My rummaging does not provide concrete implications or findings, but rather new questions positioning future science teachers and teacher educators to enter the complicated conversation of science teacher educator preparation from an onto-epistemological perspective, instead of the prevailing epistemological views. By approaching science teacher educator preparation in such a way, the deconstruction of dominant conversations shaping science education is (re)engaged. Furthermore, by re-conceptualizing the day-to-day realities of becoming-science teacher educators, researchers can begin to intentionally explore the wonderings of Winfield (2010) and Taliaferro-Baszile (2010). They ask, "To what extent does ideological residue coat our imaginings and filter the light that might be" (Winfield, 2010, p. 153) and in what way is "the ontological held hostage by the epistemological" (Taliaferro-Baszile, p. 491)? Through the centering of these two questions aspiring science teacher educators are positioned to dig deeper and grapple (Sizer & Sizer, 2006) with their ontological becoming (Deleuze & Guattari, 1987). It is from these questions I make three recommendations for preparing future science teacher educators: (a) Shift from fixed surficial meanings of science teacher identity to a Deleuzian notion of becoming; (b) utilize *critical* autobiographical inquiry with science teachers and teacher educators; and (c) explicitly examine the scientism of education.

From Identity to Onto-epistemological Becoming

Do not ask me who I am and do not expect me to stay the same. (Foucault, 1972, p. 17)

Evident in each of my tensions, there is a great deal of ideological residue that must be peeled away from science teacher educators' in order for adequate preparation to occur. From an early age, establishing a strong confident and empowered woman was evident in my familial upbringing. Long before I took a graduate course on Feminism and Foucault or Sociocultural perspectives of Math and Science, I experienced a different kind of curriculum. Originating from my Mother's influence, I often chose to work in male-dominated activities or work environments in an attempt to disrupt peer expectations and the prevailing calls for support.

From entrepreneurship workshops for high school girls, to finding modes of intervention for my "failing" students, to being recognized as one of my students' first female science teachers, I recognize that when researchers and educators use the term of "identity" it is often happening within a power/knowledge relationship. In schools, identity serves a set of demographics as a means to sort individuals. Researchers move to ask individuals "how or with whom do they identify and why". While this line of questions provides the opportunity to have a personal response, I contend the responses to such personal questions are always knowingly and unknowingly productions of our cultural intra-actions (Barad, 2007). Interestingly, it is also in these personal responses researchers and teachers begin to describe another form of preparation outside of formal graduate coursework and professional development. I conceptualize this preparation as onto-epistemological becoming.

Barad (2007) describes the notion of onto-epistemology stating, "knowing is a direct material engagement, a practice of intra-acting with the world as part of the world in its dynamic material configuring, its ongoing articulation. The entangled practices of knowing and being are material practices" (p. 370). In true

Deleuzoguattarian form there is no single definition for the process of becoming since the nature of the concept is constantly shifting, transforming, and acquiring/following new lines of flight. For Deleuze and Guattari (1987) "[becoming] is not a progress or regress along a series" (p. 238), but a "cofunctioning by contagion, [to] enter certain *assemblages*; it is there that human beings effect their becoming-animal" (p. 242) or in this case becoming-science teacher educator.

I connect Barad's (2007) perspective with Deleuze and Guattari's (1987) description of becoming as an assemblage of multiplicities. Seen in both Barad and Deleuze and Guattari's perspectives "something very important transpires at the level of relationships" (Deleuze & Guattari, 1987, p. 234). By conceptualizing the preparation of science teacher educator onto-epistemologically and as a process of becoming-teacher educator, the nature of preparation transforms into a matter of examining relationships. For example, how might overemphasis on the most effective approach to developing pedagogical content knowledge shape the ontologies of becoming-science teacher educators?

In an attempt to avoid ambiguity, Deleuze and Guattari (1987) share a more concrete description of how a becoming-science teacher educator exists as a multiplicity,

> a multiplicity is defined not by the elements that compose it in extension, not by the characteristics that compose it in comprehension, but by the lines and dimensions it encompasses in 'intension.' If you change dimensions, if you add or subtract one, you change multiplicity. (p. 245)

By shifting surficial notions of identity to a process of becoming teacher educators acknowledge the eternity of ideas and ideology. Simply put, "Ideas do not die" (Deleuze & Guattari, 1987, p. 235). Moreover, socially and subjectively embedded ideologies, even though their application, status, form, and content may change, ideas "retain something essential" (p. 235) in becoming. Ideas are a byproduct of ontology *and* epistemology. Through the coexistence of ontology and epistemology, onto-epistemology (Barad, 2007), science teacher educators become across the displacement and distribution within the new domains in which inevitably they engage.

As science teacher educators, we must examine the limitations and possibilities of fixed linear notions of identity, preparation, and development. It is in these epistemologically driven spaces that science teacher educators can knowingly and unknowingly perpetuate and privilege certain kinds of knowing and being human/student/teacher/scientist. Just as Anyon (1980) describes an implicitly and explicitly designed hidden curriculum within K-12 schooling for certain social classes of students, science teacher educators must also consider the hidden curriculum embedded in science teacher preparation and how it shapes processes of being and becoming.

Critical Autobiographical Inquiry

> *The predicament of ideology lies in the suggestion that it is precisely because of the way in which power works upon our consciousness ... we need to expose how power works upon our consciousness. (Biesta, 2013, p. 82)*

My second recommendation for the preparation science teacher educators is to extend the traditional conception of preparation from purely epistemological to a deep examination of how the subjectivities of aspiring science teacher educators are socially produced. Simply stated, examine how subjectification works on science teachers and teacher educators. Before and during a doctoral program, aspiring science teacher educators hold many personal experiences that inherently shape the epistemological and ontological assumptions they bring into the classroom. Through critical autobiographical inquiry, the self becomes a new text under examination in the minds and hearts of aspiring science teacher educators.

Drawing on the "results" of my self-study, I am now uncomfortably attuned to the normalizing, gendered, racial, neoliberal, and capitalistic processes infiltrating my onto-epistemological becoming. In my scientific preparation as a Geology major, I acknowledge that there were times I was likely complicit in perpetuating certain forms of scientism. Looking back on my experiences I was only subtly aware of the gendered nature embedded in studying the sciences; however, this capillary circulation of power/knowledge did not become evident through an epistemologically guided lesson or presentation on the underrepresentation of certain races and genders in science, but rather a personal feeling of frustration and emotion driving me to seek a field where I found myself naturally welcomed. I now see how dominant perceptions and structural discourse shape who "should" and "shouldn't" be a teacher, and also a geologist.

Several years later I have come to know a different me. I no longer find it easy to answer the common introductory question of, "what do you do"? Before doctoral education, I quickly responded, "Oh! I am science teacher!" Now, however, I struggle to respond. Most recently and consistently I draw on the response, "That is a good question. I am many things". Between these informal inter-personal exchanges, I think, "little do they know how difficult it is to answer this question." While I orally communicate the aforementioned response, I hear and internalize a different set of responses. I imagine Foucault's response, "We are all an ever-changing societal production constrained by power/knowledge structures." Then I hear Deleuze and Guattari's (1987) response, "Slow down Maria. We are multiplicities simply becoming-animal. While we may be constrained, this tension is the generative space you must explore."

This example of my personal negotiation provides another look at the ways in which critical autobiographical inquiry can expose new ways of being and knowing. It is in these inter-personal exchanges my subjectivity continues to become. Similarly, Pinar (2012) demonstrates how the use of *currere* can uncover new ontologies. Pinar states, "writing, in particular the craft of autobiography, can soar, and from the heights, discern new landscapes, new configurations…" (1988, p. 27). Autobiographical inquiry positions one to embrace the treasure of life's messiness and begins purposefully blurring the imposed demarcations science teachers and teacher educators co-construct from within. Questioning the clarity of identity, ideas, procedures, or legislation positions educators to begin disrupting the dominant narrative of science teacher and teacher educator preparation. Popkewitz asserts, "'Clarity' is always a distinction made through positions of power … to sanction what is legitimate (1997, p. 18). Questioning the façade of tranquility leads to wondering and wondering leads to subjective reconciliation; often demonstrated in the questions we ask and not the meaning we, students/educators, rationalize. St. Pierre states, "Surely, this is the hardest work that we must do, this work of being willing to think differently" (2000, p. 478).

Critical autobiographical inquiry allows pre-service science teachers and teacher educators to engage in preparation as a non-linear rhizomatic function. When educators work to debunk or disrupt normative perspectives of their identity and the identity of their practice, the fractures of society (e.g. American education system, education research, and "reform" movements) are exposed leaving space for shaping new ground. Furthermore, *how* do we, future and present science teacher educators, want pre-service science teachers to conceptualize the enduring implications for shaping the future of science education and dominant perceptions of science?

The goal of critical autobiographical inquiry and exploring the aforementioned items for sale is to not to convince pre-service teachers to change their subjectivities to be a certain way, but rather deliberately rummage through the production of their subjectivity. Moreover, this intentionality is grounded in the process of exploring the imposed, co-, and self-constructed phenomena of becoming a science teacher and teacher educator, what it means to know science, and create science knowers.

Examine the Scientism of Education

Lester Frank Ward (1841–1913) regards that there is "nothing 'natural' about the status quo". (Pinar, Reynolds, Slattery, & Taubman, 2004, p. 103)

My third recommendation is to explicitly expose and discuss the limitations and possibilities embedded in the scientism of education. More specifically, science teacher educators should not only grapple with the nature of science, but also how Cartesian modes of inquiry shape the dominant representations and enactment of science. In order to carve out innovative spaces for learning, teaching, knowing science and being a scientist teacher educators must unveil the ways in which science has implicitly and explicitly manipulated(s) and worked(s) on educational systems.

This becoming-result is truly one of the more difficult aspects for me to engage as it is so deeply engrained in society, my life as a science teacher, and my day-to-day personal life. I often struggle to move between the ways in which I engage with science and the dominant representations of science. For example, when education researchers and curriculum theorists describe how education has been reduced to a science and strict methodological epistemology I feel my stomach start to churn. This is not how I experience science. Extending my tension further is the connection American education has to the eugenics movement (Pinar et al., 2004; Winfield, 2010). For me this relationship is Earth-shattering. How could I some how be perpetuating such an awful movement? More importantly, how could society knowingly and unknowingly be participating in such an dehumanizing ideology? It is with these ideological and epistemological remnants science teacher educators must engage.

The eugenics movement underpins the notion of the "survival of the fitness" in education. The phrase "sink or swim" begins to depict the survival mentality most classroom teachers experience at one point or, more realistically, at many points during their careers. Through tales of surviving teaching, the scientism of education continues to be depicted. Edward Thorndike's contributions to the field of education were immense, but as a behavioral psychologist he viewed his work in education as "a form of human engineering, and [profits] by measurements of human nature and achievement as mechanical and electrical engineering have profited by using the foot, pound, calorie, volt, and amphere" (Thorndike, 1922, p. 1). Now almost a decade later, this vision has become a reality in the American education system. To equate student and teacher learning experiences to issues of mechanical functions and measurements is dehumanizing. Dominant perceptions and methodologies of science provided the inspiration for an education system working to breed productive citizens. Thorndike's epistemology continued to legitimate the human mind as behavioral instrument (Rippa, 1988) as a measure for another emerging reform movement; social efficiency (Pinar et al., 2004). Pinar et al. continues to describe how eugenics and education were regarded as interdependent and championed as two new sciences. Currently in the United States teachers, students, and educational research are under extreme pressure to perform and demonstrate quantifiable outcomes. While this motivation can bring new opportunities for some individuals, upon realizing its historical connection this sense of rationality can be seen in a new light.

Obviously there is value in fostering opportunities where individuals are thoughtful democratic citizens; however, my point of recommendation is to position future science teacher educators to grapple with the hard, often unexamined, questions:

- What is the purpose of education? And for whom? And at what costs?
- In a complex, capitalistic, mechinic, and reductionist educational system, how can science educators re-imagine new possibilities and what might be their enduring implications?

Education has become normalized as means of social utility. Society and educators often present education as holding great possibilities for individuals, but science teacher educators must also examine ways in which it also keeps certain groups of people "in their place". By engaging in the field of science education, science teacher educators are inherently implicated into a content area that trains humans to think and be a certain way. While the nature of science has been well documented as tentative and subjective, what becomes a deeply ethical question to grapple with is how these subjectivities are shaped within the residue of American culture (e.g. mass productivity and profits shifting educational reform from a factory mentality to a corporate one; Fiske, 1991; Pinar, 1994).

Conclusion

Throughout my self-study I pose many questions. As a feminist post-structuralist, this is the primary mode for which I come to know and suggest becoming-science teacher educators begin their inquiry/preparation. More importantly, it is unlikely that any of my questions will ever be fully answered. This is okay. While at times frustrating, the process of unlearning oneself and negotiating each item for sale leads to a critical process of inquiry. It is through the narratives of becoming-science teacher educators we can begin to realize the enduring implications their preparation holds. In summary, becoming-science teacher educators must re-conceptualize how their practice is manufactured and intentionally interrogate their sense of self to engage teaching as an ethical endeavor. It is in this vulnerable in-between space where the treasure of "knowing" science and being a science teacher educator emerge.

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Chapter 19
Supporting New Members as They Transition into Our Science Education Community of Practice

Gayle A. Buck and Valarie L. Akerson

Introduction

In the science education research community, the doctoral program is the traditional pathway into the profession. Students are expected to take rigorous classes, become actively involved in research projects, contribute to knowledge generation and work toward establishing themselves as experts in an area. Like the wearing of the robes and doctoral hoods at graduation ceremonies, there are many aspects of the doctoral program that predate the existence of the various doctoral programs or their faculty members. Some of these aspects are maintained because they serve the program well, some because of tradition, and others simply because we have not stepped back and reflected on the purpose or effect of our procedures. In part, this can be attributed to the fact that doing so involves time and effort for something that was not valued at most academies in terms of merit review, tenure and promotion. This is changing, however, due to the increasing understanding, acceptance and value for self-study research at many institutions of higher education.

Our doctoral program, part of the Department of Curriculum and Instruction in the School of Education, prepares future science educators with a primary focus on their efforts in science teacher education at all levels/venues of science education. We bring in new members with the promise that, while here, they will "build upon [their] own passion for science with the knowledge and skills to teach this material effectively to a diverse, multicultural student body. [They]'ll also hone [their] data interpretation skills and participate in diverse research projects aimed at improving young learners' understanding of scientific concepts and best practices for educating the next generation of science teachers" ("Degrees & Programs: Science Education", 2015 http://education.indiana.edu/graduate/programs/science-ed/index.html).

G.A. Buck, Ph.D. (✉) • V.L. Akerson, Ph.D.
Department of Curriculum and Instruction, Indiana University, Bloomington, IN, USA
e-mail: gabuck@indiana.edu; vakerson@indiana.edu

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We bring in two to six new members every year, most of them supported by assistantships involving teaching future formal K-12 science teachers in our undergraduate program. Many of the past graduates of this program are now science educators at institutions of higher education around the world; conducting research, teaching and service that involves science teacher education. Ours, like most doctoral programs throughout the world, is steeped in history and tradition.

Over the course of the next 5 years, we will systematically explore the curriculum of our graduate program. Curriculum is being defined as students' actual opportunities, experiences and learning (Posner, 1995). The purpose of this self-study, the first in a series of studies, is to explore how well the traditional interdependent processes inherent in the curriculum of our science education doctoral program is functioning in terms of bringing newcomers, first-year doctoral students, into the contemporary field of science education. Specifically, we looked across the components of our doctoral program curriculum by focusing on how well it influences identity formation and legitimate participation in the science teacher education community of practice.

Initial Theoretical and Practical Understandings

Social constructivist theory explains how social and cultural interactions influence an individual's creation of understanding (Vygotsky, 1978; Wertsch, 1991). The explanation is grounded in the notion that understandings are mediated within the milieu in which they are carried out (Wertsch, 1991). Thus, the focus of this orientation is not solely on the individual learner; but rather on the learner and learning process as participation in experiences in a socially constructed world. Sociocultural theory of practice (Lave & Wenger, 1991) explains both a socioculturally structured world and the persons who function within that world. Sociocultural structure refers to the institutional, historical, and social activities in which humans engage as a matter of survival and comfort (Giddens, 1979). When humans share a commitment to a shared domain of interest and build relationships that enable them to learn about and within that practice, they form a Community of Practice (CoP) (Wenger, 1998). These communities often have core and peripheral members. We all belong to many communities of practice, serve in a peripheral capacity to many others, and travel through numerous communities in the course of our lives.

The members of a CoP engage with one another and thus identify themselves and others as members of that community. In light of this, there is a connection between identity and practice as the formation of a CoP involves the negotiation of identities (Wenger, 1998). We view identity as developing through individual and collective processes that occur in social institutions such as K-12 schools, or in our case, universities (Gee, 2005; Packer & Goicoechea, 2000). Through participation in social activities and discourses within institutions, individuals form values and ways of being, which enable them to develop identity (LeCourt, 2004). Identity formation is a process through which individuals come to "know and name themselves"

(Danielewicz, 2001, p. 3). Membership in a CoP translates into a sense of familiar, understandable, and judging oneself and others to be competent in that community (Wenger, 1998). In order to make a successful transition into the CoP, new members need to take on an identity of a member of that community. Gee (2001) describes four perspectives for understanding identity development. He labels the four perspectives as follows: the nature perspective, the institutional perspective, the discourse perspective, and the affinity perspective. These perspectives are not separate from one another, and act in concert with one another. The nature perspective includes aspects of identity which are recognizable and with which we are born, such as gender, race, personality, and physical characteristics. Sources of identity for the institutional perspective are the institutions and those in power in the institution. Those in authority can grant or impose roles on individuals—e.g. as advisors we can impose roles on individuals to help them become part of the institution so they can take on the identity of a science educator. The discourse identity indicates that individual identities are created, recognized, sustained in and through the dialogue with others. It is through this process that identity is claimed for oneself and named by others (Danielewicz, 2001; Gee, 2001, 2005). An identity is claimed by how we define ourselves and to others. Affinity is the fourth perspective, which is comprised of individuals who are available to one another in terms of access and participation in certain practices. Affinity groups work in the sense that its members all accept, believe in, value and abide by a set of practices.

Lave and Wenger first coined the term 'community of practice' while studying apprenticeships. This theory allowed for a more comprehensive understanding of an apprenticeship experience that involves a complex set of relationships that serve as a living curriculum for the apprentice. Wenger noted that learning in practice, as is done in an apprenticeship, is negotiating an identity. Depending on how a community of practice negotiates individuality, different degrees of continuity and discontinuity fashion the members' identities. The encounter is a complex meeting of the past and the future of a community (Wenger, 1998). This process by which new members become part of the community of practice is termed 'legitimate peripheral participation' (Lave & Wenger, 1991). Members of a community make decisions about their participation and act on those decisions (Giddens, 1979). Although these members are guided by historical precedence (continuity), they have the ability to introduce new practices (discontinuity), which may change the visions of other community members. The change a member attempts to make to a CoP creates tensions; as such transformations are resisted by a tradition of social reproduction (continuity-displacement contradiction). This is referred to as the 'dialectic of practice' (Giddens, 1979; Lave & Wenger, 1991). The newcomers, however, do not necessarily provide the displacement. Wenger noted that often the new members do not necessarily want to emphasize discontinuity as they seek to gain access to a community and sometimes old-timers may welcome the new potentials afforded by incoming members.

Many of our current practices and understandings in carrying out our work in higher education are based on the theoretical notions of CoP and identity (as explored above). Higher education communities, however, involve unique characteristics that must be taken into account when applying these understandings. The members of the university are providing students with the knowledge and experiences to be applied outside the learning system. Specifically, in doctoral programs in science education the students are expected to leave our university and become part of a broader learning system. That larger learning system, however, is our science education CoP. We are not only the old-timers referred to in the CoP literature, but also the teachers. In light of these unique aspects of our community, we and the initial theoretical and practical understandings that we are bringing into our study must themselves be the primary participants.

Self-Study Approach

Self-study in science teacher education is being defined as rigorous, critical inquiry in which science teacher educators research themselves and their practices. Russell (1998) describes self-study as learning from experience embedded within the teachers' process of creating new experiences for themselves and those whom they teach (p. 6). Loughran and Northfield (1998) define self-study as recognizing that the dissonance between beliefs and practice is fundamental to action. One common thread throughout all of these definitions is studying or voicing one's own experience, expressing oneself or knowing oneself and one's practice better. It is within the self-study tradition that we put our selves and our practices within the academy in the forefront. In terms of the methodological approach, "we," the authors of this study, and our theoretical and practical understandings are the primary focus of the data collection and analysis process.

The self-study approach utilizes a wide variety of methodologies. These include case study (e.g. Kroll, 2005), narrative (e.g., Kitchen, 2005) and heuristics (e.g., Oda, 1998). The methodology used for this self-study was heuristic. Heuristic methodology (Moustakas, 1990) seeks to uncover the nature of phenomenon that is being studied through the use of internal pathways of self through utilizing the processes of self-reflection, exploration, and elucidation (Douglass & Moustakas, 1985). This methodological approach is "…concerned with meanings, not measurements; with essence, not appearance; with quality, not quantity; with experience, not behavior" (Douglas & Moustakas, 1985, p. 42). This approach is different from other methodologies in that the researcher is a participant. It is that person that identifies the meaning and essence of the experience. If other participants are involved, they are viewed as important co-researchers who are an integral part of the heuristic process (Moustakas, 1990).

We, more specifically our theoretical and practical understandings of doctoral education, were the primary participants. Our self-study group included two professors whose main responsibilities were to a science education program at a major research-intensive university. Each of the authors has a story to tell about this process and personal understandings and practices, yet we worked through the process presented in this chapter together. This process included much collaboration, consensus and social construction of understanding. Thus, the first-person "we" is used in reference to this experience. Although the specific data (e.g., quotes) may have been from one of the two authors, they were selected to represent "our" experience and not that of the individual. Thus, they are credited to authors.

The focus of this 1-year exploration was on our understandings and practices in regards to supporting new doctoral students as they transition into our science education CoP. The first-year students were more than subjects in our journey. They were considered co-researchers in our meaning-making journey. Three of these students were from science education areas outside of formal K-12 education. One is an environmental educator working to enhance her understandings of that field and the preparation of future environmental educators. Another is working to enhance her understanding of informal science education and informal science educator preparation. The third student of this group wants to continue to make an impact in regards to equity and social justice issues in science education. She is seeking to enhance her understanding and opportunities to make such impacts, including preparing science teachers who teach in equitable ways. Two of the students are both former high school science teachers seeking to enhance their knowledge and practice in regards to preparing teachers for the formal K-12 classrooms. Each student, of course, has a unique story throughout her or his first-year in a doctoral program, yet the professors' theoretical and practical understandings of mentoring first-year doctoral students were the major focus on this chapter. Thus, only the specific aspects of the students' stories that impacted our own understandings are shared.

The main data sources were audio-recordings from our meetings and written reflections by the students and by the faculty members. To better connect these understandings and practices to the lived experiences of the students they affect, we analyzed the program data of the entering doctoral students. The qualitative data tools used to collect this data included: (1) audiotapes from seven collaborative researcher reflective meetings, (2) researchers' individual written reflections following reflective meetings, (3) field notes of individual and seminar meetings, (4) audiotapes of six doctoral student focus-group meetings, and (5) written documents, including forum responses, from seminars and program activities.

The heuristic analysis process sought to capture the experience and our understandings within. This process included engagement, immersion, incubation, illumination, explication, and critical synthesis (Moustakas, 1990). The initial engagement was a time for self-dialogue and inner search to discover the topics and questions that need to be addressed. This was a personal process that involved much contemplation on the nature and focus of the program and the reasons for doing this study. During the immersion stage, we became totally immersed in the experience, questioning, dialoging, indwelling, feeling, etc. Once the questions were decided upon, the data collected from the first year of these doctoral students' experiences, noted above, were reviewed with those questions in mind; however, 'the' answers were not sought. This was a time for us to reflect and contemplate on the questions and possible answers. This was followed by the incubation stage: a time to step back and allow tacit understandings and new understandings to take place. We took several weeks off from meeting or discussing the project to allow for personal illuminations. After this is the period focused on illumination. We came back together to share and discuss the illuminations and seek a consensus of understanding. This is the point where the researchers allowed themes and patterns to emerge. This was refined during the explication stage when the patterns and understandings were refined and relationships were sought. Finally, we put it all together through the creative synthesis stage; focusing on fleshing out the new perspectives and meanings. This is a personal way of communicating our self-study process and the understandings that resulted from this process. We chose to communicate through a narrative of the areas in which we believe our understandings and practices have grown. We locate the following discussion in a theoretical framework that draws on sociocultural understandings of learning, community of practice, and identity development. Throughout, this narrative is supported with the findings of our own understandings and experiences, as well the student voices that shaped those understandings.

Context

The doctoral program requires a minimum of 90 semester credit hours, the successful completion and defense of a professional portfolio and a science educational research dissertation. The required coursework for our program involves three main areas: (1) the field of science education (major), (2) the discipline of science (minor); and (3) research methodology, The coursework for the field of science education has a common core of courses that includes professional seminars and topical seminars. The seminars represent a broad overview of the science education CoP. The assignments in these seminars are, in part, structured in a manner that allow the students to focus on an area of specialization from multiple perspectives. The minors are developed with a faculty member from one of the science departments. In addition to the courses in these areas, students are required to select elective/support courses in their own areas of study. Following the completion of the courses, students present a professional portfolio that is assessed for its written components and the student's oral defense of such. This portfolio includes aspects of the doctoral program experience that are not achieved through traditional coursework. These aspects include research experiences, publications, presentations, grant-writing experience, evidence of the scholarship of teaching in higher education, and evidence of skills in research design. Following a successful written and oral defense of the professional portfolio, students complete the dissertation. On average, the students complete the program in 4-to-5 years. Throughout the program, students take part in focus-group sessions designed to further foster a sense of community, reflection and allow the faculty to remain informed about the graduates students' lived experiences within the program.

During the first year in the program, the focus of this chapter, the doctoral students take the first two professional seminars, design and implement a self-study or action research project on their teaching, select an advisor, develop a program of study, take part in professional seminars and focus–group sessions, and begin to take part in current research programs in the department. They also take several elective/minor courses depending on their area of interest.

Findings

In this section we describe our results. We organized our findings in subsections that relate to the exploration of our CoP and our insights into confronting our own understandings of how we are supporting the development of our students' identities as science educators.

Our Understandings of the Boundaries and Peripheries of Our CoP

We acknowledge science education as a multifaceted CoP focused on enhancing scientific literacy of all learners. There are various sub-communities within the CoP that differentiate themselves and also interlock with each other. We recognize that science education goes beyond formal K-12 science teacher education. Each of the faculty members within our program, however, held formal K-12 teaching positions prior to entering higher education and strongly values our state certification program for science teachers. So much so, that despite the fact that we acknowledge other aspects of science education (e.g. higher education, informal science education, etc.), our data suggests our actual shared practices were confined within an unintentional boundary around formal K-12 science teacher preparation. Although the connections and overlaps with other communities in science education were theoretically acknowledged, they were not evident in our practices. As a result, we were leaving some of our new students feeling like they were entering the wrong CoP.

For example, the three incoming students who were not public school teachers, and who did not intend to work in formal K-12 science teacher preparation, reported feeling disconnected from our science education program. These reports came early in their transition into our program. In a forum discussion in September, one of these students reported that she felt disconnected because her interest was in higher education, working in chemistry education to encourage and open doors for underrepresented science students. A second felt disconnected because her emphasis was on environmental education and was not seeing that as part of science teacher education. Similarly, the third student felt disconnected due to being interested in informal science education. Early in the program, these students started questioning whether they had entered into the wrong CoP. At one point, all three told us that they seriously considered leaving the program due to this perceived disconnection. In contrast, the two incoming doctoral students who were former classroom science teachers and who intended to become formal K-12 science teacher educators felt no disconnect from the science education program. They also began to question the fit for the their fellow students pursuing different pathways. For example, one of them asked, "What do those of you who do not intend to be university professors [in K-12 teacher preparation] hope to gain from the program?" (Forum, December). Such statements indicated that something about our program made it appear to be a mismatch for anyone outside of formal science teacher education.

As we reviewed our curriculum for insight into how such feelings of disconnect could occur, we realized that many of our practices were developed based on our narrow definition of our CoP. One example is our science education pro-seminar that occurs once every month. We added it to our program as a way to connect all our students—incoming and experienced—as well as all faculty, and to build our CoP. However, our self-study made us realize that it did not seem to be serving that function. Indeed, something about it seemed to foster a sense of disconnect for some of our new members. Several of the students expressed feelings of discomfort and expressed that it had nothing to do with areas of science teacher education that exist outside of K-12 formal teacher preparation. Another example is our required readings list. When we came across one student's comment that nothing connects to environmental education—we took a critical look at our list and realized that none of the readings that we required, and therefore deemed important for all to know, connected to environmental education, informal education, or higher education. We realized that the major projects in our doctoral qualifying portfolio could be adapted to a broader view of science education beyond formal K-12 science teacher education. However, nearly all of our required course readings and assignments, as well as our field-reading list, were focused on formal K-12 science education. This can cause a problem as it establishes boundaries we do not wish to have, nor did we realize that we had them. When we reflected on this narrow understanding and the accidental boundaries, we questioned whether we were poised to address other areas outside of formal K-12 teacher preparation. After analyzing the data from the first semester, we noted:

> The second thing that surprised me the most was the degree to which we may not be meeting everyone's needs. They seem unfulfilled by what we're offering in our classes/program and are looking outside of our program…I question whether we are a science education program or a science teacher education program. We don't seem to be meeting the needs of those that don't see themselves preparing future [K-12 classroom] science teachers. (Researcher Reflection, 1)
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> We wondered, "Can we even really support people with different career goals than our own? How can we help mentor someone for a career that we don't know?" (Researcher Reflection, 1).

As we continued data analysis with these questions in mind, we noticed that the sense of being in the wrong CoP seemed to disappear. We realized that the students had made connections with others in the peripheral of our CoP over the course of their first year that ultimately helped them realize their place in our community. The student that focused on equity issues in higher education found connections through a second major in educational research methodology, the student that focused on environmental education found a connection with a professor in environmental and public affairs who is now serving as her minor advisor, and the student emphasizing informal education found connections through the Informal Science Education Strand at NARST. They came to believe that they had a place within the larger CoP. The students themselves worked through their own thinking and were able to articulate how their ideas of science teacher education were different from the working definition of such in our CoP. The environmental educator noted that her definition of 'teacher' included future environmental educators in the field or at a particular outdoor center. With the doctoral degree, she wanted to be prepared to educate those that she may supervise. The informal science educator noted that the doctoral degree would allow her to prepare/work with people in informal science education environments such as museums. The student emphasizing equity issues noted that she is preparing to educate instructors at all levels, pre-K-university, to teach science in an equitable manner. These students indicated that they were glad that the curriculum of our doctoral program enabled those connections to be part of their program, and they affirmed that they enjoyed the program. We noted, "ironically, this reveals that because of the connections outside of the program they felt more at home within the program" (Reflection Meeting, 5). These connections were allowed, in part, due to the electives/support areas of our program, required minor outside of our program, and opportunities to build collaborations within course projects.

Another aspect of our program that was revealed to be instrumental in fostering a sense of belonging in our CoP was the responsive curriculum. This was fostered by the: (1) faculty's willingness the discuss areas of expertise differently from their own; (2) series of semi-structured focus group sessions that took part throughout the year; and, (3) annual review of the doctoral students. These aspects of the program allowed us to hear the first-year doctoral students' explicit and implicit concerns about the CoP, and we were able to respond both verbally and in practice. This helped us to provide a responsive curriculum that ultimately allowed them to find a place in the CoP. A student, reflecting on finding a place in the program in the first year, noted: "The faculty is open to new thoughts, other ideas…it would have alienated me if I felt like I was being put into a box." Another student agreed, "Yes, that's something I appreciated…I feel like we have a lot of agency … to do what we're really interested in and not forced to do something just for the sake of doing it…" They continued and ultimately noted that this was realized through the components of the program that allowed them to voice their needs and concerns. They seemed to enjoy the focus-group sessions and found the informal conversations to be a time and place for them to explore and challenge their ideas about the science education CoP. They requested that these continue in the coming years in the program and increase in frequency. For example, one student noted, "I feel like these conversations are really helpful…sometimes I have things figured out in my head, but it sounds differently when I'm actually saying it out loud." Another student strongly agreed, "Oh, it helps." And a third student followed up, "I think it helps! I don't know what I don't know… these conversations bring things up that I just wouldn't have figured out on my own" (Focus Group, May).

Overall, our findings challenged our narrow definition of our CoP. This was a definition we did not realize we held. Fortunately, the unintended boundaries of the CoP that resulted did not result in the loss of new potential members. This was, in part, due to the aspects of our curriculum that allowed the students to extend those boundaries on their own and our discussion of our theoretical understandings of the CoP. To address the gap between our understanding and practice, we need to revise those aspects of the curriculum that were too restrictive.

Our Understandings and Practices Associated with Students' Identity Development

In our program, we seek to use the components of identity formation (noted earlier) to help our doctoral students develop identities as science educators and join our CoP. With this self-study, we sought to decipher at what point they took on the discourse identity of a science teacher educator, as well as a science education researcher. At several points throughout their first year, we asked them to consider these identities and whether they believed they were a science teacher educator and/or researcher. They seemed to struggle with determining exactly what that meant for them. Early in the school year they were concerned about teaching science to undergraduates. For example, one student stated, "I am concerned with my lack of being a "science teacher" because I am an environmental educator. Science can be construed as boring and negative (Forum, September)."

What we were surprised about is that they did not see themselves as science educators very early—they seemed to struggle with developing that identity. Some of this, of course, lines up with what was later discovered to be our narrowly focused practical definition of our CoP. Our own identities as science teacher educators influenced how we approached our mentoring of new doctoral students—intending to support them as they identified as formal K-12 science teacher educators. The struggle, however, was not reserved for those students. The students that were former K-12 classroom teachers also struggled with defining and taking on these identities.

As the semester went on, the students reflected on themselves as teachers in higher education, and seemed to focus mostly on teaching their students. They were first seeking to develop a conception of an effective teacher educator. For example, a student noted, "I am busy reflecting on myself as a teacher, wondering how teaching at the college level is different from what I did before" (Forum, October). Another student followed this statement with, "My ideas about teaching have shifted, and I am transforming to one view about effective teaching" (Forum, October). Regarding their views of being science education researchers, they seemed very jumbled and confused. In fact, one student stated, "I have no conception of myself as a researcher—I am a jumbled hot mess, and I am working on a focus" (Forum, October). This statement clearly indicates that he had not begun to develop an identity as a science education researcher. Another in the group was a bit more positive, stating, "Others may see us as researchers when we ourselves don't yet—we are transitioning" (Forum, October). This statement indicates that though she has not taken on an identity as a science education researcher, she recognizes that those outside may see her as a science education researcher (Discourse Identity), and recognizes the transition toward that identity.

At the end of the first semester, there were still questions among the students as to whether they actually were science education researchers. Most had not taken on that identity. For example, one student said, "A science education researcher is someone who contributes to the field of science education research through their work. I am not one because I have not contributed" (Forum, December). Similarly, another disagreed that he was a science education researcher because he had not published. A third student provided a definition, but did not claim to be a science education researcher. A fourth student, on the other hand, had developed an identity as a science education researcher. This was evident in quotes such as, "A science ed researcher is someone committed to understanding and improving science education through research. And yes, I am one—because I am committed to understanding and improving science education" (Forum, December).

This slow development of an identity as a science education researcher carried through to the end of the school year for most students. It seems that the one student that did identify as a science education researcher maintained her identity by her own realization that it did not need to be part of a university setting. She stated: "It is not limited to the academy—it is anyone who wants to improve science education. And yes, I am one because I am doing research and producing knowledge" (Focus Group, May). We found it surprising that the three students who did not initially see themselves as part of our CoP identified as science education researchers before the two students that never questioned the fit. The two that immediately identified with the CoP did not show indication that they had developed an identity as a science education researcher. One stated, "I am on a continual path toward being a science ed researcher. I still need to find myself as a researcher." The second stated, "I am not a science education researcher. It needs to be someone who has published. I have not published research in science education" (Focus Group, May).

In the institution of the science education program, the science education faculty members are the authorities, and therefore, the source of power (Gee, 2001). How we approach mentoring students into the CoP is therefore very important. The discourse we have with our students, as well as the discourse they have among themselves, and with more senior students, will influence their identity development (Danielewicz, 2001). They may develop an affinity group that consists of students, and therefore their identities may be more aligned with those students rather than aligned with a conception of a science educator, unless those students also have a well-developed identity as a science educator. For us to better foster their development of an identity as a science educator we realized that we needed to better understand their current identities, and the identities that they intended to take on within the science education community of practice. However, it is not clear to us that they actually know this information themselves. We noted, "…the students don't seem to know what they are pursuing. How do they know how they fit if they don't know what they are (to be) or we are?" (Researcher Reflection, Final)

Because the students seem to enter our program without an idea about what a science educator is and does, and because of our narrow (and unintentional) focus on science teacher education, there was a mismatch between their identities, and the identities they intended to develop, and sometimes even a conflict between what they saw as the identities of the science education faculty who were available to mentor them. We are hoping to improve the path of this identity development as a science educator by making some adjustments to how we present our program. We will describe changes in our program that we have made from our self study in our discussion section later in this chapter. However, through our discussions, we realized that while we expected them to develop an identity as a science educator, we never painted a picture of what one actually was during throughout this first year. We strove to prepare them to see themselves as part of the CoP of science educator, but did not provide them with a picture of what members of that CoP actually do.

Our Understandings of How to Help Students Negotiate the Path to the CoP

Many of our practices and understandings in transitioning new members into our community are based on the theoretical notions of CoP and identity development. Doctoral programs in science teacher research/education, however, are unique in that we are the teachers and colleagues of these new members. They will not join our program for long; instead taking a position outside our institution but inside our CoP. The students' time in our program is limited to 3–5 years, but they are entering the science education CoP for the duration of their career. To that end, we have established a curriculum aimed at preparing them to take on this new identity over the course of the program. It was not surprising to us that as we reviewed the data we found that our students were very focused on the path through the program. We were surprised, however, at how they were deciphering that path.

One thing that certainly surprised us from the data was the leap-of-faith, in terms of the curriculum, the students felt was required. Although we believed our planned curriculum was well defined, we started to hear doubts in their responses. For example, during one focus group session, the students were asked about obstacles to navigating the path through the curriculum. A discussion ensued that directly revealed such doubts:

> I would say my obstacle is myself trusting the system. I like to know what's coming up, where it's going, and why it is going that way…people have gone through this system and been successful. I just need to realize I will learn things as I need them and not know why ahead of time. I guess I'm trusting the system—that it works; but not knowing every answer ahead of time… (Focus Group, May)

When we brought up the sample checklists and directions we had provided in this first year, they were dismissed with:

> I got the checklists…but, then when I'm talking to people that have been through…I'm like "(sarcastic tone) OK, good luck with that checklist, it is different for every person," I'm just trying to figure out how will it be different for me. Will I be able to do this in the time required, will I be able to figure it out… (Focus Group, May)

This lack of trust did impact the students' actions. For example, another student boldly stated that she did not follow our curriculum noting that she had been told she should not by the more senior students. She stated, "most of the other students have really suggested (a different timeline)" and that she came up with several good reasons on her own to alter the suggested path. When we noted that, although it is good to hear the experiences of other students, they need to carefully consider the type of information they are receiving and whether they are getting it from the most reliable source. With that, the student quietly commented to another student: "We need a checklist for who to ask what" The other student responded, "*You* need to figure that out (both laughing)" (Focus Group, May).

The expressions of doubt prompted us to look closely at our students' actual opportunities, experiences and learning (Posner, 1995). We saw the various voices inherent in that curriculum. We were confronted with the realization that it was not just our planned experiences that made up that curriculum. We realized that the curriculum included the voices of other students; many certainly giving what they felt were words-of-advice; albeit filled with their own experiences and interpretations. For example, one more senior student offered impromptu advice on a forum (the questions were not designed to capture such advice). She told the new students about the experiences they would have throughout the program, and not all of what she reported was accurate. The new students expressed their appreciation of her advice and noted that soon they would be in a position to offer such advice. One new student responded, "Wow! [senior student] you're full of so much information! Thank you for your advice … I am sure I will think of some questions, but for now I am just soaking in everyone's input!" (Forum, September). Another added: "You are full of great advice! Thank you! Maybe in a year or two I will be in a position to offer some good advice too. So please keep it coming!" She did,

> Another thing to remember is that in science education because your minor is outside of education you will not need to take a minor qualifying exam, so it does make sense to be less concerned about taking science courses initially, and enroll in more inquiry courses initially so you can get a jump on doing research sooner. (Forum, September)

We also realized that the curriculum included the voices of other administrators/faculty members. For example our planned activities had the students developing their program of courses in the second semester. The students, however, heard that this was to be done in the first few weeks from one of the associate deans. This advice was rooted in the program in the associate dean's home department. This lead to a great degree of anxiety, distrust that were being advised through the program and mismatch between what the students were seeking and what our program was offering.

It was these experiences that prompted us to take a good overall look at our community. When we tuned into the other voices our students were hearing, we found that the curriculum became very loud and confusing. Our first reaction was to silence the other voices. We noted:

> I am actually surprised that they still listen so strongly to other students when they have been told by advisors and also provided handouts with the information about the process that they will need…It surprises me very much. I don't think it is necessarily bad for students to get information from other students, but it is the inaccurate information that they get that is bad. But we can't really stop them from talking to other students…it is a conundrum. (Reflection Meeting, 3)
>
> I think the distrust came as a result of poor higher communication skills and an uncertainty about who to ask. I think the checklists/review documents have helped. I think that right now we need to listen closely to the things they don't know/the questions they are asking (mostly others) and address them (meaning we need to figure out who to ask) in a booklet. (Reflection Meeting, 3)

During our heuristic analysis, however, we did explore the fact that these other voices are a significant, and perhaps unyielding, aspect of the doctoral CoP. One of the characteristics of a community of practice is a shared repertoire (Wenger, 1998). CoPs develop resources for negotiating meaning over time. In doctoral education, senior students, relationships between faculty and students, stories are such resources for negotiating meaning over time. These things make up a significant part of the enterprise. Thus, we turned our attention to the understandings that are necessary to negotiate this additional layer to our already complex community. In doing so, we realized that much of the confusion in the noise was more of a reflection of the lack of understanding of our CoP or the identity of a science researcher/educator; for it is the qualities/competencies of the persons in this community that are ultimately being assessed. It was clear to us that what we thought we were teaching was being overshadowed by other components of the CoP. For example, the students negotiating amongst themselves about how early a person can complete the field paper component of the portfolio revealed a lack of understanding that this paper demonstrates that they are an expert in a field of study and able to synthesize current theoretical and empirical understandings to identify the themes, gaps and strengths of current work in that area. Instead, the students discussed it as a 30–40 page document summarizing the research that has been done on a topic. The latter can be done in the first couple of semesters; the first is an individualized process that typically takes considerably longer.

Our Distinction Between Reified Standards and Competent Engagement

Looking at our CoP as a process that includes a shared repertoire, we realize that many of the associated resources, understandings and standards are negotiated in practice. The process is generative, pushes the community forward, and constraining, keeps it in check (Wenger, 1998). We entered this self-study process believing that our program was appropriately balanced in terms of the generative/constraining aspects. We believed that our curriculum invited new ideas as much as it sorted them out. Our findings, however, prompted us to question if the generative and constraining process inherent in our curriculum was, in fact, appropriately balanced. Specifically, our initial analysis prompted us to question whether the students were being allowed to challenge the curriculum while we were working to hold them to the necessary standards of competence.

Our analysis revealed three challenges to our curriculum, as well as how our community was/was not responding to them. The first major challenge, of course, is explored above. The students challenged the boundaries we had established around our science education program. For the most part, our curriculum was designed to respond to the challenge and changes are currently being made that will allow it to respond even more thoroughly. In addition to this challenge, however, we also 'heard' challenges to the inclusiveness and work/life balance of our CoP.

An important component in teaching and learning experiences is self-questioning, self-doubt, and disappointment of expectations (Kerdeman, 2003). Hans-Georg Gadamer (as cited in Kerdeman, 2003) describes this as "being pulled up short" (p. 295). Much to our surprise, our CoP was "pulled up short" with our second major challenge—inclusiveness. Although our CoP has made great strides in terms of gender representation, we have not made the same progress in terms of racial representation. At the time of the study, we had an approximately equal number of male and female students, as well as students from many different countries, but only one woman of color. Over the course of the first year, she made a few references to underlying racial discrimination found in the periphery of our community and a sense of exclusion from the student social interactions inside the CoP. She expressed that it was not a single person or persons that made her feel excluded, but the community overall. In one focus-group session, she addressed her feeling of being excluded in the social community of students, telling the other students:

> I feel like being a Black woman disconnects me from this space. I see you guys all socialize together, but it's like "Where am I?" I'm not present. You guys hang out and help each other. And I think part of that has to do (pause) maybe with preconceived notions…but, I go to other places, other departments and I socialize well…when is the last time anyone here in this department had to interact with a Black woman? When did they have to talk to a Black woman? So, maybe there are apprehensions about interacting with me? Maybe even there are preconceived notions or assumptions…So, I think it is really hard for me to put myself out there and socialize with the group. Just because of that—the interactions that I do have. So, in some ways I feel really, really excluded. (Focus Group, May)

The others noted, "I think I sensed that [you] felt excluded. But, I don't think it is our intentions to make you feel excluded in any way." She noted that she didn't feel it was intended or on an individual basis, but by the decisions that are made by the group on what to do and who to talk to/invite in regards to social interactions (Focus Group, May).

Later, we reflected on her comments:

> It surprised me that [she] was feeling so disconnected from the other students. It also surprised me that she was willing to state it to them and confront them. It surprised me because I was a) unaware of it, and b) I don't believe I would have been able to do the same thing in the same gracious way that she was able to do it. She seemed so calm, yet serious and non-accusatory—she was simply sharing her feelings, and not really putting blame on others. I would like to try even harder than I believe I already do to help all students feel connected to the program; yet I am not sure how to help them feel more connected to one another. (Reflection Meeting, 3)

We discussed the understandings inherent in our CoP that fostered such feelings. As a full-time doctoral program made up of individuals who left jobs and families behind, our doctoral students do tend to develop a family structure. We were hearing from one member who saw that structure and understood that she was not a part of it. We understand there could be others now or in the past that didn't have (or take) the opportunity to express such feelings. This prompted a lot of discussion as to what actions we should take in regards to the students' personal relationships. To complicate the discussion even more, it was occurring at the very same time as the work/university balance issues (explored below) came to light that emphasized the need for us to refrain from intruding in the graduate students personal lives. Thus, we wondered if it was our place to intervene in regards to the social life of our students (fearing that would be too much control). We felt a huge conundrum of what we should do to intervene, and even whether to intervene—surely we needed to do something to ensure all students felt part of the CoP. But, we soon realized:

> After reconsidering what the doctoral students said, I realize that I have been thinking about what we should/shouldn't do—not what we do (unintentionally). By turning the "socialization" over to the more senior doctoral students, we are allowing the problems inherent in society into our program…this is their social lives—however, we need to structure it to be more inclusive. Perhaps by making it an official committee, we are making someone(s) responsible. (Reflection Meeting, 3)

Our discussions quickly turned to what actions we will take, which prompted a lot of reflection, some changes to the curriculum, and a lot of questions to pursue as we delve into the complexity of the understandings in this area and how they are/should influence the curriculum. Our understanding and practice in regards to the equity aspects of our CoP need further adjustment. At this point, we do know that our community was able to 'take' the criticism gracefully and seriously. There is an obvious desire of the community to be inclusive. That approach to responding to students' concerns should be maintained. Addressing these weaknesses regarding our own understandings of how this is affecting and being affected by our practice will take much more time and effort. This will be explored in the full 5-year self-study.

The third challenge we found to our curriculum involved the work/life balance issue that plagues much of higher education. Although the new students appeared to figure out a balance that was a good fit for them and their families throughout this first year, the fact that this was found to be significant to all the students prompted us to explore this issue and the aspects of our curriculum that allowed resolutions.

Throughout the first year, the new students made comments such as:

> My obstacle is more of the balance between this space and my world outside. My world outside is more important to me than this space, I think, not that this isn't important to me. So, its continuing to keep that balance…the more I start focusing on this and letting things go outside of this—the fun just starts plummeting. (Focus Group, May)
>
> I think some for me, it is a challenge to be in school, a mother, a new wife…I understand there are consequences… I don't feel like I socialize, just into the science education department in general, part of it, because I think there are lot issues with me trying to navigate this space because I don't really fit in…by my standards, to the group. (Focus, May)

As we reviewed and reflected on the data across the entire first year, we found that the students figured out a balance that suited them and their families. We found that our curriculum allowed for the compromise in the following ways:

> In regards to family versus work, I continue to think that we do a good job… the students are figuring out ways to achieve this balance (our program is allowing for it). These include the ability to take time off (as long as they work hard while they're here) and the ability to focus the work during traditional working hours (while kids are in school). We don't make a point of making them prove they're committed by scheduling unnecessary things that would intrude on their personal time. We schedule our tasks/expectations during the workday. I know there's a lot, but that is the nature of the level of education they are at. The problems come up when they allow themselves to get behind or take the stress home. They may procrastinate on their work and let the stress affect every aspect of their life. (Reflection Meeting, 3)

Realizing how to achieve a work/social life balance is critical as these students take their places in our CoP. These are important aspects of our curriculum that allowed them to work through this issue on their terms. These aspects need to be maintained as we consider the practical implications from the overall study. This ability is largely modeled by the science education faculty, who work specific hours each week, and who also have fulfilling and active home lives.

Discussion and Implications: Changes to Our Theoretical and Practical Understandings

What we are describing in this chapter is, of course, not our full program or our students' entire experience. We are sharing what challenged our own understandings of how we support new members as they transition into our science education CoP. Also, we recognize that the first year is a transition year. All of the students are transitioning from a former identity and career to an identity of a science education doctoral student, and ultimately an identity of a science educator. Their perceptions of this transition are valid, and whether or not they prove to be accurate portrayals of the field or our program, or match our own, are still perceptions that influence their transition into our science education CoP.

Fostering Legitimate Participation in Our COP

Regarding changes in our understandings of how we support students as they join the larger science education CoP, we have several that were especially challenging for us. First, we were surprised to realize that we had unintentionally built boundaries around our CoP that supported future K-12 science teacher educators, but did not provide the same support for those who did not intend to prepare teachers for formal K-12 classrooms. As both the teachers and old-timers in the CoP, our intention was to foster a smooth transition for all of our students. However, we realized the structure did not make broad connections to the full field of science education, leaving some students feeling disconnected. This finding is similar to the Discourse identity described by Gee (2001) in which we believed our discourse with our students was helping all students, and yet it did not support all students in the way we intended. Second, we were surprised by how our students' participation in peripheral communities supported their participation in our own. In many ways, these other communities allowed our science education CoP to develop a dynamic discourse that was addressing diverse needs. Unknown to us, this discourse was helping us to avoid the consequences of those noted unintentional boundaries.

Third, we were surprised to realize that one of our students, the first Black female that has enrolled in our science education doctoral program (at least under the current faculty), felt excluded from the social interactions within the CoP. This is a tricky balance, because we realized from the other students' responses that the exclusion was unintentional—this was not purposeful and intentional discrimination. However, for us not to question the current structure and practice or intervene is not acceptable. The question becomes how much do we intervene, given the discrimination was felt during social activities. How much really can we, or should we, influence social activities? We realize that students who come to us as doctoral students are adults, with personal lives, and we are unsure of how much influence we should actually have on these personal lives. This is particularly problematic given the work/social life balance concerns of the students. Should we be influencing how they spend their time away from work, and with whom they choose to spend this time? And if so, how do we do this? It seems that to develop a healthy CoP that builds on social constructivist theory we need to focus, in part, not only on the practical work of science education, but also on the social interactions that aid in the development of such an identity (Vygotsky, 1978, Wenger, 1998). Perhaps some of the historical precedence (continuity) needs to be shared to better enable feelings of inclusion by all members (Giddens, 1979).

How Our Structure Supports Identity Formation

Through this self-study we also realized that though we intended to help our students develop identities as science teacher educators, our structure could be more effective in enabling this development. We were unaware that students came to our program without a solid conception of a 'science teacher educator,' and though we formally and over time asked them whether they believed they had become a science teacher educator, we really never helped them to define what that meant, and how they would know they had become one. Of course, all identity development is bumpy, and not straightforward, and indeed, no identity is done. In essence, all science educators and science teacher educators continue developing their identities over the course of their careers, with continual solidifying, change, and modification in how self is viewed and how others perceive one. This continual development is common with all identity development (Gee, 2001) and it should not really surprise us that they did not develop one identity as a science educator. In fact, it may have been more realistic for us to consider how they transitioned from one career to science education doctoral student on the way to becoming a science educator, because simply transitioning from one role to a new role is a big change in identity. Furthermore, the challenges students had in developing an identity should not be surprising given all identity development is difficult (Packer & Goicoechea, 2000). The institutional perspective of becoming a science educator develops over time with those who have already taken on the identity of a science educator (e.g., faculty) and who try to support others in their own identity development. This support often takes place through discourse and dialogue, and in our case this discourse took place not only orally, through focus group meetings and private meetings with individual students, but also through written discourse in terms of checklists and written information provided to the students. There was also discourse that took place outside of the direct science education CoP in terms of providing erroneous information, as well as erroneous information provided to new students from returning students. The process of sifting through information, engaging in discourse with different members in the CoP and members in the periphery contributed to the new students' development of identities as science educators and researchers (Danielewicz, 2001; Gee, 2001, 2005). Furthermore, we came to realize that although we have developed a procedure for assessing the qualities of science educators and researchers with tangible outcomes or milestones, we have not taken the time to convey the nature of that identity that necessitate these outcomes and timelines. Such an understanding, we believe, would help the students explain and negotiate the existence of multiple paths and voices found within our CoP.

Implications of New Understandings on Practice

Based on the findings of the self-study, we developed a list of four aspects of the nature of our CoP that fostered some of the confusion. The aspects of our program that need to be conveyed to eliminate the confusion we noted include:

1. Our community has a necessarily high degree of individualization. Our CoP is structured to allow individuals to become experts in their lines of inquiry. Although there is an apparent level of uniformity in regards to seminars and portfolio requirements, these also have a degree of flexibility such that they can be tailored to accommodate a line of interest as well as new ideas. This level of individuality requires a high degree of self-monitoring and goal setting. Attempting to mirror the path of others is frustrating in such an environment, and may not lead to attaining individual goals.
2. Our community is multi-disciplinary and multi-departmental. By its nature, our CoP is a complex system. In addition to the peripheral communities added to enhance our students place in the CoP, there are levels of administration and various policies within the community. These various components of our CoP, as well as the peripheral communities, have additional requirements and different practices. For example, the experience with the associate dean conveying the experiences of her home program. The students need to work through these levels and the required vs. recommended procedures involved.
3. Our community has tentative aspects. Although many of the traditions and expectations inherent in the doctoral program community predate the faculty, there are also changes that occur on a continuous basis. For example, economic or political influences on the profession precipitate changes in our program.
4. Our community has high expectations for all of its members. Our checklists may convey an understanding of tasks that can be completed in a short period of time to be checked off and stories may support such a notion. That is not an inaccurate portrayal of the process. The 'tasks' are products demonstrating professional experiences and competencies within our CoP. For example, research papers are a reflection of the research experience.

In thinking about these aspects of our program, we have been considering what kinds of changes we can make in our approach to supporting students in developing identities as science educators and becoming part of the broader CoP of science education. It is clear to us that one major change that we should make is to revise our readings and course assignments to focus on the science education field at large, not only on formal K-12 teacher education. While we try to make our program flexible enough for all who wish a degree in science education, we tend to focus on K-12 teacher education, and need to think more broadly about informal and higher education.

Another change we are considering implementing is a focus on identity and identity development. We would like to explore whether sharing the research on professional identity development would help our students not only navigate their development toward thinking of themselves as science educators, but also see that the struggles and discomfort that they may feel during the process is common with any identity development.

While we are unsure of what our role should be in terms of intervening into social aspects of the doctoral student experience, we believe we should make more formal efforts to contribute to all members of our CoP being included in science education social events. Of course, when we ourselves hold social events for our science education program, we invite all members. We are still considering the most appropriate intervention aimed at including all students in the social structure of the program. This item relates to the next two, which are to continue research into inclusiveness of the program and also work/social life balance issues. While we believe that our program is inclusive, future research through self-studies may highlight ways we can be better inclusive, and to support our students in being more inclusive themselves, and among themselves.

This inclusiveness also relates to work/social life balance. Indeed, the social aspects of doctoral students should be personal, and it seems that we are also obligated to not only support the work/life balance of our students, but also to contribute to their identities as being inclusive, further helping them to recognize the broadness of the CoP to which they will belong, and also the broad varieties of people who are part of the science education CoP. We believe we should include discussions on work/life balance within our proseminar. Again, we also believe we need to provide more opportunities for social events that include all science education doctoral students, which may enable students from many walks of life to get to know one another, and then actually be more inclusive in the student-organized social events that include only students and not faculty.

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Chapter 20
Developing Knowledge of Practice Through Self-Study: Becoming a Science Teacher Educator

Jennifer Mansfield, John Loughran, and Gillian Kidman

Background

This is my story of how I am beginning to 'become' a science teacher educator. My name is Jennifer and in the past I was an accomplished Senior Secondary School Biology teacher (student ages 17–18) and also a professional scientist. I am now on a journey to 'become' a science teacher educator, currently in relation to the core years of schooling (student ages 5–16). In this story of my journey I am accompanied by two critical friends, John and Gillian. Gillian is also my co-teacher and colleague. Together we invite you into my lecture theatre and workshop laboratory to experience my discontent and joys during my transitioning.

There has been a growing interest in the experiences of beginning teacher educators like me, and the notion of our 'becoming' that underpins the transitionary process (see for example, Bullock, 2009; Dinkelman, Margolis, & Sikkenga, 2006; Murray & Male, 2005; Swennen & van der Klink, 2009). Such studies illustrate that the shift from teacher to teacher educator can be difficult, challenging and confronting (Martinez, 2008), not least because the work itself is embedded in a landscape in which:

> curriculum, pedagogy and research … are expected to [be] attend[ed] to … [as teacher educators] experiment with, clinical aspects of practice in order to develop into skilled practitioners … [while] pursu[ing] rigorous programs of research. (Gallagher, Griffin, Parker, Kitchen, & Figg, 2011, p. 880)

John introduced me to 'self-study' as a meaningful way of basing a rigorous program of research on my learning about teaching *and* my learning of teaching

J. Mansfield (✉) • J. Loughran • G. Kidman
Faculty of Education, Monash University, Clayton, VIC, Australia
e-mail: Jennifer.mansfield@monash.edu; John.Loughran@monash.edu;
Gillian.kidman@monash.edu

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through my own practice. The importance of so doing is partly caught up in the fact that teacher education is sometimes held responsible for all of the suggested ills of the schooling system because it is seen as the first place in which views of how to teach are purported to be transmitted. However, it is this very view of transmission that is at the heart of the disparity between perceptions and reality in understanding teacher education practices. As the literature continually demonstrates, a similar conception exists about the nature of school science teaching and learning. If teaching is seen as the delivery of information (and there is little doubt that science teaching is certainly viewed that way by many), then learning is perceived as a simple task of absorption of information. Good teaching is then equated with the right information being transmitted and appropriately absorbed by students. Quality (science) teaching and learning is far from that simple, and by extension, quality in (science) teacher education is at least equally complex.

Through the learning about my teaching of science teaching described as my story in this chapter, it is anticipated that simplistic views of teaching as transmission (Barnes, 1976) in teacher education will be challenged as the complex nature of the work of teaching science teaching is made strong and clear. In so doing, my chapter is also designed to offer insights into what it means to 'become' as a science teacher educator.

Teacher Education

> The past two decades have witnessed a remarkable amount of policy directed at teacher education – and an intense debate about whether and how various approaches to preparing and supporting teachers make a difference. (Darling-Hammond, 2010, p. 36)

In these challenging times when teacher education appears to be under siege about what it should look like, how it should be structured, and the immediate and measureable impact it should have on beginning teachers' practice (Ravitch, 2007), it is important to remember that teacher education encompasses much more than that which Schön (1983) described as 'technical rationality'.

Through his account of what it means to educate reflective practitioners, Schön (1983, 1987) described how professional education had long suffered from issues associated with differences between the high hard ground of academia and the swampy lowlands of practice. Teacher education is a field of professional preparation that is very familiar with arguments around the theory-practice gap (Cabaroglu, 2014; Pekarek, Krockover, & Shepardson, 1996). But it is worth remembering that such issues are not confined to teacher education alone as similar arguments persist in the education of other professions (see for example, Allmark, 1995; Pilecki & McKay, 2013; Reed, 2009).

It might well be argued that in coming to understand the different expectations, requirements and demands of school teaching and teacher education that the oft' bemoaned theory-practice divide might be better understood, and as a consequence, bridged. In so doing, a shift in the nature of debate around quality in teaching and teacher education might also be possible.

Challenging Assumptions About Teaching Science Teaching

I found that my pre-service teachers entered their teacher preparation program (a 4-year dual primary and secondary teacher qualification) with well-developed views of teaching and learning that inevitably impacted upon their expectations about what learning about teaching might entail. Lortie's (1975) *Apprenticeship of Observation* has long been recognized as a defining feature of these pre-determined views and has been noted by many as creating a challenge for teacher educators that is difficult to address because it '… requires new teachers to understand teaching in ways quite different from their own experience as students' (Darling-Hammond, 2006, p. 35).

Martin and Russell (2009) noted the likelihood that the *Apprenticeship of Observation* sub-consciously created a view in pre-service teachers that teaching looks easy. In order to combat that view they suggested the need for pre-service teachers to actively recognize and confront their taken-for-granted assumptions of practice; they also thought teacher educators should do the same:

> Given that prospective teachers are indeed armed with extensive personal observations of teaching with little or no access to teachers' rationales for acting as they did, then it is only through a disciplined approach to teaching and learning that they may begin to move beyond the familiar and simplistic view of teaching as telling. Much the same can be said for those about to begin academic teaching careers in our universities. (Martin & Russell, 2009, p. 322)

I find that it is in coming to see the complexity of teaching that the teaching of teaching begins to assume added significance. Just as the science education literature on conceptual change demonstrates how resistant students' alternative conceptions are to change (De Jong, Korthagen, & Wubbels, 1998; Duit & Treagust, 2003; Posner, Strike, Hewson, & Gertzhog, 1982; West & Pines, 1985), so too the same exists in the teaching and learning about (science) teaching. For example, Schuck and Segal (2002) studied their teacher education practices and the ways in which their efforts were understood and taken up by their pre-service teachers in their first year of teaching. They were surprised at how difficult their pre-service teachers found it to apply their learning from teacher education in the real world of practice. Not only did the conditions and expectations of schooling reinforce practices contrary to the views of good science teaching and learning they appeared to adopt as pre-service teachers, but the practices they employed harked back to taken-for-granted assumptions about practice that they had previously seen a need to actively confront as pre-service teachers. Although these beginning teachers had had experiences in their teacher education program designed to help them teach in ways that supported what they considered to be quality teaching and learning in science, enacting such practice when teaching full-time was much more difficult than initially envisaged.

Schuck and Segal's (2002) research illustrated that in order to challenge pre-service teachers' taken-for-granted assumptions of teaching and learning required more than offering them an array of interesting teaching procedures or useful 'tips and tricks' about teaching. Their work illustrates the need for deeper conceptual shifts in the practice of teacher educators if there is to be a commensurate shift in the knowledge and practice of their pre-service teachers.

As a physics teacher educator, Bullock's (2009) research illustrates one way of responding to the need for a deep shift in thinking and practice in science teacher education. He set out to challenge his taken-for-granted assumptions about practice as he came to see that the knowledge of practice he constructed through his school teaching experiences could not simply be applied in the university context. 'Learning to teach teachers is a complicated process that requires a teacher educator to confront and re-examine his or her prior assumptions about teaching and learning … [and] requires a sustained, systematic, and careful inquiry into one's own practice' (p. 292).

Bullock offered a strong example of how, when researching his transition into being a science teacher educator, by confronting his existing views of practice, he was able to develop more meaningful ways of understanding and responding to the demands of teaching science teaching. The transition into teacher education, the notion of becoming, highlights an important initial challenge to taken-for-granted assumptions.

Many beginning teacher educators struggle with the issue of 'losing street credibility' (Dinkleman, Margolis, & Sikkenga, 2006, p. 119) as a teacher. Further to this, it can be challenging for them to see beyond teacher education as just another type of teaching. Bullock's research makes clear that he was very well prepared to confront such a situation. He could see that just because he had been a good high school physics teacher that did not mean that quality in teaching of science teaching amounted to simply transplanting his school practice into his new context of teacher education. As with the work of Schuck and Segal (2002), Bullock's disciplined inquiry into his practice made clear to him that quality in teacher education required considerably more than sharing his teaching tips and tricks with his pre-service teachers.

Bullock's research illustrates to me just how important it is to help pre-service teachers move beyond a technical-rational view of learning to teach science in order for them to come to experience science teaching as more than the transmission of information and science learning as more than the absorption of facts. As his work makes clear, doing so is heavily dependent on how teacher educators think about and enact their practice as teachers of teaching, or as it has been described by some, the pedagogy of teacher education (Korthagen & Kessels, 1999; Kosnick, 2007; Loughran, 2006; Ritter, 2007; Russell, 2007).

Like me, Berry (2004) came from a background in Biology. As a biology teacher educator, Berry described how she conceptualized her developing pedagogy of teacher education. Over time, as she confronted her assumptions about science teaching and learning, she learnt how to create conditions for her pre-service teachers to do the same. Her research offers insights into the complexity of teaching about science teaching through what she described as *tensions* (Berry, 2007). Her use of tensions (e.g., the tension between *telling and growth*: the desire to give students answers as opposed to the desire to create opportunities for them to learn for themselves) illustrates, to me, what it means to become a science teacher educator and how that entails moving beyond technical-rational views of learning to teach. Berry helped her pre-service teachers begin to see teaching differently through sharing her pedagogical reasoning with them. In so doing, she not only helped them understand teaching as complex and problematic, but also highlighted that for herself. As she came to recognize and respond to her own issues and concerns in teaching about teaching, so she made the tacit aspects of practice explicit. Through that process, she was able to frame her teaching of teaching in new ways which simultaneously did the same for her pre-service teachers who then developed a new appreciation for the complexity of practice and what it means to not only learn about teaching, but to teach in ways that genuinely engaged students in learning science. I see parallels in the research that led Berry to describe her tensions, and what Southerland, Sowell, Blanchard, and Granger (2010); Southerland, Sowell, and Enderle (2011) describe as the pedagogical discontent experienced by school teachers in their practice – an idea explored further later on in my story.

This brief exploration of the literature makes it clear to me, that real gains in understanding the teaching of science teaching occur when teacher educators, through disciplined inquiry, seek to collect data in order to better inform their practice and to gain insights into their pre-service teachers' learning about science teaching (Berry, 2004; Bullock, 2011; Bullock & Russell, 2012; Garbett, 2011; Russell, 2007). Through a self-study methodology (Hamilton, Pinnegar, Russell, Loughran, & LaBoskey, 1998; LaBoskey, 2004) I can become better informed about the ways in which I approach, and learn from, practice and as a consequence, begin to develop my professional knowledge of teaching teaching. In so doing, the roots of a pedagogy of teacher education begin to become clear to me, articulable and meaningful and transform my understandings of the complex and sophisticated business of teacher education; all of which helps me to illustrate why becoming a teacher educator can be so challenging.

Method

John indicated that science teacher educators' self-studies are increasingly finding a place in the research literature (see for example, Bullock, 2011; Bullock & Russell, 2012). Such studies illustrate to me how important it is to develop my knowledge of practice in order to impact the learning about science teaching of the next generation of science teachers. One particular aspect of self-study that I think can be very important in moving beyond individual views of practice and gaining alternative perspectives on experience is by working with a critical friend (Schuck & Russell, 2005). Hence, my telling my story was heavily dependent on the data sharing, alternative perspectives and analytic advantages associated with working with my critical friends Gillian and John.

As a beginning science teacher educator, I was involved in teaching a compulsory science education unit in a pre-service teacher education program. There were approximately 100 pre-service teachers in the unit, and all were completing their third year of study. This was their only science education unit which put a lot of pressure on me 'to get it right'. Gillian and I co-designed and co-taught all lectures (1 h duration), and the four iterations of the workshops (2 h duration). As the experience of becoming a science teacher educator challenged my understandings of practice, I increasingly reflected on that which I was experiencing and the nature of the learning about teaching of our pre-service teachers. As a consequence, I began to question how my knowledge of teaching science teaching was changing over time and how those changes were different to that which I had experienced as a high school science teacher. I therefore decided to embark on the self-study and to do so in such a way as to 'move beyond the story' (Loughran, 2010) in order to formalize my learning about 'becoming' a science teacher educator as well as beginning to articulate my developing pedagogy of teacher education.

Self-Study

> Self-study provides a framework to move thinking beyond the technical considerations of teaching about teaching to the pedagogical reasoning underlying the teaching. These reasons lie at the core of the values of science teacher education pedagogy and the inevitable desire to improve teacher education practices. (Keast & Cooper, 2012, p. 65)

Self-study is rooted in the desire of teacher educators to become more informed about the teaching and learning of teaching through disciplined inquiry (Clarke & Erickson, 2004; Cochran-Smith & Lytle, 2004; Ham & Kane, 2004; Hamilton et al., 1998). LaBoskey (2004) proposed five characteristics of self-study as a methodology for studying professional practice settings. She stated that self-study: is self-initiated and focused; is improvement-aimed; is interactive; includes multiple methods; and, it defines validity as a validation process based in trustworthiness. Guidelines for quality in self-study have been suggested (see for example, Bullough & Pinnegar, 2001; Northfield, 1996) by some in response to the need to better articulate the learning and knowledge gains from such research.

The self-study I report in this chapter is structured around four major data sources:

1. capturing my thinking about planning and teaching through my written notes before and after teaching – which included pre-teaching and post-teaching of both a lecture and tutorial each week across the 12 week semester;
2. audio-recording of the weekly planning and de-briefing sessions with Gillian as my critical friend and co-teacher (later transcribed);

3. observation and field notes of Gillian (an experienced teacher of teaching) at regular intervals throughout the semester (approximately, once/week); and,
4. completion of a 'learning list' and associated self-reporting transitional perception tools (Balan, 2005).

The use of these data sources was important as we anticipated that they would offer us appropriate access to my developments and changes over time in both the teaching about teaching and the learning about teaching across the semester in which the science education unit, in which my story is situated, was being taught.

Data recorded was based around the planning, enactment, reflection and learning from experience encompassed by the following four questions:

1. What happened? (describing specific examples)
2. What did I do and why? (describing specific examples)
3. What might I do next? (outlining future actions)
4. What did I learn from the experience?

In so doing, each of the data sets allowed for an organised and structured approach to thematic analysis and in a similar vein to that of Southerland et al. (2010), the notion of pedagogical discontent arose as a recurrent issue across all data sets. Consistently, the data highlighted to me that discontent arises as a consequence of 'problem recognition' (Dewey, 1933) followed by a range of ideas, issues and tentative solutions in response to the situation, eventually followed by a form of enactment designed to change or modify the pedagogical behaviours, practices or situation. This process sometimes led me to a chain of connected events, which offered insights into my thoughts, actions and learning from experience, as highlighted by the indicative example below:

> *With some discontent, I have then tried something different in my second and third tutorials* [*repeat classes*]. *For example, when introducing Slowmation with the first group, I did not emphasize the depth of science content that was to be explored and presented by the students. As a result of my lack of experience, this class produced Slowmations that did not really have much specific science content in them – yet that was the point of the exercise. After watching Gillian's class and listening to her emphasis on content, I then emphasised that point with my second and third classes. As a result, the students attempted to address the science content more explicitly, but they seemed resistant/unable/reluctant to delve deeper into their own content knowledge … Making the change illuminated new discontent about something deeper which moved me to a new way of thinking about teaching science teaching and my own learning.*

As the example above illustrates, problem recognition is highlighted through the language of discontent and the manner in which action to address that discontent was experienced offers insights into actions and possibilities for new learning about teaching and learning of science teaching – in this case, through consideration of the teaching of science through Slowmation (see, Hoban 2007; Hoban, Loughran, & Nielsen 2011 for full description). Across all of the data sets, this strong connection between events, new teaching and learning outcomes, and reasoning about practice are strong. However, in order to capture learning outcomes that extended beyond the individual pedagogic episodes, we needed to conduct a thematic analysis across all of the data sets.

The thematic analysis was independently conducted by John, my critical friend and the resultant 'big picture' themes were then systematically verified with Gillian and me. This form of verification through triangulation was designed to ensure that the outcomes of analysis resonated in such a way that the resultant learning was not in opposition to my felt learning from the experience but also not driven by one perspective on the overall experience.

The importance of the data sets being both structured and challenged through the conversations with Gillian at the time, and later again through analysis is important in maintaining both fidelity with events but also to ensure that any alternative perspectives through reframing (Schön, 1983) situations could be appropriately sought and tested. Our analysis resulted in a categorization of the following themes that underpinned my major issue of pedagogical discontent:

1. Seeing what I don't know: The novice in me.
2. The shift: Transforming science content into meaningful science teaching and learning.
3. How do I put theory into practice?

The next part of my story examines each of these themes in detail and then considers them in relation to the notion of a teacher educators' developing sense of pedagogical discontent.

Results

John's thematic analysis led to the development of three categories that appeared to be consistent across all my data sets; each of which is examined below. As the university semester included periods of school teaching experience (practicum) during which pre-service teachers did not attend university, there were times during the semester in which classes were not conducted. Analysis therefore has been organised thematically in relation to the different pedagogical experiences associated with my overall teaching commitment for the semester (i.e., pre-class, lecture, tutorial, post-class, etc.) rather than a strict adherence to a chronological time line.

Seeing What I Don't Know: The Novice in Me

There is a very personal aspect to teaching that, regardless of previous experience, influences one's approach to teaching. Despite being an experienced senior secondary school biology teacher, I was conscious of my new situation and how it influenced my thinking and practice. I had a strong sense of discomfort with aspects of my teaching and my pre-service teachers' learning, but I was not always in a position to know what to do about it.

Workshop 2: '*Science Conceptual Understandings*'

Feeling discontent from Tuesday … I am really uncomfortable with the fact that I don't have all the knowledge and experience that I would like. A couple of times I went down and watched Gillian. She is so relaxed and at ease. She has the ability to see things that are happening that I cannot see because I am so concerned about doing well and getting it right. Not that there is a clear cut right, I want to do well, but I know I don't have something that enables me to function at a higher level. I don't know how much better it could be if I could function at a higher level. I think it is PCK. I don't think I have well developed PCK yet and I don't want to dwell too much on the fact that I don't, as the fact that I don't is obvious, but I am still learning and developing and have to cut myself some slack. But the fact that I don't, makes me feel less confident. As I was saying to Gillian – I am using everything I can get my hands on [*literature, theory etc.*] *to help me, because I cannot see what can be pared back and what things are more important than others. Also, after watching Deb* [*guest speaker*] *do her palaeontology lesson, I can see the ideas. The way she presents them makes them seem straightforward and simple. The ideas are powerful. But I don't know which of my ideas are going to be the most powerful on their own without trying to cram in everything. I think now instead of content knowledge at the forefront; I think it is now PCK I am obsessed with trying to accumulate. But it is not something that can be rushed. Also, watching Deb, she has a well-developed understanding and she is able to clearly articulate the ideas. I don't have the well-developed understanding or the well-developed vocabulary or the ability to link between the ideas as clearly as she does. Our ideas are similar, as what she says really resonates with me. But I don't think I have all the pieces clear enough in my head for me to make the story convincing. I have lots of pieces, but I don't have the ability to put them together to make a pretty picture. That's frustrating. I will try and be relaxed about it, as it will come with time but it is really frustrating and it adds to the pressure to do well.*

They [*pre-service teachers*] *look like adults but sometimes they act like children. I am confused by that mismatch of stimuli. I don't know how to treat them, as my instinct is to treat them the way I would like to be treated. But that did not work in this instance.*

With regards to the science I did not know to tell them how to drill down. Once I watched Gillian in her group, I could see what she expected them to do. I now know what do to and what it could look like when it works. I will do that for my next two groups.

As my reflection above illustrates, I experienced a certain sense of frustration as I endeavoured to develop a number of important pedagogical practices simultaneously. As the data shows, I am concerned with developing my PCK as I feel it is important for shaping my teaching of science teaching (or perhaps demonstrating my expertise as a science teacher), but at the same time I am conflicted by the manner in which my pre-service teachers act as learners. By observing more experienced science teacher educators, I see what I think I need to develop, but I am not necessarily sure how to do that. I know what I don't know and am beginning to embark on ways of learning how to do something about it.

Workshop 3: '*Exploring the Science Curriculum*'

I AM TRYING to model the behaviour I want – that is I want them to think and to question – so I am modelling that I am modelling! *There is so much theory and there are so many ways of presenting this … how do I know if this is the best way… how do I learn about other ways*? *… I am torn between wanting to give stimuli and also giving the answer. I don't want to just give them tips and tricks … I knew something needed to be done to help them along, but I did not know how. Gillian was able to do that and I am glad she did as it showed me* *how it could have been done. She showed me a possible solution to my dilemma. On Tuesday I was getting overwhelmed with how much I did not know … That desire to improve is driving me*.

Lecture 3: '*Exploring the Australian Curriculum*: *Science*'

Nervous about this one. I have been working on this one for a long time. I can see the importance of the knowledge I want them to gain on this topic. I am torn between not wanting to tell them. I don'*t want to tell them but I suspect there is too much telling in what I am doing. But also*, *how do I get them to be cognitively dissonant or at least receptive to what I am saying … I have plenty of examples*, *but now I am worried I will explain them wrong. What if I forget bits*? *I know I miss bits and I know I will forget to say things*, *but I hope the overall message works*.

Post Lecture 3 reflection: '*Exploring the Australian Curriculum*: *Science*'

… the interdisciplinary nature of Primary [*elementary*] *science is scary for me* [*as a high school teacher*]. *I don*'*t know about the literacy and numeracy components. I can see how they can be interweaved*, *but I can*'*t see* [*how to do that*] *… I don*'*t know if my conception of primary school is correct … I was excited and keen to give it a go*, *but I thought*, *oh*, *I don*'*t know how to do that*.

Lecture and workshop 3 occurred mid-way through the semester following a 3-week period where the pre-service teachers were on their school placement (practicum). I was aware of a number of issues which worried me about my teaching and my pre-service teachers' learning. As a beginning science teacher educator I was feeling a sense of discontent driven by the realization that teaching as telling was pedagogically unsatisfactory, but knowing how to move beyond that was demanding. Just as Berry (2007) interpreted her learning about the teaching of biology teaching through the notion of 'tensions', I similarly experienced the tensions associated with accepting that practice is dilemma based (Lundeberg, 1999; Shulman, 1992) and as a consequence felt what it was like to make the shift from first order to second order teaching (Murray & Male, 2005). In this case, it was accompanied by a 'reduced capacity' as a teacher and a sense of being a novice again. A crucial aspect of my feeling like a novice again was linked to the types of issues I was being confronted by as a teacher of science teaching. The demands of second order teaching made me see things in my practice that I had perhaps not been as cognisant of as a school science teacher; issues that are important when pedagogical purpose is more to the fore in shaping what I want my pre-service teachers to learn, and the manner in which they might engage with that learning.

Lecture 4: '*Nature of Science & Science as a Human Endeavour*'

They need to do the hard work – thinking and reasoning. We cannot give them the answers. I need to be stronger and more confident in my convictions and my ability and knowledge. Just because I am a novice does not mean I don'*t know the* '*what and how and why*' *of what I am doing. I am nervous and novice I am frustrated about being like that.*

The Shift: Transforming Science Content into Meaningful Science Teaching and Learning

Russell (1997) noted how important it was for science teacher educators to respond to a need to teach their pre-service teachers more than subject matter content. He was of the view that in developing a pedagogy of teacher education, science teacher educators needed to make a 'pedagogic turn' if their pre-service teachers were to experience learning science in ways that went beyond their own school science learning experiences. Russell was arguing that the 'why of teaching' needs to be made clear so that pre-service teachers themselves could see beyond the subject matter content and into the learning associated with better understanding that content. However, doing so is a challenge for me as there is little in the literature to guide me, the beginning science teacher educator, in that work. Therefore, my recognizing the situation is a good starting point, as the data that follows illustrates, but responding is an additional challenge.

Post Lecture 2 reflection: '*Science Conceptual Understandings*'

… it's a new content now. Rather than being scientific content … instead of scientific content being important, this… pedagogical content? … is now important …

Post Workshop 2 reflection: '*Science Conceptual Understandings*'

After teaching this week, I have come to the realisation that I am still hanging on to content knowledge as comfort. I did not think the activities related to the heart were that bad [I enjoyed doing them and I taught with similar activities]. But from what happened today, I think they [the activities] are missing the mark altogether. Although one chap said to me, "I really like doing these kinds of activities and I love the certainty of science." That got me thinking, "Oh, um, yeah, that's not what I wanted to achieve." As I was questioning and probing, I came to the realisation that the activity was actually reinforcing what it was I was trying to get away from.

I am a bit ashamed, that I was still so heavily driven by content. That really came home when I saw how they were struggling with the task. That task was not great. So, I have had another big shift in my understanding of how science can be represented in ways that makes it intimidating and can turn people off. The upshot is that I saw it unfolding before my eyes and was able to use it as a teachable moment.

Post Lecture 3 reflection: '*Exploring the Australian Curriculum: Science*'

Content matter knowledge … They did not seem to be engaged … They listened, they listened well enough. Again, I am coming back to just telling. And if I am just telling then that is not going to work. That is not effective … they were sitting there, they were listening. What did I expect them to do other than that? … Maybe it is still about content – but a different kind of content – knowledge about teaching … So I am feeling a bit crappy … I am unhappy, angry, hurt, confused, tired and sick of trying. I am sick of trial and error and I want more certainty and more comfort. I miss my comfort zone and I am fatigued. This is hard.

Post Lecture 4 reflection: '*Nature of Science & Science as a Human Endeavour*'

This kind of scares me a bit … I know there was too much telling. Wanting to move away from telling and getting them to think and learn for themselves …

Post Workshop 4 reflection: '*Nature of Science & Science as a Human Endeavour*'

How do I model good learning behaviour? How do I get them to recognise it? Some just sit here, do just enough. Some engage well.

Post teaching visit [*pre-service teachers taught a science lesson in a primary school*]:

Feeling a bit defeated. Feels like it is harder now than at the start. More difficult and more roadblocks now. At the start I had a lot more enthusiasm. I still have enthusiasm, but now some of the realities have hit home and it is feeling more difficult and I guess I am more tired. I have put in a lot … That is frustrating.

As my quotes (above) demonstrate, making the pedagogic turn is challenging. John drew my attention to that which is needed in order to help my pre-service teachers see beyond the subject matter content, but the demands of so doing for extended periods of time and in pedagogically well-constructed ways is hard! It is a shift that requires much more than that which Myers (2002) described as 'telling, showing and guided practice' (p. 131). There is little doubt that although the notion of transforming science content into meaningful science learning is a laudable goal of science teacher education, the ability to do so requires skills, knowledge and expertise that are not simply borne of being a successful school science teacher. Developing that expertise is frustrating and demanding; it is hard work, not least because theory does not necessarily readily translate into practice.

How Do You Put Theory into Practice?

Although the literature is awash with issues in science teaching and learning, I could argue that much of what is written speaks to researchers rather than teachers. For example, as teacher researchers, Berry and Milroy (2002) became aware of the importance of confronting students' alternative conceptions from reading the literature. However, when they sought practical advice on how to do that, the literature was bereft of meaningful applications. They found themselves in an endless cycle of 'trial and error'. Having been alerted to an important aspect of science learning, they struggled to determine appropriate (and manageable) ways of responding in practice. In a similar way, my understanding of the complexity of science teacher education is developing, although I am increasingly well informed about the theoretical underpinnings of many science teaching and learning issues, being able to respond pedagogically is really difficult. I find that challenging my pre-service teachers' desire to accumulate 'tips and tricks', moving beyond subject matter content or teaching to transform science learning, although theoretically sound initiatives, are exceptionally difficult to address in practice.

Workshop 2: '*Science Conceptual Understanding*'

I am using everything I can get my hands on [*literature*, *theory etc.*] *to help me*, *because I cannot see what can be pared back and what things are more important than others.*

Post Workshop 2 reflection: '*Science Conceptual Understanding*'

… there is a general negative perception of science … know this from the literature (*less than 3% of time devoted to teaching science*). *Try and explain what is bad/wrong with school science – transmissive*, *content based*, *decontextualized*, *not useful etc. Aikenhead work … There is so much theory and there are so many ways of presenting this … how do I know if this is the best way … how do I learn about other ways*?

Lecture 4: '*Nature of Science & Science as a Human Endeavour*'

What is the best way? Literature says good way is through examples. I have plenty of examples, but now I am worried I will explain them wrong. What if I forget bits?

Post Lecture 4:' Nature of Science & Science as a Human Endeavour'

I also now see the importance of the [*new Australian*] *curriculum, according to the literature* [*this –Science as a Human Endeavour*] *is a good way of presenting science …* [*As a science teacher*] *I could see that I was making the links between science being useful, but I did not know why I was doing it. It was a rudimentary understanding and very much intuitive. My intuition seems to come first. But I cannot articulate why or the purpose for what I am doing until I go to the literature and then I can see why I did that.*

Post teaching visit reflection:

… I have done all this reading and studying and exploring and practicing (not as much practicing as reading) to try and create situations that the literature says they need to be in or exposed to or have the skills to do in order to be able to be confident and competent practitioners. I want them to feel that the unit has helped provide the grounding with the skills to feel like competent and confident practitioners. And they will go into a school and they may not know everything but they will have the skills that enable them to find out. Sigh. I don't know whether that message is getting across. I have been working toward getting to that point and I haven't made it explicit. Now I am wondering whether making it explicit so late in the piece is even going to make a difference.

I suspect they are stuck on "we want content and tips and tricks". I know from my reading that is not going to work. It is not fulfilling. We are designing a course that transcends that, but they can't see that. They don't know the wealth of literature … They don't know what they don't know. They are resistant to it. So it is frustrating. How do you meld those two? How do you get the two to meet? Even at some rudimentary level. It is different from teaching [*in school*] *… here it is not about content. Trying to prepare students … They see the quick fix as being 'teach me the content' and a lot of high school teachers see the quick fix as being, "I will teach you the content." But here it is different. I cannot articulate how. It is very different though.*

Like Brookfield (1995), I recognized the value of supporting my pre-service teachers in confronting their taken-for-granted assumptions about teaching and learning to teach, but finding productive ways of so doing in teacher education programs is fine in theory but not so straightforward in practice. I consider a key element of my developing expertise as a teacher educator hinges on my moving from problem recognition to pedagogical actions that make a difference for pre-service teachers' learning about teaching.

Pedagogical Discontent as a Beginning Teacher Educator: A Personal Perspective

> … knowledge is the completed resolution of the inherently indeterminate or doubtful. (Dewey, 1930, p. 217)

The previous sections of this chapter outlined in detail the major themes that emerged from John's data analysis. What follows is my learning from these experiences – I endeavour to make clear how I use the learning experiences impact on my understandings of, and practice in, science teacher education.

Through this self-study I have come to understand teacher education differently to that which I had envisaged when I was not as intimately involved in it as an active participant. The experience has helped me to see the complexity in teaching science teaching that was previously not so obvious. As a novice teacher educator, I found learning from experience to be difficult (and at times even painful), but framing my learning through the lens of 'pedagogical discontent' helped me develop and grow in the role of teacher educator. By discontent, I mean feelings of misalignment between what I set out to do and what actually happened, or as Whitehead (1993) described it, 'being a living contradiction'. Yet I do not mean to imply that discontent only carries negative connotations.

My experiences of discontent proved to be both negative and positive in nature. In the case of negative discontent, I felt that something was missing, for example a lack of knowledge on my part to carry on a fruitful discussion in class or a lack of active student participation in a pedagogical episode. Experiences of positive discontent occurred when I felt as though I had sufficient competence to capitalise on a situation, such as identifying a teachable moment 'on the fly', or when I was able to envisage how to improve on a situation that was not previously evident to me; situations that caused me to reconsider how I had interpreted and responded to a given episode or event.

By considering my experiences through the notion of discontent, I was able to critique my actions and experiences and go beyond viewing them as mere episodes of 'success or failure'. Through the process of working with a critical friend, I found myself considering the what, how and why of the discontent. In so doing, my examination of situations meant that that which might normally develop as tacit knowledge became much more explicit.

Another benefit of viewing my experiences through the notion of discontent was that I was able to 'delight in the problematic' and 'enjoy the doubtful' (Dewey, 1930, p. 217). Doing so was important because it encouraged me to frame my practice as problematic rather than seeking to avoid failure. The notion of discontent therefore encouraged my approach to learning as being driven by individual inquiry where questioning and learning was natural and highly valued. As I came to realise, viewing practice as problematic and going beyond teaching as delivery of information helped me to be comfortable with uncertainty; something I also hoped to instil in my students, but also something that demanded a lot more of them than I necessarily recognized at the time.

Being a novice teacher educator is frustrating at times. It feels very much like being a beginning teacher again – which was challenging. I found that my previous school teaching experience did not translate into positive outcomes as I might have anticipated. My capacity was reduced and my confidence was low; again, somewhat odd for an experienced teacher, but it illustrates how the change of context impacts practice. I found it difficult to decide on suitable teaching approaches to teach science teaching as my experience in that context was limited. As an experienced science teacher, selecting particular approaches to cater for different groups of students was relatively straightforward. I had done it before, knew what worked and was comfortable with the processes, actions and reactions. My previous experiences rooted in the collection of approaches to teaching science was underdeveloped in relation to being a science teacher educator and it is difficult to achieve what I am trying to achieve when I am unsure of how to confidently create (pedagogically) the story I am trying to tell.

As a novice I did not know the best methods, readings, activities, and sequences of lessons that would help me best achieve my purposes. At the start I was unable to choose teaching approaches that might be most effective in a tertiary context as I lacked experience to guide me. I knew from my readings and previous teaching experience that a transmissive approach, content driven teaching and the sharing of 'tips and tricks' would be ineffective. It did not represent the kind of science education that I wanted to model and yet I still found myself sometimes reverting to that form – which was very frustrating. However, over time, I developed a stronger sense of pedagogical purpose and a shift in my understanding of what science education could be.

I found that by considering one question, new questions arose. When I learned more about what I did not know, more complex and complicated questions arose. Discontent became increasingly apparent the further into the unit I progressed. But, even though it got harder, the questioning (inquiry) fuelled a deep sense of learning and became an ingrained process. Rather than searching for solutions, I found myself seeking greater understanding and thus becoming more informed about particular teaching and learning situations. My pedagogical questioning and inquiry developed, as Dewey (1930) described it, through a process in which as 'one question was disposed of; another offered itself and thought was kept alive' (p. 218).

As a high school science teacher, my focus was on teaching by the mandated curriculum. Success was measured mostly by summative topic tests and exams. In that context, my comfort resided in the accumulation of content knowledge. With more content knowledge I could plan better units, teach more competently and help my students learn the content. Over time, I came to feel that content driven pedagogy was ineffective and so I sought to make my lessons more relevant to students' everyday lives. Despite that shift, I was still driven by the end goal of instilling my students with content knowledge. Although not named that way at the time, I experienced discontent as tension as I began to find the culture of school science unsatisfying and wanted to know more about why I felt unsettled and unsatisfied – which prompted my journey into post-graduate study.

In becoming a novice teacher educator, I experienced a massive shift in my beliefs about what science education should be. My focus shifted from being driven by content to being driven by the need to make science accessible to all and to tackle issues of scientific literacy. I developed a deeply felt moral purpose about pre-service teacher education and developed a powerful sense of agency about the importance of science teacher education. This fuelled my desire to learn about the theoretical aspects of pre-service teacher education and to continue to learn and improve through the experiences of teaching. My focus centred on trying to work out meaningful and purposeful ways of teaching the science teachers of tomorrow's students.

As both the literature and my experience made clear, I needed to teach for conceptual change (De Jong et al., 1998; Hewson, Beeth, & Thorley, 1998; Posner et al., 1982; West & Pines, 1985) if students were to engage in learning about science education that moved beyond mere content knowledge, tips and tricks. Just as I had experienced a conceptual challenge in my understanding of science teaching and learning so too I needed to create conditions that encouraged my students to consider science teaching and learning in new ways and/or different to their own schooling experiences. Accepting the challenge of so doing placed added pressure on me as a novice. Teaching for conceptual change is dramatically different to teaching content like mitosis or electrical circuits. This made my science teacher education plight more difficult as it required me to teach about ideas that I only knew from a theoretical perspective – what practical approaches could I use to implement teaching for conceptual change; an issue also noted by Berry and Milroy (2002).

My discontent about transforming science content into meaningful science teaching and learning engendered within me a drive to help my pre-service teachers see that content driven, transmissive teaching practices, did not fundamentally change students' learning about science and would do little to enhance scientific literacy. I aimed to encourage a sense of dissonance in them about their own school science teaching and learning experiences and to therefore be open to the idea that science education comprises much more than teaching a static body of knowledge. My discontent drove me to try and create conditions to support my pre-service teachers in making their own shift in understanding and practice and to appreciate science education in new and different ways.

Pedagogical discontent played a huge role in helping 'name and frame' my situation. I felt frustrated at times but was able to see progress through episodes of positive discontent, such as when many students started to enjoy classes and engage more readily with the concepts and ideas under consideration – such things as giving students permission to make mistakes and to be comfortable with uncertainty, and recognizing that science knowledge itself can be uncertain and tentative.

Working with a critical friend to reflect on episodes of discontent helped me to frame discontent in different ways. It was a collegial relationship that enabled growth in knowledge and understanding through experience as a result of challenging ideas, practices and thinking and not allowing 'rationalization to masquerade as reflection' (Loughran, 2002). Theoretical perspectives about science education were ever present in the literature, but practical approaches for teaching were not so readily apparent. Being comfortable with uncertainty came slowly at first due to my inexperience, but I gave myself permission to not know everything and powerful learning about pedagogy followed. Helping my pre-service teachers do the same is what I now understand as a crucial aspect of being a science teacher educator and a central element of second order teaching. In many ways, this self-study has highlighted how, through inquiry into one's own practice can be transformative and genuinely impact understandings of what it means to be a science teacher educator.

Conclusion

This chapter aimed to tell my story and illustrate how my understanding of, and knowledge about, science teacher education is being developed and shaped through my self-study. As a consequence, the nature of teaching and learning about science teaching stands out in ways that has shed light on the complex and sophisticated knowledge and practice essential to quality in teacher education. Although self-study is often used as short hand for the fuller terminology of self-study of teaching and teacher education practices (Lighthall, 2004), I have found that the reality is that self-study is as much about learning as it is about teaching; something John, Gillian and I trust this chapter has also highlighted for you.

Attention to learning through self-study matters because it is through considering how and what one learns that a qualitative shift in perception and meaning making (by the learner – me) can result through a process of reframing one's existing assumptions and thinking customs. Sterling (2010–2011) described such a qualitative shift as transformative learning and just as Murray and Male (2005) considered the change in context from school teaching to teaching in teacher education as a shift from first order teaching to second order teaching, so too Sterling draws on similar thinking to describe transformative learning.

Sterling (2010–2011) described first-order learning as the most common form of learning. It relates very much to the world external to the teacher. The content of the lesson is often delivered through traditional transmissive teaching approaches and information transfer often leads to surface learning in the student. Second-order learning occurs when there is a change in thinking or personal awareness by the teacher. The learning takes on an internal dimension whereby a critical examination of the self, in relation to the subject matter occurs – a form of meta-learning. Such learning is considered to be deeper than the surface learning evident in first-order learning. Prior teaching skills are questioned and the purpose of an activity or the subject matter is explored.

Kelly and Cranton (2009) explained that when learners question their assumptions it can lead to a shift in how they see themselves in relation to the world and the subject matter, in so doing, they have engaged in transformative learning. Through successive iterations of questioning, inquiring, reframing and learning through experience, deep learning supports a process of meta-learning and the learner becomes much more aware of them-self in the learning process. In the process, deep conceptual and pedagogical learning is catalysed and the focus is squarely on the learning process derived of the pedagogue's teaching rather than the product per se.

Sterling (2010–2011) described the shift from first-order to second-order learning as sometimes painful to the learner. Resistance may occur as existing understandings, beliefs and values are challenged; being confronted by being a 'living contradiction' (Whitehead, 1993). The learner is required to reconstruct meaning which can clearly cause discomfort. However, a learner may also experience excitement and inspiration; key elements that can kindle learning from, and production of, new knowledge of the teaching and learning relationship.

We suggest that genuinely engaging in self-study of one's own teaching and learning about teaching can facilitate transformative learning for teacher educators. In many ways, doing so is at the heart of developing a pedagogy of teacher education and is the cornerstone for explicating the specialist knowledge, skills and ability that underpin what it means to be a scholar of teacher educator.

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Chapter 21
Reflections on Self-Studies and the Preparation of Future Science Teacher Educators

Justin Dillon

On Reflection

By way of introduction, after taking a degree in chemistry, I trained as a teacher during 1979–1980 and then taught science in London high (secondary) schools until January 1989 when I joined King's College London as a lecturer in science education. I've taught in ten high schools with three spells as a full-time teacher and a short spell on a peripatetic science support team filling in for long-term absences. My current position as Head of School (Dean) of the Graduate School of Education allows me some time to teach on pre-service courses of which England now has several different models. I've also taught Master's degree courses on teacher development and supervised over 20 doctoral students to completion.

What I haven't done much of during my career is self-study with the exception of a couple of autobiographical pieces at the invitation of other people. It's not my default position. So although I came to these four complementary chapters as an experienced science teacher educator, my understanding of self-study was rather limited.

That's not to say that the courses that I have worked on don't encourage self-study or reflection, quite the opposite, in fact. Reflective practice is the *zeitgeist* of teacher education in England as it is in many other countries. Although, having said that, I'm not sure how well we teach people how to reflect – we rather assume that asking people to write a reflective piece is the verbal equivalent of handing people a mirror – it needs no explanation.

One of the advantages of teaching at Master's level is that it keeps you up-to-date. A digression: my advice to less-experienced academics might be don't turn down opportunities to teach – I don't think I've ever regretted saying 'yes' when

J. Dillon (✉)
Graduate School of Education, University of Bristol, Bristol, UK
e-mail: Justin.dillon@bristol.ac.uk

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asked to teach a course. Back to the point: one paper that I read that has stayed with me for over a decade is Dennis Atkinson's 'Theorising how student teachers form their identities in initial teacher education' (2004). In a section headed 'Teacher as rational agent', Atkinson writes:

> In our everyday understanding of teachers and their actions it is quite normal to view the teacher as a self-conscious, reflective and hardworking individual whose practice is consciously planned and initiated. The assumption here, of course, is that of the effective teacher as rational individual, who is able to bring rational judgement and reflection to evaluate the quality of his or her teaching. (p. 380)

He goes on: 'In the domain of action research in education a number of what might be termed "rational discourses" (although different in intention) have been developed to legitimate and support practitioner-based research into teaching'. The term 'reflective practitioner', according to Atkinson, is underpinned by a notion of the teacher engaged within a single hermeneutic process looking backwards and forwards at what goes on in the classroom. He then describes the 'reflexive practitioner', also involved in rational reflection on what goes on in the classroom but who also cogitates on 'the effect of institutional structures on teaching as well as reflection on the self in action in terms of interrogating one's beliefs, attitudes, assumptions, prejudices and suppositions that inform teaching' (ibid.) – a double hermeneutic process. Where I see myself and where I hope teachers get to in their development is an identity of 'critical practitioner', 'interrogating political, ideological and social processes that frame educational work in order to expose, for example, power relations in which teachers function, discriminatory practices, victimization and inequalities' (ibid.). Atkinson points out that the idea of subjectivity 'relies upon an essentialist position from which the subject is able to look outward towards the world and inward towards the self.'

In what I find quite a powerful insight, Atkinson concludes, having gone on to describe and analyse two case studies of 'student teachers':

> From a Lacanian perspective the problem with reflective practice is that it fails to acknowledge the lack in the Other, the symbolic order, through which understanding is achieved, and the persistence of the Real. If we only consider the imaginary and symbolic constituents of reflection when trying to evaluate problems in teaching then we fail to take into account how the real-of-teaching is screened through processes of desire and fantasy in which problems become problems within ideological frameworks of reflection. The unavoidable difficulty with reflective practice is that the Real cannot be symbolized and yet its inevitable omission from the symbolic means that we are forever seeking answers to the Real through the symbolic and the answers are always lacking… and so we keep on inquiring. (ibid. p. 393)

I've used this paper with several classes and they've all found it hard work. It's partly to do with the language – it's not surprising that practicing science teachers, tired after a long day's work or full-time overseas students for whom English may be a third or fourth language, struggle with writing such as '…Zizek develops the notion of quilting with reference to the Althusserian idea of interpellation and shows how key signifiers interpellate or 'hail' individuals into subject positions' (Atkinson, 2004, p. 390). But I still think they can get something from the paper and it opens up new ways of looking at reflection, a term which is, perhaps, over-used and little understood in teacher education.

The Four Papers

Being asked to comment on these four contributions felt like being dealt a hand of cards – I lifted up the corner of each one to identify its suit and value and then looked at the whole hand to see how good it was. In general, while they differ in tone and style they all offer positive messages that can be generalized to a number of contexts.

One is struck immediately by the gender inequity in the section – seven authors of whom one is male. Education seems to be increasingly seen as a female dominated profession. I'm not convinced that this is seen as being a problem in the way that it was when it would have been one female author and six men.

All four chapters focus on the trials and tribulations of major life transitions. While Gail Buck and Valarie Akerson reflect on how their institution prepares doctoral candidates during their first year of study, the other three chapters examine the challenges of transitioning from being a teacher to working as a teacher educator.

My own experience as a science teacher educator began while I was working as a classroom teacher. I mentored many student teachers during their teaching practice at a number of schools. I also contributed to King's postgraduate certificate in secondary education (PGCE) by accompanying a group of chemistry education students and their tutor on a short residential earth science field-course. I had completed a Master's degree part-time at King's while working as a teacher, so by the time I started in 1989 I knew most of my new colleagues quite well. I could not have wished to work with a more collegial or supportive group. Perhaps as a consequence, I did not encounter many of the challenges faced by the authors of the four chapters.

Each of the chapters describes the challenges of transition. Anne Hume describes her growing sense of unease thus: 'My confidence quickly dissipated as uncertainty about the precise nature of my new role began to grow' and Jennifer Mansfield describes her frustration: 'I was aware of a number of issues which worried me about my teaching and my pre-service teachers' learning'. Gail Buck and Valarie Akerson, writing from the position as 'old-timers' 'were surprised to realize that [they] had unintentionally built boundaries around [their] CoP [community of practice] that supported future K-12 science teacher educators, but did not provide the same support for those who did not intend to prepare teachers for formal K-12 classrooms'. Maria Wallace describes how she is 'now uncomfortably attuned to the normalizing, gendered, racial, neoliberal, and capitalistic processes shaping [her] onto-epistemological becoming'.

Returning to Dennis Atkinson's discussion of student teachers and their identity formation, there seems to be a trend in some if not all of the contributions that the effective science teacher educator is a 'rational individual, who is able to bring rational judgement and reflection to evaluate the quality of his or her teaching'. Both Hume and Mansfield initially seem to fit Atkinson's notion of the 'reflective practitioner', however, with the aid of self-study and some critical friends, both shift to be more identifiable as reflexive practitioners reflecting by 'interrogating one's beliefs, attitudes, assumptions, prejudices and suppositions that inform teaching'. Both Hume and Mansfield emerge from the process seemingly empowered and enlightened although neither seems to reflect on 'the effect of institutional structures on teaching' such as the seeming lack of adequate support for people in their position.

Buck and Akerson describe the experiences of people in transition – so we can only appreciate their students' perspectives second-hand. Indeed Buck and Akerson are part of the 'institutional structures' that impact on their students. In their concluding 'implications' section they note that 'there are levels of administration and various policies within the community. These various components of our CoP […] have additional requirements and different practices'. I'm not sure what to make of the comment that 'students need to work through these levels and the required vs. recommended procedures involved'. Does that mean that the students need to conform because that's how the system works or does it mean that the inflexibility of the system provides a hurdle that the students must negotiate? Perhaps there's a clue in a subsequent comment that students need to 'see that the struggles and discomfort that they may feel during the process is common with any identity development'.

Maria's contribution stands out in several ways. It is she, perhaps, who reaches the level of critical practitioner, able to interrogate 'political, ideological and social processes that frame educational work in order to expose, for example, power relations in which [teacher educators] function, discriminatory practices, victimization and inequalities'. But while Maria has reached the highest level of enlightenment it seems to come at a cost. While the other three contributions clearly identify students as those who suffer from the inadequacies of the authors' teaching, Maria's students are barely visible.

The Preparation of Future Science Teacher Educators

Each of the four contributions opens up opportunities to reflect on how science teacher educators are prepared. Anne Hume's use of the model of PCK proposed by Magnusson et al. (1999) has some affordances. The five dimensions: orientations toward science education teaching; knowledge of science education curriculum; knowledge of students' understanding of science teaching; knowledge of instructional strategies; and, knowledge of assessment provide a useful heuristic but perhaps there is too much of a focus on knowledge. What I found most useful in learning to be a teacher educator was planning sessions with colleagues. In some cases this would be in England but I also spent time running 'train the trainer' workshops in Nigeria and Indonesia. Planning is the key to effective teaching so it is not surprising that planning teacher education sessions with colleagues can be so empowering.

To what extent is self-study the answer? I think the evidence from the four contributions is mixed. For Anne Hume and Jennifer Mansfield, self-study seemed to be a post hoc treatment rather than preparation. Indeed Hume's early experiences left her feeling dissatisfied: 'I was really only scratching the surface in relation to my own understanding of the nature of reflection and devising pedagogies for acquiring reflective capabilities'. My feeling is that the ability to engage in effective self-study develops in parallel to becoming an effective teacher educator – one feeds off the other. I would be surprised if you could learn to become effective at self-study without several years of experience as a teacher educator.

I do like the strategy, which I associate with John Loughran and colleagues at Monash University in Melbourne, of, as Anne Hume describes 'explicitly sharing the pedagogical reasoning behind [her] own teaching in the workshops with my student teachers in ways in ways that modeled the reflective thinking I wanted my students to engage in'. I can see why this strategy would work although I have rarely used it myself.

In England the government has announced that it is bringing in a Teaching Excellence Framework (TEF) to complement the Research Excellence Framework for universities. Universities that do well in the TEF will be able to charge more for their courses – there are very few private universities in the UK compared with the US so the influence of the national government is much greater. Such an incentive will refocus universities on the support they give to new staff who, in most cases, have little experience of teaching. Many of these courses, however, are less appropriate for teacher educators who are usually experienced and know one end of an interactive white-board from another.

Anne Hume benefitted from her PGCertTT task which offered her time and space to 'reflect upon and articulate another of [her] evolving PCK components, namely [her] *orientations towards teaching science education*.' She found the task of formulating her teaching philosophy very beneficial in 'bringing coherence to [her] teaching of the science education course. However, this seems to me to be scratching the surface, too; what is needed, perhaps, is more effective mentoring so that new staff are not simply writing to and for themselves. There should be more systematic support than, as she puts it: 'timely advice and tips from several supportive colleagues'. As Anne puts is 'My initiation into tertiary teaching did not involve a process of carefully scaffolded induction, but rather one of 'jumping in at the deep end' – it really should not be like that.

Maria Wallace's contribution helps us to see that teacher educators would benefit from opportunities to reflect on more than white-board technique. Wallace reflects on her pain in recognizing that she is working in 'a society built by unquestioned human conditioning in a standardized education system'. What support is needed by someone who aims 'to disrupt, or resist, this inherent tradition in science teacher educator preparation by exploring the ways in which dominant epistemologies influence prevailing assumptions regarding science teacher educator preparation'? At some point idealism and pragmatism need to accommodate each other. During her time as a school teacher, her administrators told her that if her 'instruction did not produce higher test scores on the regular district benchmarks, [her] contract would not be renewed for the following year'. I suspect that she will face similar challenges as she embarks on her career. Wallace recognizes that 'becoming-science teacher educators must re-conceptualize how their practice is subjectively guided and intentionally interrogate their sense of self to engage teaching as an ethical endeavor' but what does that look like and what support does it need to develop?

Gayle Buck and Valarie Akerson describe a doctoral education system which is most unlike the ones that I am familiar with in England. I have sat on the committees of doctoral students at UC Santa Cruz and Cornell so I know something of the US system. I've also examined doctoral theses in different countries including Denmark where students are expected to submit a document which is an agglomeration of around four papers which have been published or which could be submitted for publication. In the UK such an approach is rare but students are encouraged to finish their studies in 3 years and they take far fewer courses than students in the US. No one system is better than the others but I do feel that we should spend more time looking at other systems because it challenges the assumptions that we make.

Buck and Akerson describe their community of practice but it is essential that new researchers see themselves as part of a worldwide community as well as part of their institutional community. I have coached at several doctoral summer schools organised by the European Science Education Research Association where around 50 students from Europe and elsewhere come together for a week to share their work. Such opportunities are, I believe, invaluable in developing an international community of scholars.

Jennifer Mansfield's contribution (well supported by John Loughran and Gillian Kidman) points to the value of teacher educators researching their practice 'to gain insights into their pre-service teachers' learning about science teaching'. As an editor of an international journal I see far too many studies of science teachers' understandings of X, Y and Z. In essence they all seem to show that student teachers don't know much. Indeed, one wonders why they were selected for the pre-service courses in the first place. I think we have enough studies of pre-service teachers' knowledge – what would be useful would be examples of interventions that have massively increased pre-service teachers' knowledge and improved their students' learning.

Mansfield points out that Tom Russell (1997) 'noted how important it was for science teacher educators to respond to a need to teach their pre-service teachers more than subject matter content'. It is indeed the 'why' of teaching that is as important as the 'what', something that policy-makers and politicians signally fail to realise.

Final Thoughts

Reading these four contributions and writing these reflections have been helpful in developing my own thinking. It's hardly surprising that in a book on self-study the contributors are positive about the benefits of the approach. My critical eye questions whether we know enough about the technique to be describe exactly what takes place and explain why it is or is not successful? Individual case-studies are interesting but they are colored by personal bias and narrow in their potential for generalisation. As Atkinson says reflective practice 'fails to acknowledge the lack in the Other, the symbolic order, through which understanding is achieved, and the persistence of the Real.' (2004, p. 393).

The four contributions provide insights into the identity of the science teacher educators that they want you to have. What can you learn from them with any degree of certainty? I think that I would like to see a more collective approach to self-study – group-study, perhaps, that offered a more systematic and collegial approach to academic development. I'd also like to see some innovations in how universities worked that made self-study part of a systematic induction process rather than, as is the case in these contributions, an attempt to deal with 'jumping in at the deep end' as Anne put it.

Finally, I would like to see self-study that helps to develop Atkinson's critical practitioner – people able to see how their lives are fashioned by wider socio-economic forces – without being disempowered by that knowledge. However, there is an inherent difficulty implicit in this endeavor as Atkinson acknowledges when he concludes his paper:

> The unavoidable difficulty with reflective practice is that the Real cannot be symbolized and yet its inevitable omission from the symbolic means that we are forever seeking answers to the Real through the symbolic and the answers are always lacking… and so we keep on inquiring. (ibid.)

Maria concludes her chapter by stating that 'it is unlikely that any of my questions will ever be fully answered. This is okay.' Indeed.

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Part VI
Epilogue

Chapter 22
Here's Looking at You Kid: When the Researcher Becomes the Sample

Norman G. Lederman and Judith Sweeney Lederman

The quality of the K-16 science curriculum and the level of students' science achievement remains a critical global concern. Science education has always chased the ever elusive goal of scientific literacy and dissatisfaction with students' knowledge and ability typically leads to concerns about the science curriculum and science teachers. Eventually, stakeholders and policymakers focus on teacher education programs (i.e., graduate degree programs, preservice programs, and professional development programs) and those directly involved with the education of teachers. This concern often leads to discussions about whether teacher education programs are needed at all, or even detrimental. Needless to say, the audience for this book does not need to be convinced of the value and importance of systematic teacher education programs in science. Although many recognize that postsecondary science instruction is critically important, the overwhelming focus on the improvement of science teaching (conceptually and empirically) is at the K-12 levels. We strongly believe that many of the problems related to science instruction in K-12 levels should be a concern of those who teach science at the university level. That said, science teacher education is believed, by many, to be the root cause of many of the problems related to the quality of students' learning of science.

We have the privilege of editing the *Journal of Science Teacher Education*, the flagship journal of the Association of Science Teacher Educators. It is the only peer reviewed research journal that focuses solely on science teacher education at all levels. The manuscripts we receive focus almost exclusively on systematic research on the impact of various forms of preservice and inservice teacher education with the typical outcomes being teacher knowledge and practice (Abell, 2004). The general design of the studies submitted to *JSTE* for potential publication is usually one or

N.G. Lederman (✉) • J.S. Lederman
Department of Mathematics and Science Education, Illinois Institute of Technology, Chicago, IL 60616-3793, USA
e-mail: Ledermann@iit.edu; ledermanj@iit.edu

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more researchers studying the development and/or change in science teachers' knowledge and/or practice. Rarely do we receive manuscripts that involve a science teacher educator turning a reflective eye on her/him self. If we can assume that you have sequentially read all, or a subset, of the chapters in this text, you should already realize that there is much to be gained from studies that generally adhere to the genre of "self-study," popularized by Bullough and Pinnegar (2001), LaBoskey (2004), and Loughran (2014), among others. That is, studies in which the science teacher educator/researcher looks in the mirror and is transformed into the unit of analysis. It is true that self studies often involve "critical friends" who are colleagues of the researcher and serve as a source of data, but in the end the researcher in a self-study becomes the research sample. Our purpose here is not to provide a critique of the individual studies provided in this text. Rather, our purpose is to ultimately discuss the implications of self-study research for science teacher education, from our perspective as editors of *JSTE*.

Before continuing the discussion of the implications of self-study for research on science teacher education, it should be of some value for us to discuss the overall criteria used for making editorial decisions about the publication of research manuscripts submitted to *JSTE*. In general, Editorial Review Board Members, Associate Editors, and the Editors-in-Chief consistently ask the following questions with respect to each submitted manuscript:

1. Are the purpose and research questions clearly stated?
2. Does the literature review provide a rationale and theoretical/conceptual framework for the proposed study?
3. Is the research methodology clearly described in detail?
4. Do assessment instruments have appropriate validity and reliability?
5. Is the data analysis appropriate and clearly described?
6. Are the conclusions supported by the evidence?
7. Do the findings add to the literature on a question of importance to science teacher education and have practical applications for the practice of science teacher education?

Naturally, there are many specifics that undergird each question, but the general questions should provide a good description of the parameters that are used to make editorial decisions. Item #2 is the criterion that is the primary reason for manuscripts being rejected for publication, and this will be discussed in detail later. Question #7 is of critical importance and deserves some further elaboration, especially with respect to the implications of self-study research for research in science teacher education. On occasion, manuscripts are received that replicate findings that are already well known with numerous articles supporting articles. For example, it is well-known that with respect to professional development, "one size does not fit all." Best professional development must be customized to teachers' needs and take into account where teachers are in terms of their knowledge and skills (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; Loucks-Horsley, Stiles, & Hewson, 1996). A new study in a different location that just reiterates what is now common knowledge is not adding to the empirical literature. In addition, some research studies are so esoteric that, in our opinion, they have no immediate or possible practical applications for science teacher education. For example, there are some researchers that are very interested in levels of cortisol as a measure of stress in teachers. In particular they complete studies that look at the variations in cortisol levels relative to various stressors in teaching. There are numerous problems with the measurement of cortisol levels and its immediacy in appearance relative to stress. In short, it is difficult to track cortisol production back to a particular stressor and especially since the presence of cortisol remains in your system many weeks after it is released. We are not convinced that there are any practical applications of this research for science teacher education. Importantly, we are convinced that many, but not all, of the self-study investigations in this text do add to the empirical literature and do have practical applications for the practice of science teacher education.

Just as science teacher educators find themselves in various contexts and roles, the 15 chapters in this text are quite varied and diverse in foci. In our way of thinking, the chapters fall into five loosely constructed categories with, of course, some necessary overlap, that provide a global view of the terrain of self studies within science teacher education. The three most common categories found were studies in methods courses (e.g., Bowen, Bartley, MacDonald, & Sherman; Capobianco; Gilles & Buck; Makki & Holiday; Subramaniam, Asim, Lee, & Rideaux), studies in subject matter courses (e.g., Conner; Nyamupangedengu; Fuentes & Bloom; Trauth-Nare, Buck, & Beeman-Cadwallader), and studies of the development of one's personal identity as a science teacher educator and/or making the transition from classroom teacher to science teacher educator (Davis; Mansfield, Loughran, & Kidman; Hume; Wallace). There were two other categories that provided equally important insights, but were definitely not the norm. One category focused on how science teacher educators enacted and revised a PhD program (Buck & Akerson) while the other involved professional development of science teacher educators (Marble, Kamen, Naizer, & Weinburgh). Each of these categories is important in their way and are rarely seen in the literature. We will refer to these further later in this chapter.

As you might expect self-study investigations are typically qualitative with multiple data sources. In some sense these investigations are quite similar to case studies, notwithstanding the clearly introspective preference. The focus of reflective on one's practice is not a new idea, but it has typically been applied to self-reflection by teachers (Schon, 1987). The multiple data sources provide a strong argument for the validity and verisimilitude of the research findings. This is critically important because most individuals are a bit skeptical of researchers collecting and analyzing data they collected about themselves. These multiple data sources of data are wide ranging and may included observations of teaching by others, interviews with colleagues and students, written and oral feedback from students about their perceptions of the researcher's teaching practices, and personal journals written by the researcher, instructional and artifacts such as lesson plans and assessments. A unique source of data is evident in the studies presented by Davis and Hume, in which each referenced their own personal scholarship (i.e., publications and professional presentations), among other things, to help document their development of identity as science teacher educators. The diverse and multiple data sources used in self-study coincides nicely to items #4 (Do assessment instruments have appropriate validity and reliability?) and #5 (Is the data analysis appropriate and clearly described?) in the list of criteria focused on by reviewers of manuscripts for *JSTE*. Although self-study investigations are different than what is typically found in the literature, their collection and analysis of data to answer the research questions align well with what is found in the more "traditional" empirical literature.

As mentioned previously, we are strong believers that quality research in science education should impact and/or change classroom practice and learning, whether it is in K-12 settings or preservice/inservice contexts. We are not strong supporters of research that does not appear to provide answers to questions of educational importance. Given the importance of affecting positive change, it seems to us that self study provides a more direct connection to change than researchers studying other individuals. After all, when one collects data on her/him self the data are not abstract or distant. The data are about themselves. When we all read research about people we do not know or even when we directly complete research on others, it seems one step removed from having an effect. Instead of having to just convince yourself to change your practice, you have to convince others to change their practice from the findings of research conducted with others.

It became immediately clear that one of the most important outcomes of self study was the necessary heightened attention to students by the researcher (i.e., teacher educator). This was immediately obvious in the studies in methods and science courses. This attention to the concerns and interpretations of students had a direct and almost immediate impact on instruction. This seems like an odd comment to be making because, of course, all teachers should be cognizant of their students' needs, understandings, etc. And, of all people, a science teacher educator should have students as a prominent concern. Perhaps, heightened is the best word to use. In general, the common notion that it is important to be cognizant of your students is not new and earth shattering. But the critical issue here is that the self-study methodology, through its data sources, really facilitates and necessitates attention to students through its systematic collection data from students about one's teaching.

The findings from studies of the development of one's personal identity as a science teacher educator and/or making the transition from classroom teacher to science teacher educator (Davis; Mansfield, Loughran & Kidman; Hume; Wallace) were enlightening because the perspective was on teacher educators' rather than students on preservice/inservice teachers. Often, in our field, it is not recognized that being an excellent science teacher involves a very different skill set than being a science teacher educator. All too often, we are quick to hire classroom teachers as adjuncts to teach a science methods course. All too often, we look to classroom teachers to help with the supervision of student teachers. But the content of a methods course is different than the content of a science classroom. Therefore, the content of a methods course has its own pedagogical demands with which even the best of classroom teachers may not be familiar as new science teacher educators. This is in line with what we have learned from the research on pedagogical content knowledge. Alternately, if one steps back a bit the findings in this category of studies is very similar to something we have seen before. There is a parallel between these studies and studies of student teaching. In each case the individual is learning how to do something that they have not done before. There are differences of course, but there were just as many similarities. Capobianco's study took place in a methods course, but is consistent in the insights it provided in terms of learning how to do or teach something you have not done or taught before. In her case, the challenge was to integrate engineering design into her science methods course. We imagine that most of our colleagues in science education are experiencing the same uncertainty as a consequence of the unveiling of the *Next Generation Science Standards* (Lead States, 2013). How many of us have ever taken a course in engineering? How many of us have ever taught engineering design? The same studies also can be used to highlight the differences between preservice teacher education and preparing to become a teacher educator.

The investigation by Subramaniam, Asim, Lee, Rideaux is interesting in its perspective and it is sure to promote much discussion. There has been much written about diversity and cultural differences in students' learning of science. There has not been much written about this issue from the perspective of the science teacher educator. That is, what are the dynamics of a methods course in science teacher education when the faculty are from racial and cultural groups different than the students? This study investigates the thinking of the methods instructors and the challenges that were created by the cultural and racial differences. The final interpretations and conclusions are interesting and are sure to promote discussions of alternative interpretations of the data. But, isn't this the point? Discussions about the issues created by cultural and racial differences between preservice students and their instructors are important. What impact does this have on the quality of preservice education? Is it a benefit or an obstacle?

Sometimes, self study investigations seem very similar to "traditional" designs in their more narrow focus. Still, they can provide very insightful and important findings. The study by Gilles & Buck focused on students' perceptions of the teacher's enthusiasm during lectures and inquiry. Their study was in a methods course and an inverse relationship was found between the students' (i.e., preservice teachers) perceptions of enthusiasm of their teacher during inquiry and lecture. That is, the students found their methods instructor more enthusiastic during lecture than during inquiry. This finding is contrary to what we typically find in a K-12 context. It seems counterintuitive, but the more you think about the situation the more intuitive it feels. When the methods instructor is conducting a teacher centered lesson such as lecturing, all students, hopefully, are focused on and paying close attention to the teacher. However, during an inquiry based, student centered activity, attention is not on the teacher and her/his enthusiasm or lack thereof. Sounds similar to the principle who observes an inquiry activity and walks away thinking the teacher was just standing around and not teaching. Self studies need to be aware of these differences.

Needed Self Study Investigations That Can Contribute to the Literature on Science Teacher Education

This text provides readers with a good functional knowledge of the methods and nuances of self-study research. In addition, it provides a variety of examples of studies that have the potential to impact science teacher education. Naturally, there are many more samples in the literature as well as many more possible situations that could benefit for self-studies. As Editors of *JSTE*, we feel the following suggested studies, or categories of studies, also would have the potential to improve science teacher education research and practice.

The Professional Development of Science Teacher Educators

One of the studies reported in this text (Marble, Kamen, Naizer, & Weinburgh) took the unique perspective of science teacher educators studying the effect of a self-designed professional development effort, through the use of lesson study, to improve their practice. It is not at all common to see studies of the professional development of science teacher educators after they have officially received their rights of passage in the community (i.e., a PhD is science education and procurement of a university position that involves teacher education at some level). It seems that the field can be enlightened and move forward significantly if a culture of continued professional development was in place within the community. Science teacher educators would quickly point to their attendance and presentations at the meetings of professional organizations as professional development. And, of course, they certainly are. However, how does the attendance at such professional meetings change one's practice? How do science teacher educators use such experiences to reflect on their own practice? More adventurous is the initiative taken by Marble, Kamen, Naizer, and Weinburgh because they were not required by the usual tenure and promotion guidelines to design their own professional development. They embarked on a self imposed study as seasoned tenured professors with the sole intent to improve practice. That said, there are many ways that we can all improve our practice through professional development activities. The field needs self-study research in which science teacher educators study their participation and reactions to professional development activities (self-designed or the usual types). Hopefully, we all get better at what we do over the years, but there is no systematic documentation of our personal development and which types of activities seem to have the most impact on our practice.

The Process of Developing Preservice and Inservice Teacher Education Programs

Concerns about the quality of teacher preparation in science has been a constant over the past several decades. That is, there are perennial complaints and policy makers and governments continue to mandate changes in such programs. As science teacher educators most, if not all, of us have been involved in revising program requirements or even creating totally new programs. How to we decide on what changes need to be made? What sources of information do we use to make such changes. How do we arrive at consensus with our colleagues? How do we personally feel about the changes that are made and how does this impact our commitment and enthusiasm for the enactment of the program changes? How do we each personally perceive the enactment of the changes and their effectiveness? Many of these topics are discussed "off line" at social gatherings and informal conversations with colleagues at other institutions. However, there is no large volume of research in the empirical literature. It is an important topic and could be significantly addresses through self-study research.

Similar issues arise with respect to inservice teacher education programs. In general, the restrictions are different in terms of government mandates. Inservice programs (usually leading to a Masters degree) can be more flexible in terms of courses and experiences offered. Still, all of the questions listed for preservice programs remain. Yet, there is just as much paucity of systematic work in this area as with preservice program changes.

Development of new programs and revisions of existing programs is a reality of the teacher educator's life. The decisions that are made can be both painful and joyous. Regardless, there is always a level of deep personal concern. Whether we like to admit it or not, we all have are own personal biases or, to be more positive, professional convictions. Some of us are only marking territory and some of us are looking out only for the needs of our students. Regardless of how you want to look at it, we can all be helped by having systematic self study research documenting how others have confronted such situations. We all can benefit from being more reflective on our own reactions to these situations of change.

Program Development for Science Teacher Educators

Studies in this area would represent of subset of the type of investigation reported by Buck and Anderson in this text. They studied the development and revision of a PhD program for science education researchers. Naturally, many of the students graduating from their program will become scholars focused on teacher education, but not all. Still, the situation is the same. Many of us work in departments that offer PhD degrees and serve students who are primarily looking for careers as university professors. In some cases, you may be partly responsible for the creating of a new degree program. We were responsible for doing this at Illinois Institute of Technology. More commonly, most of us are involved in program revision.

When creating a program, what goals are guiding your program development? How do you see the skill and knowledge set of a PhD in science education and how does this influence the courses and experiences you choose as critical? Do you consider that some of your students may choose to remain in the K-12 school system? How do you simultaneously insure that your program requirements meets the needs of those who wish to remain in schools, those who will be at 4 year institutions, and those who will be hired at intensive research institutions? Of course, once you and your colleagues have created this new program, you will need to know if it is succeeding as planned. What is your thinking process in this regard? These are all very complex and critical questions, which can not all be addressed in a single study. But we think these are all questions that need to be thoughtfully researched and would be a strong addition to the literature on science teacher education.

Program revision is a more common experience for most of us. Still, questions very similar to those just delineated as part of program development are important in this situation as well. It is urban legend, and perhaps close to truth than legend, that we all subconsciously, or consciously, want to change whatever program we are working in to the program we graduated from. All of us spent several hard working and tension filled years getting a PhD through a program that we loved, hated, or had mixed fillings about. But, now that we have received our degrees we hold some level of sentimentality about our personal programs. We have some attachment to these programs and they are most familiar to each of us. How does this impact our decisions concerning program revisions? How do we react to our colleagues not accepting changes that would be more consistent with your thoughts? How thoroughly do you refer to research on the importance of program components you are recommending? The list of questions is endless, but how programs are configured and revised is critical to the future of our field. The study of these very personal questions that are made within a group colleagues can certainly be enhanced by self-study investigations.

Personal Development of Becoming a Researcher in Science Teacher Education

The previous recommendations for self study investigations have focused on the perspectives of current science teacher educators. However, the perspectives of students making the transition to becoming a researcher in science teacher education is just as important. For sure, data are collected from a student perspective in some of the studies previously discussed, but these data were all for the aid and development of the already minted science teacher educator. The recommendation here is for more studies in similarity to what was reported by Mansfield, Loughran, Kidman and Wallace in this text.

Students come to PhD programs in teacher education from a variety of backgrounds. In general, they are a mixture of current/former teachers, individuals in non-teaching science related fields, and individuals in education related fields, and informal school settings (e.g., museum educators). Their one commonality is that they want to focus on doing research in science teacher education. It is easy to collect data on PhD programs throughout the world and it is not too difficult to collect data on how graduates from such programs fare in their post graduate careers. However, much less is know about the developmental changes in thinking that occurs as a student makes the transition to a science teacher education researcher. How does their perspective on teaching and learning of science change? How do their prior conceptions influence their development? How do they perceive the focus of each of the program experiences they encounter? One could try to find answers to such questions by getting a sample of PhD students and administering carefully constructed questionnaires. However, the goal of a self study would be for each of these individuals to look inward and critically reflect on their own development. The goal is that this self-reflection will impact their own thinking. It will give them insight on their own learning and provide insightful context for their beliefs. The process may serve to reinforce and strengthen their beliefs and convictions or the process may case them to question their beliefs and convictions. These outcomes are far different than the traditional study that would just survey groups of these students.

Case Studies of Personal and Professional Development of Teacher Educators with and Without Teaching Experience

There is a perennial discussion concerning the importance of having teaching experience before embarking on the path of becoming a teacher educator through graduate education. On the one hand, there are those who will say that it is doubtful one can offer credible advice to a preservice or inservice teacher if he/she has never taught. The same would be said about doing research on teacher education. After all, we often say that "you can't teach what you have never done." On the other hand, there are countless examples of individuals who have been successful teacher educators (and teachers) without ever having taught or completing a teacher education program. In North America some states require that all university teacher educators have previously been certified to teach or are currently certified to teach. Again, this is only legally mandated in some states, but not all. Outside of North America it is very common that for individuals to teach in schools without going through a teacher education program or become university teacher educators without ever having taught. Most of the discussions around this topic are usually theoretical, there is scant empirical research that supports one side or the other.

It seems intuitive that the thought processes and professional development of individuals who have taught and those who have not would be very different as they travel the path to becoming a teacher educator and/or science teacher education researcher. Davis' investigation comes closest to this issue, but her investigation described her thinking after she had already become a science teacher educator. Having some introspective data on what these individuals are thinking and how they are perceiving and reacting to the courses they take would be significant and it would have the potential to transform the nature of our graduate programs. Should there be different curriculum tracts? Are there certain experiences that are essential for all, or does it make no difference? In any case, it appears that self-study investigations that establish single case studies or compares two case studies would be quite illuminating and significant to the field. Certainly these studies and their findings can be useful to science educators who are grappling with similar issues.

Personal and Professional Development of a Person with Secondary Education Experience Becoming an Elementary Science Teacher Educator

The structure and nature of PhD programs in science education around the world requires graduate work in a science area that ranges from "some" graduate work in a science area to either a Masters degree or the equivalent. Most people who have worked in elementary schools who choose to move to university positions do not have the science backgrounds to complete graduate work in the sciences. Hence, they usually enter PhD programs in curriculum and instruction or elementary education. Preservice elementary education programs are quite abundant, but it is difficult to find university science teacher educators with a focus in the elementary grades. Consequently, those individuals working as elementary science teacher educators are all too often secondary science teacher educators that have a desire to be involved with elementary teacher education or whose positions require that they do some work with elementary teachers. In either case, there is clear recognition of the situation that many elementary science teacher educators are really individuals whose previous focus was on secondary level teaching. Once again this is a PCK issue. There is considerable literature on the different focus of attention that exists between elementary and secondary teachers. That is, elementary teachers focus more on the emotional and social development of the student, while secondary teachers are more concerned with their subject matter. Both are concerned with students, but from very different perspectives. Our role here is not to take a position on whether this is an accurate conception or not.

What would be very interesting would be some self-study research on the thinking processes of a person who is transforming from a focus on secondary teachers to a focus on elementary teachers. Some of this thought process comes out in the studies of subject matter courses taught by teacher educators to preservice teachers (e.g., Funtes & Bloom). And, it is often the case that teacher educators are assigned the task of providing science subject matter courses designed for elementary teachers. However, whether it is a science course or a methods course, how is the secondary education person perceiving his/her audience? Is he/she working from a deficit model in a science course? Should he/she be doing so in a science course, or should he/she be teaching the same science that a secondary teacher would need? In terms of methods courses, does the teacher educator feel there may be a credibility problem? How is the potential credibility problem alleviated? What does the secondary teacher educator learn from elementary teachers? Again, all these questions are important and they are best answered through the self-reflection of the teacher educator. In addition to providing insight to others, the self study investigation should directly inform the practices of the secondary science teacher educator. One might even consider how the teacher educator's work with elementary science teachers impacts his/her work with secondary teachers.

Self Study by Science Teacher Educators in Teacher Preparation Programs, Inservice Programs and PhD Programs

Studies of this nature are clearly presented by many of the investigations reported in this text. The studies of methods instructors (e.g., Bowen, Bartley, MacDonald, & Sherman; Capobianco; Gilles & Buck; Makki & Holiday; Subramaniam, Asim, Lee, & Rideaux), subject matter instruction (e.g., Conner; Nyamupangedengu; Fuentes & Bloom; Trauth-Nare, Buck, & Beeman-Cadwallader), and studies of the development of one's personal identity as a science teacher educator and/or making the transition from classroom teacher to science teacher educator (Davis; Mansfield, Loughran, & Kidman) are the best examples.

The Association of Science Teacher Educators (formally AETS) was one of the first, if not the first, research organizations to have sessions in which teacher educators shared the curriculum for their courses as well as many of the experiences/activities they used with their students. These sessions were always well attended and we are sure that it was valuable for all attendees. The sessions were primarily focused on preservice science teacher education and were reminiscent of a "share-a-thon" that you might see at a practitioner meeting. We see nothing wrong in this, but it was not typical of a research organization. However, there is now a relatively "new kid" on the block. Self study research has the potential to leverage the success of the ASTE/AETS innovation into a rigorous research-based benefit for science teacher educators. Having science teacher educators engage in research on their thinking and practices in a reflective and critical manner at all levels of science teacher education can provide much insight to their colleagues, in addition to benefiting their personal practice. Bringing to light the decisions that were made, why the decisions were made, and students' (pres-service, inservice, and PhD) reactions to these decisions could have an enormous impact on the field.

Classroom Teachers Studying Their Own Teaching

The investigation of teachers' reflection on their practice is an important and vibrant area of research (van Driel, Berry, & Meirink, 2014). At first glance it might seem like having teachers participate in self study research on their own practice is a bit a field from the focus of this text. The focus of the book is on science teacher educators, not science teachers. However, let's look at this a bit closer. Having teachers do action research projects is a common practice in teacher education programs, both inservice and preservice. The argument is that this represents good professional development because teachers' practice will improve if they systematically study their own teaching. The research is not quite in on this yet, but it does intuitively sound like a good practice. In some instances, action research projects can resemble a self study investigation, but usually not. If teachers were guided more in the direction of a self-study approach, this reflective stance may very possibly produce significant impacts that exceed what results from completing an action research project. In general, action research projects are a little less risky as they typically do not involve the teachers in getting feedback from students on their own teaching and then reflecting on that practice to change instruction. Given the risk, self study may be more reasonable for inservice teachers than preservice teachers. Using self-study investigations as assignments in inservice programs may inevitably be more useful than the less specific action research assignments.

The science teacher educator could reflect on the effectiveness of the teachers' self study and gather data on the teachers' reactions to the experience. This in turn could change the teacher educator's classroom practice and approach to teacher education. Just a thought, but this is the connection we see between having classroom teachers complete self-study investigations and the focus of this text.

Self Study: Quo Vadis

It is time to return to our original task. As Editors of *JSTE*, do we see value in self-study research, as represented through the examples in this text, a research genre that can provide significant impact on science teacher educators and science teacher education in general? Our answer is a definite YES. The subtext to this question is whether we consider self-study as a legitimate form of research, and we certainly do.

There is much talk about the problems of self-study because the sample size is one or close to one, which raises concerns about the ability to generalize (Krathwohl, 2009). Self-study also involves a person analyzing data about him or herself, and this, of course, raises questions about potential bias, which seems to clearly exceed what can happen in more traditional research designs. In some ways this harkens back to the contentious debates about the value of qualitative research (Peshkin, 1993; Rist, 1977). And, this can be expected because self study research by nature will lean toward qualitative research paradigms rather than quantitative research traditions (Jacob, 1987).

It is true that the sample size in self-study research is one or close to one. However, the purpose is not to generalize from a single investigation. The purpose of a single investigation is to potentially effect change on the researcher and his/her practice. It is only after several similar studies yield similar results that considerations of generalizing to other situations and individuals may be pursued. And, there are many qualitative researchers that deny that generalizing is ever a major concern. Quantitative research, which is based on theoretical sampling distributions attempts to generalize from single investigations. In terms of any bias created by the researcher analyzing data collected on her/himself, this is a bit of a misconception. In self study investigations it is clear that there are typically multiple data sources, not just the reflections of the researcher. Consequently, there is more than enough opportunity to triangulate data and not simply rely on the data collected by the researcher about her/himself. In short, it is clear from the investigations in this text that the researcher's conclusions were reached from a combination of data collected from sources other than self reflections. The important strength of self study research is that it aims to arrive at findings from an "emic" or insider's perspective rather than an "etic" or outsider's perspective (Bogdan & Biklen, 1982).

The support for strong emphasis on self-reflection evident in self-study is either by coincidence or design consistent with the current consensus around the importance of self reflection evident in the formative assessment approaches in the NGSS (NGSS Lead States, 2013) and the new edTPA assessments of preservice teachers that are now required by a number of states (AACTE, 2013). Assessments for the NGSS vision of science education revolves around increased levels of formative assessment that both teachers and students can use to monitor instruction and learning. These assessments provide the teacher with feedback that can guide adjustments to instruction and they provide students with feedback on their own learning so they can adjust their approach to classroom tasks. In effect, these formative assessments provide students and teachers the opportunity to reflect on their behaviors.

The edTPA system for the assessment of preservice teachers has been accepted by 36 states (at the time of this publication) in the United States and is applied to all teachers in all grade levels and subject matter specialties. In this assessment system preservice teachers are required to reflect on videos of their instruction, assessment tasks, and students' work with the express purpose of these reflections guiding subsequent instruction and changes in pre-planned lessons. For example, here are some of the questions preservice teachers are expected to answer:

What changes would you make to your lesson to support learning for your whole class and subgroups? Support these changes with research and theory.

Based on your analysis of the student learning presented (this is typically a hypothetical scenario) in the examples provided, describe next steps for instruction for:

- the whole class
- Subgroups
- individual students

Explain how these next steps follow from your analysis of student learning.
Support your explanation with principles from research and/or theory.

In effect these preservice teachers are engaging in self reflection that is somewhat similar to what is seen in self-study research. In retrospect, the connections among edTPA, NGSS, and self-study is more likely coincidence since self-study existed long before the former two. It should be noted that many university programs that prepare preservice teachers require rigorous and detailed portfolios that require students to reflect on their teaching and their students' learning. Similar to the edTPA and sometimes beyond the scope of the edTPA, these portfolios include students' reflections on their lesson plans, lessons, videos, and in depth analysis of assessments and their students' achievements on these assessments. Additionally, some programs require reflective essays on students growth as science teachers as they proceed through their teacher education programs.

Finally, as Editors of *JSTE* one of the most important criteria considered when making editorial decisions on submitted manuscripts refers back to item #2 previously mentioned in our list of criteria used for the journal, "Does the literature review provide a rationale and theoretical/conceptual framework for the proposed study?" This is also a primary concern of editors of virtually all peer reviewed research journals. Failure to have such is the primary reason that manuscripts are rejected by *JSTE*. What constitutes a theoretical framework is often misunderstood to mean that a theory must be driving the research questions and design (Lederman & Lederman, 2015). This is not the case, and is certainly not the case for the overwhelming majority of qualitative studies (Wolcott, 1990). Most qualitative studies are inductive and attempt to develop theory as opposed to quantitative studies, which are deductive and typically test theory. Given that self study research is generally qualitative and is probably not immediately trying to develop any theory (although it may eventually do so), there may be concerns about its acceptance for publication in some journals. It is all dependent on how the editors of the journal construe what is meant by a theoretical framework. As far as *JSTE* is concerned this would not be an issue at all.

In summary, from our perspective, and as is readily evident in the investigations reported in this book, self study is a powerful research approach that has the potential to significantly impact science teacher education and science teacher education research. It appears to be useful as an experience in professional development program as well as a research endeavor for scholars in the field. At a minimum, it can effect change during the actual investigation in terms of revisions to instructional practice. As opposed to being limited to impacts following the investigation. Most research may impact change, but only after completion and after reflection by the researchers and other researchers. More ambitiously, self study can eventually serve to develop theory in the field as well as give rise to changes in policy related to science teacher education.

It is important to note that the manuscripts in this book, and our discussion, have primarily focused on science teacher educators whose role is that of a university professor. However, science teacher education occurs in many contexts and there are much broader conceptions of what fits under the rubric of science teacher educator than university professor. For example, museum educators can claim to be science teacher educators and so can subject matter specialists who teach science courses in which future teachers are enrolled be considered to be science teacher educators. State and local curriculum directors can also be considered science teacher educators. Outside of North America, non-government organizations (i.e., NGOs) also meet the criterion of the label. Regardless of how broadly one wants to define what constitutes a science teacher educator, all of these individuals can certainly benefit from a self study of their practices.

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Chapter 23
Turning a Critical Eye on Our Practice: Influence of Current Stories

Valarie L. Akerson and Gayle A. Buck

Introduction

As found from Chap. 1, self-study research in science teacher education has previously explored areas such as theoretical notions in science education, underlying assumptions in teacher preparation, and science teacher educator identity development. From reading the chapters in this book we see some of the same themes, but we have also found other ways self-study can be used in science teacher education. It is clear that self-study methods allowed science teacher educators to admit to perceived shortcomings and then resolve them to become better instructors. Like previous self-studies, in most of these chapters it is clear that the very identity of the instructor was influenced by implementing the self-study methodology—by considering their perceived shortcomings and seeking to overcome them through research, the instructor identity was influenced. Part of the influence was dependent on critical friends that served to be a sounding board to the instructor as they aided the instructor in thinking through the data that were collected as part of the self-study. Data sources were often personal to the instructor, such as journals or reflective writings that were kept by the instructors. Other sources indicated collection of student work, but very often the discussion and interaction with the critical friend(s) was a major source of data. While the voice of the instructor emerges within the chapters, another key finding is the presence of the student voice—and the encouragement of the instructors of a powerful student voice as well as interactions between instructors and students. These themes are noted in most chapters. Table 23.1 illustrates the specific chapters in which these themes are found. The sections below will elaborate on the themes that we have found in these chapters and will conclude with recommendations for using self-study in science teacher education.

V.L. Akerson, Ph.D. (✉) • G.A. Buck, Ph.D.
Department of Curriculum and Instruction, Indiana University, Bloomington, IN, USA
e-mail: vakerson@indiana.edu; gabuck@indiana.edu

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Table 23.1 Categories of themes identified in chapters from the book

Study	Confront weakness	Voice of student	Critical Friends	Identity
Bowen et al.	"pulled up short" at a science fair	Students struggled with conceptualizing inquiry	Worked as a team on the research; no specific mention of critical friend	No mention of identity change, but did change practice
Buck and Akerson	Our definition of community of practice was challenged	Important: how much do we influence these voices	Important role—co-instructors and co-authors; numerous meetings	Identity of students changed
Capobianco	"pulled up short" in focusing on engineering—"wanted to focus on science"	Student voices also highlighted desire to focus on science	Important role: preservice teacher participants and colleague from biomedical engineering: balance between being critical and being trusted	Identity as a science educator—not engineering educator
Conner	Students' reflections triggered instructor's development	Student voice influenced practice	Important role: colleague conducted focus group session and provided feedback to instructor	Identity changed from "knower" to knowing about student experiences
Davis	Acknowledgement of tradeoffs over time	Students not part of study	Important role: two graduate students who had formerly co-taught	Identity and change in identity over time
Fuentes and Bloom	Conflict resolution was focus of study: conflict between perceptions of quality of work	Student voice through written and oral reflection; voice to TE and PST	Important role—colleague who taught same students	Preservice teachers are developing a professional identity as a teacher: Dual identities

(continued)

Table 23.1 (continued)

Study	Confront weakness	Voice of student	Critical Friends	Identity
Gilles and Buck	Focus on how enthusiasm is infused in class; how students perceive	Focus is on self; however focus also on feedback via exit slips to instructor	Important role—mentor; course coordinator; advise, challenge, and provide feedback	No mention of identity
Hume	Called up short—again a novice—learning to teach how to teach	Students influenced the instructor	None mentioned	Identity development as a teacher educator
Makki and Holiday	Modified course to challenge their assumptions	Students as change agents	Collaborative group/critical friends/weekly meetings to reflect and make changes	Identity change—urban, or "too urban" or "too different"
Mansfield et al.	Challenge assumptions of what it meant to be a science teacher educator	Author is student	Important role: independent analyses and "big picture" ideas were discussed	Science teacher to science teacher educator identity
Marble et al.	Seeking to try out a strategy	Voices of "field"	None mentioned, but team worked together	Not an emphasis
Nyamupangedengu	Seeking to help preservice teachers learn content (genetics), and to learn from teaching her students	Interactions with students influenced teaching	Important role—four critical friends: dialogue to mediate and critique work	Students in the class began to take on the identity of a future teacher; sometimes held identity as learner, sometimes as senior students
Subramaniam et al.	Trying to "prove" themselves	Student voice strong: "leader battling subordinates"	None specifically mentioned, but colleagues worked together	Instructors seen as "others"

(continued)

Table 23.1 (continued)

Study	Confront weakness	Voice of student	Critical Friends	Identity
Trauth-Nare et al.	Realized it was difficult to share authority for instructor	Sought to promote student voice and authority	Important role: multiphase analysis; two critical friends, one who reflected on instructor's interpretations, one who posed critical and provocative questions	Not discussed
Wallace	Began to question the very purpose of education	Sought to develop students as "knowers of science"	Important role: classmates who responded	Becoming a science teacher educator—tension with identity

Themes

Admitted Weakness to Resolve

One immediate insight we gleaned from reading this set of self-study chapters is that, in general, the authors each set out to improve on a self-identified weakness on which they sought to improve. This self-identified weakness prohibited the authors from making the impact they wished to make on their students' understandings of either course content or their development in a program. The first column in Table 23.1 identifies the perceived weaknesses that the research/instructors identified in each study. For example, in the Mansfield, Loughran, and Kidman study, Mansfield describes how she felt "pedagogical discontent" at being a novice when she thought about her transition from a biology teacher to a science teacher educator. She felt deep frustration at being a novice who was struggling to put theory into practice. She reported feeling like a "new teacher" again. Hume reported a similar experience, of feeling like a novice again, and feeling "called up short" in her efforts to teach people how to teach rather than teaching content only. She described how her students' reflections improved her own teaching as it lead her to consider how her students influenced her Pedagogical Content Knowledge. She realized a distinction between what she initially believed was a variety of action research where she would be influencing the ideas of her students, to a focus on self-study where the interactions with students influenced her own teaching practice.

In some of the chapters it was evident that the problem or weakness being resolved was not immediately apparent until the self-study began. In some of the studies the problem to explore changed after the self-study was underway. In

Capobianco's study, for instance, she began with a stated problem of trying to figure out how to include engineering into her science methods courses given the new emphasis on engineering practices in the Next Generation Science Standards. She began the study feeling very confident, but her confidence diminished over time, and she felt less confident in inclusion of engineering into her methods course. She noted that the students wanted to focus on science in the course, and realized that so did she—feeling that science was part of who she was, where engineering was "outside." Her uncertainty about how to best approach this was an indispensable step toward genuine questioning. Similarly, Buck and Akerson began with the problem of exploring their doctoral program to better help their students become better science teacher educators. They too were pulled up short in their thinking by realizing through the self-study that there were challenges within their program, such as some students who felt at odds in the program due to the unintentional strong focus on science teacher education, the feeling of one student, a black female, as being outside the program due to race, and the tension caused by wondering how much to intervene with assisting with work/life balance issues. Their very definition of Community of Practice was challenged through the self-study, and they were changed.

The Makki and Holliday study further highlighted the perceived weaknesses that were sought to be resolved by the authors. In this study they wanted to challenge their own identities in the urban realm in which they worked—they were urban or "too urban" and questioned whether their program served the minority students of their context. They were challenged to consider critical race theory within their self-study which lead to a change in their practice through collaborative reflection.

In the Bowen et al. study the collaborators were happy with their class assignment of a science fair. However, they were very surprised by the kinds of struggles the students in their classes seemed to have, and realized that that though they instituted the science fair to help their students experience authentic inquiry, the students struggled to both conceptualize science as inquiry as well as to conduct scientific inquiry. This experience of being "pulled up short" in their teaching enabled the course instructors to reflect on current practices and change them to better serve their students.

Therefore, in most of the studies included in this volume, regardless of grade level or content, the researchers (who were also the course instructors) sought to overcome either a teaching weakness that they identified for themselves at the outset of the study, or a weakness they identified as a result of engaging in the study. Sometimes they expected to overcome a perceived weakness, and sometimes they were surprised that the strategy they believed would work well for their students "failed" in some ways to meet their goals. In both cases the researcher-instructors openly admitted to the perceived weakness, and the self-study approach enabled them to adjust and improve their teaching strategies to meet their students' needs.

Encourage Voice of Students

The importance of student voice emerged in the data in two ways. First, in some studies the instructors wanted to foster students in sharing their voices in the class (Makki & Holliday; Trauth-Nare, Buck, & Beeman-Cadwallader). Second, in other studies the instructors noted how student voice influenced their teaching (Capobianco, Conner, Fuentes, & Bloom; Hume, Nyampengedengu, Buck & Akerson). In both cases it is apparent through these self-studies that students influenced the instructors. Column two in Table 23.1 highlights how student voice is present (or absent) within the self-study chapters in this book.

In the Capobianco study the author clearly felt a struggle with including engineering into her science methods course. She found that students shared their own struggles with adding engineering into the course—sharing with their voices that they preferred science methods to remain science methods—not to add engineering into the mix. Student voice therefore was an unanticipated influence on Capobianco as she explored her own practice through self-study.

In Conner's study student voice also influenced her practice, which she did not anticipate prior to the study. In her case she was surprised that students did not include required reflections related to their professional experiences, which influenced her to re-emphasize the range of aspects they could reflect on, and indicated that they could post more reflections if they wanted. She noted that their in-depth comments acted more as a trigger for her to change her own practice. For instance, students commented that they needed to improve their content knowledge, and also wanted to support one another in improving that content knowledge. These comments influenced the instructor to focus more on content that is appropriate for school classrooms and to support the preservice teachers in their development of this knowledge.

This result was similar for the Fuentes and Bloom study where student voice – through both written and oral reflection – influenced the instructor not only in his instruction, but also in how he interacted with the students. In fact interactions with the students influenced the instructor to undertake the self-study itself, as he noticed conflict within his course. The instructor developed prompts to encourage his students to reflect on investigations that were undertaken in his content course. He found that his prompts did not encourage his students to share depth of content, and in fact, they instead shared misconceptions regarding the content. This communication from the students surprised him and served as a conflict to him because he believed they should have more knowledge and few misconceptions. The new reflection cycle that was set up by the instructor then responded to these ideas by asking them to reflect on his responses to their work on the investigation. Therefore he sought to change his instruction after more information from the students. Based on their reflections and voices, he implemented a descriptive exercise to help them conceptualize the kind of description he wanted, rubrics which guided them in components of quality responses, and identified course objectives that aided them in conceptualizing course content.

Similarly, Hume shares that the students influenced her by their responses on written reflections. She noted that though she had instituted written reflections to be submitted by her students, she realized when she reviewed them that her students really had little or no experience of what good reflective writing actually looked like, or any practice in doing it. She realized she would need to provide more support to them in their development as teachers as well as learners. This lack of experience by her students lead her to change her teaching to explicitly share her reasoning behind her own teaching, to model reflective thinking that she wanted her students to engage in, for example.

Makki and Holliday noted that students in their study acted as change agents for them as instructors. For example, the instructors were initially surprised that their teacher candidates were so focused on classroom management and on controlling students, but then realized that these concerns were not trivial. This realization influenced them to institute the use of entry slips to encourage voice of the students to use readings, course activities, and discussions with mentor teachers to collectively problem solve issues that they brought up. They made an explicit choice not to view issues of "lack of classroom control" as a problem of limited experience in the classroom, but instead to be challenged to examine how the presentation of these concerns obscure power relations in classrooms where students and teachers come from different cultural backgrounds.

Nyampengedengu noted that interactions with students influenced her teaching and enabled her to target her instruction to better serve the students. For example, she received unanticipated responses from students regarding her introduction to the genetics course. She listened to all of their responses, and without fail, she was surprised by all responses. One critical friend suggested that her kindness in listening to all responses suggested that she exhibited caring for her students, and suggested that she could use this to support her students. The self-study enabled her to notice what her students were gaining from instruction, and who were not participating, so she could intervene and support the learning of all students.

In the Trauth-Nare, Buck, and Beeman-Cadwallader study one of the main purposes was to promote student voice and to share authority with the students. The authors found that while student voice was certainly an important component of the course it was not as easy to enable shared authority with the students. The course instructor strove to enable students to find authority within the classroom through authentic dialogue and shared power. She noticed that despite efforts to share authority, which on occasion they would revert to triadic discourse in which she would pose a question, a student would respond, and she would follow with an evaluative comment. She realized that in some instances when she was focused on their correct understandings that it was difficult to relinquish control over group discourse. She did, however, continue to present opportunities for their talk to influence their learning, and used the self-study to explore ways to support their agency in the class.

Subramaniam and colleagues found that student voice was very strong in their study. They stated that it was nearly like a "leader battling subordinates" as the instructors sought to "prove themselves" as instructors to those who were different from themselves. They found a pattern in which teacher candidates' predetermined notions of them were detrimental to their work as science teacher educators. Teacher candidates did not seem to want any kind of discussion of integration/inclusion/social justice, but rather recipes for how to teach science. This insight lead the group to thinking about how they could get their teacher candidates to imagine themselves as people who might be different from the students they would be teaching.

The Buck and Akerson study found that student voice was strong in the doctoral program and they were conflicted with how much they should be influenced by student voice, and how much they should influence the student voice. For example, the instructors were surprised that students did not see themselves as science educators and that they were struggling with taking on that identity. The instructors were surprised because they seemed to have taken a leap of faith to come to graduate school to become a science educator; yet they did not seem to have a conception of what that meant, nor a realization of how they would get to that goal. The instructors also realized that student voice in terms of returning students also influenced newer students' identity development, and in ways that were not anticipated by the instructors. The instructors realized that student voice, in terms of the newer as well as the experienced students, would influence students as a whole, and in turn, the instructors were influenced to think about the structure of the program.

Therefore we can see that in most of the self-studies within these chapters student voice played a large role. This role was either being the focus of the study itself, or in student voice actually changing the focus of the study as the instructors responded to their students. The role of student voice appeared to be connected to the first theme—awareness of a perceived weakness. Often it was attending to the voice of the student(s) that enabled the instructors to either identify weaknesses or redirect their study to a different weakness that they were previously unaware of.

Role of Critical Friends

Most of the studies included the use of critical friends to not only ensure valid interpretation of data, but to also make suggestions for changes in instruction and recommendations for further data collection and raise questions of the instructor(s). In many cases the use of critical friends was a planned part of the self-study, whereas in a few the critical friend component was not explicitly planned, but rather arose as a result of collaborative work on an investigation (e.g. Bowen et al.; Marble et al.; Subramainiam et al.). Column Three in Table 23.1 highlights the role of critical friends in each of the chapters.

Wallace explored her transition from a graduate student and a teacher to a science teacher educator. Aiding her in her transition were classmates who also served as critical friends and raised questions about her ideas and thought processes while she was a graduate student. Wallace believes that they influenced her development, and that she likely influenced theirs as well. In essence, the critical friends who were in the same situation as she, aided her in interpreting her circumstances and helped her to focus on influences on her development as a science teacher educator.

Trauth-Nare, Buck, and Beeman-Cadwallader engaged in a multiphase analysis of data as Trauth-Nare worked to foster her students' authority and power in her class. She enlisted the aid of two critical friends, one (Beeman-Cadwallader) who was more of a partner and reflected on Amy's interpretation of students' learning and their needs and influenced instructional plans. The other (Buck) posed critical and provocative questions regarding Amy's interpretations about relational pedagogy and shared authority in the classroom and offered suggestions for Amy to consider in framing her practice.

Similarly, Nyamupangedengu engaged four critical friends to aid in her interpretation and critiquing of her teaching. These four friends included two professors in Science Education, one professor in English at another institution, and a colleague in the Department of Science and Technology. The professors of science education served two roles—one to respond to journal entries, reflections, videotapes, and interview transcripts, and the other critiqued planning, teaching reflections, and analyses of teaching and preservice teacher interviews. The professor of English critiqued teaching and responded to interview transcripts. The colleague from Science and Technology also critiqued teaching. From the help of these four critical friends Nyamupangedengu not only adjusted her teaching, but also her research strategies to enable her to better serve her students as well as feel confident in her research interpretations. Critical friends were crucial in aiding her to move forward with her self-study in a meaningful way.

In Mansfield's self-study the critical friend independently conducted a thematic analysis of data, and then "big picture" themes were discussed and verified with Mansfield and her colleague. The data sets and interpretations were challenged by the critical friend, resulting in a form of triangulation and confidence in interpretations of the data and results. Mansfield's critical friend was without doubt an integral part in her work.

Makki and Holliday worked together on a self-study where they not only studied themselves as individuals, but also as a group. Their collaborative group included science educators, a math educator and a STEM clinical faculty member. Curriculum specialists at the schools engaged with the group in planning and reflection, and thus, also influenced the teaching and research. The group met weekly to discuss practices in the methods course, as well as working with teachers to engage them in the most beneficial experiences in their development as teachers. This group served as critical friends for each other in aiding with data interpretation as well as modifying instruction.

Gilles and Buck also employed the use of critical friends within their study. Gilles engaged the critical friend (Buck) in advising, challenging ideas, and providing feedback. The critical friends meetings that took place between the two of them aided in valid interpretations of the results regarding themes that arose from the data on enthusiasm and Gilles' teaching.

Bloom was also fortunate to work with a critical friend (Fuentes) who was a colleague that taught the same group of students. In their work Fuentes brought a unique perspective to examining the conflict that arose in Bloom's class because her background was a different content area. The two engaged in frequent conversations about the conflict and perspectives that were brought by the preservice teachers. They also engaged in conversations about tensions that emerged in Bloom's practice, pedagogical decisions, and the outcomes of the decisions. They also both analyzed the data independently and then shared analyses and interpretations, discussing any differences until resolved, ensuring valid interpretation of data. In Bloom's case the critical friend played such an integral role that she became the lead of the research.

Davis engaged two graduate students who had taught science methods with her several times and were well versed in science education and teacher education, to read drafts of her chapter. They discussed themes within the drafts of the chapters, and suggestions they made were incorporated or considered in subsequent drafts. These graduate students who had experience in teaching science methods courses served the role of critical friends as Davis interpreted her data.

In Conner's self-study a colleague acted as her critical friend and even held a focus group session with her students to gain feedback on their perceptions of Conner's instruction. The critical friend also viewed her data and analyses, providing validation for data interpretation and critique of what might need to be changed in practice, and an interpretation of her identity as a teacher educator.

Capobianco also found critical friends useful in her self-study. She employed the preservice teachers who were part of the study, and a colleague from biomedical engineering, as critical friends in her study. This team of critical friends listened to her ideas, questions, and reflections, and asked provocative questions encouraging her throughout her inquiry. She sought critique from these friends, as well as their views through different lenses of her teaching and her research, aiding in her interpretation of her data. She welcomed and encouraged open communication among the critical friends.

Buck and Akerson served as one another's critical friend in their work, meeting often to discuss researcher written and oral reflections and field notes from seminar meetings with doctoral students during focus group meetings, as well as discussing documents from the program. They raised questions to each other and recorded written reflections that they later discussed, which later lead to better interpretation of their data, as well as recommended changes to their doctoral program.

It is clear to see that in the set of chapters within this volume of self-studies the use of critical friends was, well, critical. Critical friends served several purposes, including aid in interpreting data (e.g. Mansfield et al.; Trauth-Nare et al.), providing feedback on instruction (e.g. Bowen et al.; Conner), and serve as a sounding board for both teaching and research (e.g. Capobianco; Nyamupangedengu). Indeed, there was also a variety of different people in different roles who served as critical friends. In some cases students within the instructors' classes served as the critical friends (e.g. Capobianco; Davis). In other cases colleagues were included who were also part of the research (e.g. Buck & Akerson; Fuentes; Subramaniam et al.). In some cases there was only one critical friend (e.g. Mansfield) and in other cases there were several critical friends (e.g. Nyamupangedengu; Marble et al.). Were we to recommend an important strategy that emerged from these self-studies to those who were seeking to conduct self-studies, we would definitely recommend employing critical friend(s) as this enabled thoughtful consideration of both the data and the teaching or instruction in the studies.

Identity

Identity development was a theme that was found in most of the chapters. This theme was also present in prior self-studies as noted in Chap. 1. In some cases, the identity of the instructor was developing, in other cases identity of the students developed, and in some cases identity of the instructor and students went through a change as a result of the self-study took place. Column four in Table 23.1 whether and how identity development was manifested within the self-studies in this volume.

There were four studies within this volume that focused on the professional identity development of students. For example, Buck and Akerson sought to uncover how elements of their doctoral program fostered their doctoral students' identity development toward becoming science education researchers and science teacher educators. They were surprised to find that this identity development took longer than they anticipated, and that there were other competing identities as well as influences on their students' identities that were not expected. They realized that their program was not the sole influence on their students' development of professional identity.

Fuentes and Bloom similarly used the construct of identity to frame their study. They explored the kind of developmental stages through which preservice teachers progress so they could guide their course design and instructional decisions. They found a struggle within the preservice teachers in their course, regarding identities they held as students, and then identities they had as teachers. Some students were developing identities toward being a teacher, but some were not, and some held duel identities of that as a student and that of a teacher.

Nyamupangedengu had similar findings in that her students began to develop identities as future teachers, but still retained identities as students. Some did make the transition toward future teacher, yet others developed identities as senior students. Many held these identities all at the same time, with one identity at the forefront during different situations. Sometimes the identities they took on during teaching and learning activities caused them to view the teaching and practical activities as inappropriate. However, the ability to recognize these multiple identities enabled other preservice teachers to overcome similar problems.

In the final study that resulted in a focus on student identity, it was clear that Makki and Holiday did not seek to explore identity at the outset of their study. However, they found evidence of transforming practice as well as identity—to work on helping candidates develop identities as teachers of "urban" schools in a sense. The students in their classes needed to develop identities in line with the districts in which they would be working. Their recommendations lead to further identity development ideas, such as developing a way to go beyond maintaining the status quo and attaining what is possible—through experiences that lead to transformation of both teaching as well as teacher identity.

There were seven studies that explored the identity development of the science teacher educator. Four of these studied the identity development of experienced science teacher educators, and three studies explored the transition from doctoral student to science teacher educator.

Capobianco explored her identity as a science teacher educator who included engineering in her course. She found that her own identity as a science educator influenced her teaching of engineering in her science methods course. She strove to include engineering in her elementary science methods course to help her students be in line with state and national standards. She found that she questioned the role of engineering in science teacher education. Seemingly her identity as a science educator interfered with her desire to include engineering (and thus, develop an identity as an "engineering educator"). She also found that students in her class similarly preferred to focus on science within the science methods course, questioning the need for engineering to be included. Eventually both the instructor and students began to be more comfortable with including engineering education, with the instructor finding a way to incorporate science and its application as a way to include engineering.

Subramaniam and colleagues explored how science teacher educators of color conceptualized and operationalized their pedagogy in science methods courses. While their intention was not explicitly targeted at exploring identity, it seems that issues of identity were raised though their work. They spoke within their data analysis section, for example, as in "acquiring a role" as pattern in the data. They identified roles as "leaders" that are often at odds with "subordinates" (White teacher candidates). The White students seemed to see the identities of the instructors as different from themselves. There was a sense of "trying to prove themselves" as science teacher educators. Simply having an identity as a science teacher educator themselves did not seem enough because the White teacher candidates did not share the conception that they were science teacher educators. In some ways the researchers noted that their identities as science teacher educators of color were not always (or often) what their White teacher candidates anticipated.

Though Conner did not seek from the beginning of her study to determine how her identity would develop, she found that her own identity as a teacher educator changed from that of a "knower" (e.g. that from her experience and expertise she "knew" what prospective teachers needed to know to become biology teachers) to "knowing" more about her own students' experiences. She realized that by being someone who sought to know more about her own students she would be better able to adjust her instruction and support to students as they developed into biology teachers. Therefore during her self-study her identity changed from "knower" to "knowing more about students."

Davis set out, in part, to explore her changing identity as an elementary science teacher educator over the course of her career to the present. She focused on data sources from 1998 to 2014. It was clear to see her development through identities as someone who values knowledge, including subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge, to someone who identified with valuing planning practices and effective uses of curriculum materials, to her current identity as someone who values interactional as well as planning practices. Her work explored identity development over the course of almost two decades teaching science methods.

Hume conducted her self-study on her self-identity development as a science teacher educator as she moved from her role as a doctoral student. She found herself surprised of the difficulty she felt in making the transition and taking on the new identity. She presumed that because she had been an experienced teacher the transition to science teacher educator would be smoother and simpler. She began to focus more on her students' learning needs, which helped her to develop beyond her focus on what she believed they needed. Her scholarship also helped her to develop her identity toward a science teacher educator by exploring ideas related to teaching at the college level.

Mansfield also conducted a self-study exploring the transformation of herself to a science teacher educator. Her study explored her transition from a biology teacher to a science teacher educator. She was surprised at how much a novice she felt early on in her study. Similar to Hume, she thought the transition would be smoother and quicker. She also felt frustration as she tried to develop strategies for teaching at the university level. She used the discontent she felt to frame her practice as problematic rather than failure, and to develop more strategies, to enable herself to be more at ease with uncertainty as she was developing. In essence, she embraced the difficulty she felt in order to develop change in her instruction (and in her view of herself).

In another self-study that explored the transition to science teacher educator, Wallace explored her changing identity. Her identity was as a person who loved science—from the viewpoint of farm life. She noted in her chapter images of "farmer," "hick," and "redneck" and sought to blur these lines (and possibly overcome that identity). She later became a teacher, and felt a clear tension in her science teacher identity—she did not want to focus on standardized testing, yet her very identity at that school as a teacher depended upon it. She confronted the idea of whether to focus on those standards or to work toward aiding her students into becoming "knowers of science." She discusses reconceptualizing the entire notion of identity, questioning why we believe we can or should control identity, which is not an outcome, but a process. She notes that the concept of identity is often within a power/knowledge relationship. Identity can become a set of demographics and researchers may value one kind of identity over another. So while Wallace explored her changing identity, her exploration also caused her to re-think the entire concept of identity, as well as the power relationships that necessarily surround the construct.

From this set of studies it is clear that at times, even when the researcher did not seek out to explore identity, identity did arise as something that was influenced. We believe that a research tradition in which the researcher does study oneself is bound to explore identity, either identity of others in relation to the researcher, such as students, or the identity of the self.

Discussion

As noted in our introduction, we identified the following themes present in the self-studies within this volume: Authors had an admitted perceived weakness that they sought to resolve, they encouraged student voice as well as allowed student voice to influence them, employed critical friends to support their research as well as their teaching, and focused on identity development, either of the student or of the self. Some of the studies even comprised all four of these themes.

Similar to previous self-studies (e.g. Garbett, 2011; Wiebke & Park Rogers, 2014), identity came out strongly as a theme in the current volume. Self-study seems to continue to be an important strategy for exploring changing identities of not only students in one's class, but also identity of one's self, such as the development of one's identity as a science teacher educator from a doctoral student. The current chapters highlight that not only can one's own identity development be explored, but also that identity is a fruitful framework for self-study research. The development of student identity can also be a focus of self-study research.

Regarding confronting perceived weaknesses, this was also a theme that arose in the current chapters. These perceived weaknesses encapsulated the "confronting underlying assumptions inherent in teacher preparation" and "specific theoretical notions in science education" present in Chap. 1. Regarding "specific theoretical notions in science education," similar to prior studies such as Dias, Eick, and Brantley-Dias (2011) who studied Charles Eick returning to the classroom to teach inquiry, the chapter by Marble and his colleagues in this volume explored the use of lesson study for science methods courses. Similarly, in Fuentes and Bloom's chapter conflict resolution was the main focus of the study—exploring Bloom's desire and focus on helping his students produce high quality work.

Within the realm of "confronting underlying assumptions inherent in teacher preparation," it is clear to see that several authors had experiences similar to some of those noted in Chap. 1, such as Aubusson, Griffin, and Steele's (2010) study where they found that preservice teachers were reluctant to reflect despite modeling by the instructors. A similar result was found by Conner in this volume, where she noted that student reflections improved over time, and also triggered her own development as an instructor. Similarly, Makki and Holiday realized they needed to modify their course as their assumptions were challenged. Subramaniam and colleagues felt a disconnect with their students and felt a need (an unfortunate need) to "prove themselves" as science teacher educators to students who were different from themselves.

Interactions with others in the form of critical friends, as well as interactions with students, as noted in the focus on student voice, also played important roles in the self-studies in this chapter. Critical friends played a huge role in most of the studies, aiding in ensuring valid data interpretation, as well as in making recommendations for modifying instruction. Student voice also played a huge role in most of these self-studies as instructors attended to student voice and made modifications to their instruction, or even further encouraged student voice. It would seem an important consideration from these self-studies is that despite the study being on self, interactions with others are important. In reality, a study of self is also a study of self with others.

Thinking about Levin and Greenwood's (2002) statement that self-study "is vitally important to reconstruct universities, converting them into engaged social institutions, functioning as critical and reflective training centres for new generations of social actors," we can see that these components were present within the current set of chapters. For example, we clearly found that critical friends and student voice were quite important in influencing instructors, and these influences changed or improved the instructor practice to better serve the students (new generations of social actors). Therefore, we agree that self-study is a very important tool for transforming university teaching, and our wish is that books like these can serve to highlight the importance of the research paradigm in transforming practice and in influencing the identity not only of the student, but also of the instructor.

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About the Editors and Contributors

About the Editors

Gayle A. Buck is Professor of Science Education at Indiana University. Her scholarship focuses on relationships between learners, teachers, communities and science. Her research explores (1) student populations traditionally underserved in science education, (2) neglected epistemological assumptions in science teaching and learning, and (3) pragmatic and participatory approaches to educational research. She has taught several graduate courses focused on self-studies in teacher preparation. In addition, she has published and presented several self-studies in venues such as *Journal of Science Teacher Education, Educational Action Research, Studying Teacher Education,* and *Journal of Research in Science Teaching,* as well as the NARST sponsored book, *Moving the Equity Agenda Forward,* and the RISE volume 6, *Research Based Undergraduate Science Teaching*.

Valarie L. Akerson is Professor of Science Education and Program Coordinator at Indiana University. Her research focuses on Nature of Science and elementary science teacher education and young children's conceptions of science. She is an associate editor for *Journal of Science Teacher Education* and *Journal of Research in Science Teaching.* She has served on the Board of Directors for the Association for Science Teacher Education and is past-president for NARST: A Worldwide Organization for Improving Science Teaching and Learning Through Research.

About the Contributors

Sumreen Asim, is a doctoral candidate at the University of North Texas. Over the last 15 years she has been involved in teaching a range of classes both in elementary and secondary education. Her work includes the support for teacher candidates and

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in-service teachers- both urban and suburban- in implementing inquiry-based instructional approaches. Her research interests are in collaborative efforts for global sustainability, focusing on informal STEM education, culturally-responsive professional development, and educational technology.

Lucy Avraamidou received her PhD in Science Education from the Pennsylvania State University in 2003 and she currently works as an Associate Professor at the University of Nicosia in Cyprus. Prior to her appointment at the University of Nicosia she worked as a Research Associate at the Center of Informal Learning and Schools (CILS) at King's College London. Her area of concentration is science education and her research is associated with theoretical and empirical explorations of beginning elementary teachers' learning and development with the use of interpretive approaches. He research interests include science teacher identity and informal science. She has worked as a principal investigator and senior researcher on various EU projects, she has authored more than 45 publications and edited two book volumes with titles: *Studying Science Teacher Identity* (2015), and *Intersections of Formal and Informal Science* (2016, co-edited with Wolff-Michael Roth).

Anthony Bartley is a professor of science education at Lakehead University, Thunder Bay, ON Canada. His research focuses upon pre-service science teacher education, assessment and classroom practices. He has over 16 years of school-based experience in secondary physics and chemistry teaching. Most recently was a co-author (with Mike Bowen) "The Basics of Data Literacy: Helping Your Students (and You!) Make Sense of Data" published by NSTA Press.

Nicole Beeman-Cadwallader, Ph.D. is Director of Professional Development at Project Lead The Way (PLTW). She strategizes, develops, and manages K-12 STEM teacher professional development across PLTW's national network. Seeking to narrow STEM achievement gaps for underserved and underrepresented students drives her, and her scholarly and research interests reflect this vision. Nicole has engaged in, presented, and published several self-studies of her own teaching practice – specifically examining efforts and strategies to promote equity and cultural relevance in science education.

Mark Bloom is an Associate Professor of Biology at Dallas Baptist University in Dallas, Texas. His research interests focus on how teachers and students develop their understanding of science, how science interacts with faith, and how individuals' scientific literacy and faith-based beliefs influence their perceptions of socio-scientific issues. He is currently exploring learners' conceptions of climate change and evolution and their acceptance or rejection of scientific theories regarding these topics.

G. Michael Bowen is an associate professor at Mount Saint Vincent University, Halifax, Nova Scotia, Canada. His research focuses on pre-service science teacher education, data representations and their use in science, news media representations of science and education, and most recently on calibration issues around exams in undergraduate psychology. Michael teaches undergraduate courses in science education and critical media literacy, and graduate courses in curriculum theory and action research. He recently co-authored "The Basics of Data Literacy: Helping Your Students (and You!) Make Sense of Data" with Tony Bartley and is currently, with two co-authors, working on a book about having students use real-time streaming data in classroom investigations.

Brenda M. Capobianco is an Associate Professor in the Department of Curriculum and Instruction and holds a courtesy appointment in the School of Engineering Education and an affiliated appointment in Women's Studies at Purdue University. Dr. Capobianco teaches elementary science methods and graduate courses in teacher action research and gender and culture in science education. Her research interests include girls' participation in science and engineering; teacher's engagement in action research; and science teachers' integration of the engineering design process to improve science learning. She has published and presented her self-studies and related work in teacher action research in the *Journal of Research in Science Teaching, Journal of Science Teacher Education*, *Educational Action Research*, and *Teacher Education Quarterly*.

Lindsey Norma Conner is the Director of the Science and Technology Education Research Hub, at the University of Canterbury in Christchurch, New Zealand. For the last 18 years, she has researched learning and teaching mostly in science education contexts that consider the important role of technology in learning science and recently put forth the concept of *evaluative constructivism* as a descriptor of how students can take agency for their learning in a key article in *International Journal of Qualitative Studies in Education*. For a full research profile see http://www.canterbury.ac.nz/Spark/Researcher.aspx?researcherid=2020174.

Elizabeth (Betsy) A. Davis is a science educator and teacher educator at the University of Michigan. Her research interests include beginning and experienced elementary teachers, teachers learning to engage in ambitious science teaching, and the roles of curriculum materials and teacher education in promoting teacher learning. Davis has explored specific design features of educative curriculum materials and teachers' uptake of those educative features. Another main focus is on elementary teacher education and how novice elementary teachers learn to engage in high-leverage science teaching practices. Her research has been published in journals such as *Educational Researcher*, *Journal of Research in Science Teaching*, *Science Education*, *Harvard Educational Review*, *Journal of Science Teacher Education*, and *Curriculum Inquiry*.

Justin Dillon is professor of science and environmental education and Head of the Graduate School of Education at the University of Bristol, UK. His research explores (1) learning in out of school environments, (2) environmental education, and (3) science teacher education. Justin has published widely in science education and environmental education journals. He co-edits the International Journal of Science Education and was President of the European Science Education Research Association from 2007 to 2011. Justin has co-edited a number of books including Bad Education and the International Handbook of Research on Environmental Education.

Allan Feldman is a professor of science education in the Teaching and Learning Department of the College of Education at the University of South Florida. His scholarship focuses on science teacher education, and in particular how practicing science teachers learn from their practice in a variety of subjects including physics, environmental education, and education for sustainability in formal and informal settings. Much of his scholarship has been on teacher learning through action research and self-study, and through participation in scientific research groups. He is currently co-editor of Educational Action Research, and has published theoretical and empirical studies of action research and self-study.

Sarah Quebec Fuentes is currently an Associate Professor in mathematics education at Texas Christian University. Prior to receiving her doctoral degree, she was a middle and high school mathematics teacher for 10 years. Her research focuses on classroom discourse, preservice teacher education, teacher knowledge, educative curriculum materials, teacher self-efficacy, collaboration, and developing fraction sense.

Brent Gilles is currently a doctoral candidate in science education at Indiana University, Bloomington. His research focuses on the use of scientific argumentation and explanations within preK-16 classrooms. He is a former high school physical science teacher and currently teaches science methods and content courses to preservice elementary and secondary teachers.

Gary Holliday is assistant professor of science education at the University of Akron, Ohio. His research interests are influenced by 15 years of teaching experiences in formal and informal science classrooms. Recent research focuses on teacher professional development in informal settings (such as museums and science centers). He has published in the International Journal of Science Education and the Journal of Science Teacher Education. He has also co-authored a number of book chapters and has presented his work at professional meetings nationally and in France, Greece, South Africa, Taiwan, Sweden, and Turkey.

Anne Hume is Associate Director at the TEMS Education Research Centre at the University of Waikato, leading the Science Research Group, and she lectures in science education at undergraduate, graduate and post-graduate levels. Her key research interest is science PCK development for pre-service and in-service teachers and teacher educators. This scholarship takes the form of action research into her pedagogy for pre-service teachers and collaborative research with teachers in schools, which is published in journals such as *Research in Science Education* and *Higher Education Research & Development.* Other research involvement includes membership of the *Science Learning Hub* development team (University of Waikato), the *Curriculum Implementation Exploratory Studies* project (University of Waikato), and education consultant on national environmental sciences projects.

Michael Kamen is a Professor of Education in the teacher preparation program at Southwestern University in Georgetown, Texas. His scholarship includes research and publications in the following areas; the use of creative dramatics in teaching science, the role of language in science learning, innovation education, authentic assessment, play and learning, lesson study in teacher education, and the application of Vygotskian theory. He was and Associate Professor and Elementary Program Coordinator at Auburn University (1991–2002) and taught at the elementary and middle school levels in New York, California, and Texas.

Gillian Kidman is an Associate Professor of Science Education at Monash University in Australia. Gillian's work history includes 3 years as a field scientist, 10 years as a secondary science and mathematics teacher, 5 years as a specialist science and mathematics teacher in primary schools, and most recently, 15 years in science and mathematics teacher education. Her passion is inquiry based teaching and learning, and was a lead writer of the *Australian Curriculum: Science*. Gillian is currently undertaking large scale classroom observations of inquiry based teaching and learning in the science and humanities disciplines to determine similarities and differences in the pedagogical frameworks employed by the teachers.

Judith Sweeney Lederman is an Associate Professor and Director of Teacher Education in the Department of Mathematics and Science Education at the Illinois Institute of Technology. She has also been the Curator of Education at the Museum of Natural History and Planetarium in Providence, RI and a Science Director of a regional Science and Mathematics professional development center. Dr. Lederman presents and publishes nationally and internationally on the teaching, learning and assessing of Scientific Inquiry and Nature of Science in both Formal and Informal settings. She is co-editor of the Journal of Science Teacher Education and has served on the Board of Directors of the National Science Teachers Association (NSTA) and is past president of the Council for Elementary Science International (CESI).

Norman G. Lederman is Chair and Distinguished Professor of Mathematics and Science Education at the Illinois Institute of Technology. Dr. Lederman is internationally known for his research and scholarship on the development of students' and teachers' conceptions of nature of science and scientific inquiry. He is the Co-Editor of Volume I and II of the Handbook of Research on Science Education and of the Journal of Science Teacher Education. He was previously Editor of *School Science and Mathematics*. Dr. Lederman is a former President of the National Association for Research in Science Teaching (NARST) and the Association for the Education of Teachers in Science (AETS, now known as ASTE). He has also served as Director of Teacher Education for the National Science Teachers Association (NSTA).

Eun Young Lee is a doctoral candidate in early childhood education at the University of North Texas. Under the same institution, she has taught several undergraduate courses in the teacher education program including science methods course for grades EC-6 and early childhood education courses. Her research interests are development of scientific inquiry for young children, nature of science, equitable science teaching, and cultural conflicts of preservice/inservice teachers and their students in teaching science.

John Loughran is the Foundation Chair in Curriculum & Pedagogy and Dean of the Faculty of Education, Monash University. John was a science teacher for 10 years before moving into teacher education. John was the co-founding editor of Studying Teacher Education and is an Executive Editor for Teachers and Teaching: Theory and Practice.

Nidaa Makki is Associate Professor in the Department of Curricular & Instructional Studies with a focus on Science Education at The University of Akron. Her scholarship focuses on investigating curricular perspectives that are problem and issue based, in relation to teacher learning as well as classroom implementation. She has presented and published on (1) teachers' understanding and perspectives on integrating engineering design in science, (2) embedding community relevant issues in the science classroom, (3) pre-service teachers' learning to incorporate interdisciplinary global perspectives, and (4) implementing action research. Additionally, she is PI on several teacher professional development grants focused on integrating problem and issue based science, and Co-PI on an NSF ITEST grant that investigates incorporating engineering design in the middle school physical science curriculum.

Jennifer Mansfield is a science teacher educator in the Faculty of Education, Monash University. Jennifer's passion for science and science education has seen her work as a scientist and secondary school science teacher before transitioning into pre-service teacher education. Her research interests include the development of teachers' professional knowledge of practice and the development of teachers' understanding and attitudes towards science education.

Leo MacDonald is a professor of science education at St. Francis Xavier University, Antigonish, NS Canada. His research focuses on pre-service science teacher education, assessment and teacher professional development. Leo teaches B.Ed courses in science education and assessment, and graduate courses in assessment, action research, and theories of learning. He has also taught internationally in countries such as Trinidad, Barbados, and Bhutan.

Stephen Marble is an Associate Professor of Education in the teacher preparation program at Southwestern University in Georgetown, Texas. His research focuses on problems related to secondary teacher education, including Lesson Study, Academic Literacy and the implications of the philosophical perspectives of Gilles Deleuze. He served as Program Manager and Director of the Southwest Consortium for the Improvement of Mathematics and Science Education with the Southwest Educational Development Laboratory in Austin, Texas, for 6 years. He has also taught in public schools in rural Texas and Bush Alaska, and has worked in teacher education programs at the University of Texas at Austin and The University of Hawaii.

Gilbert (Gil) Naizer is a Professor of Curriculum & Instruction at Texas A&M University-Commerce in Commerce, Texas. His research focuses on: pre-service teacher education and in-service teacher professional development, and methods of encouraging adolescents' interests in STEM. He has served as PI on multiple funded projects at the state and national level. He has held leadership positions in several professional associations.

Eunice Nyamupangedengu is a teacher educator at the University of the Witwatersrand (Wits), South Africa. She completed her PhD studies in July 2015. Her PhD was a self-study in which she explored modelling good teaching as a way of teaching content courses for understanding and for teaching in pre-service teacher preparation programs. She has taught several undergraduate content courses to pre-service teachers and a postgraduate course that focuses on developing subject matter knowledge for teaching to in-service teachers doing MSc (Science Education). She is now working on establishing a self-study research group at Wits University's school of Education.

Joanne K. Olson is a professor of science education at Iowa State University, and former president of the Association for Science Teacher Education. Her research is focused on two areas: (1) science teacher education, particularly the impact of science teacher education program structures on the development of science teacher decision-making; and (2) the philosophical underpinnings of science teacher education, including classical philosophy and the nature of science and nature of engineering. She is a co-editor of Richard McKeon's posthumous work, "On Knowing: The Social Sciences." A former middle and elementary science teacher from the Los Angeles area, she currently co-directs Iowa State University's MAT program and works with local schools to improve science education.

Kia S. Rideaux, M.Ed. is a Curriculum and Instruction doctoral candidate at the University of North Texas. Over the last 12 years as an elementary educator, she has served in the roles of classroom teacher, science curriculum writer, and EC-6 pre-service teacher instructor. Her research focus utilizes critical qualitative methodologies and centers marginalized feminist perspectives to address issues of equity and diversity in early childhood education.

Gillian Roehrig is a professor of STEM Education at the University of Minnesota. Her research and teaching interests are centered on understanding how teachers translate national and state standards into their classrooms. Of particular interest is (i) how teachers, from preservice through induction and into the inservice years, implement student-centered practices using inquiry and STEM integration and (ii) how different induction and professional development programs can influence teachers' knowledge, beliefs, and classroom practices. She is currently on the Board of Directors for NARST and president-elect of ASTE.

Ann Sherman is the Dean of Education at the University of New Brunswick, Canada. She has been a professor of science Education and early childhood education for over 20 years. Ann's research gas focussed on developing science kits for elementary classrooms and early childhood centres to support inquiry based science learning opportunities.

Karthigeyan Subramaniam is an associate professor of science education at the University of North Texas. His research agenda is underscored by his belief that a successful future for K-12 science education is dependent on sustained studies that inform and guide the development of the pedagogical knowledge of pre-service teachers and teacher educators respectively. He has taught several undergraduate courses focused science teacher preparation, and graduate courses focused on qualitative methodology. In addition, he has published in several journals, *Journal of Science Teacher Education, Research in Science Education, Research in Science and Technological Education, Journal of Computers in Mathematics and Science Teaching,* and others.

Amy Trauth-Nare, Ph.D. is Associate Director of Science Education in the Professional Development Center for Educators at the University of Delaware. She works collaboratively with K-12 administrators and teachers to provide professional development and ongoing support that enhances science teaching and learning. Her research focuses on science teacher education, classroom assessment, and environmental and engineering education. Amy's work in science education is undergirded by issues of equity, access and opportunities for meaningful participation in science by an increasingly diverse student population in K-12 schools.

Maria F.G. Wallace is a doctoral student studying curriculum and instruction with a concentration in science education and curriculum theory at Louisiana State University. Her research interests examine (1) the social construction of science teacher subjectivities, and (2) science teachers' epistemological assumptions regarding the nature of science. Maria earned her Bachelors of Science in Geology with a minor in Elementary Education from Millsaps College, and Masters of Arts in Teaching from Trinity University. Prior to beginning her doctoral work, Maria taught third to sixth grade science in Texas and Massachusetts. Maria has published and presented on science teacher experiences in venues such as *Journal of Science Education and Technology*, International Association for the Advancement of Curriculum Studies, Curriculum and Pedagogy, and Louisiana Education Research Association.

Molly Weinburgh is the William L. & Betty F. Adams Chair of Education and Director of the Andrews Institute of Mathematics & Science Education at Texas Christian University. Her honors include the *Chancellor's Distinguished Achievement as a Creative Teachers and Scholar, Piper Professorship,* and Fellow of the *American Association for the Advancement of Science*. Her scholarship focuses on equity issues in science education and inquiry-based instruction. Her most recent research has centered on academic language acquisition and conceptual understanding in science by emerging multilingual students. She is an active member of numerous science education societies and editor of the Electronic Journal of Science Education.

Afterword

The unexamined life is not worth living.

–Socrates (Plato, 399 BCE, 38a)

Perhaps a corollary to Socrates' insight applied to practice professions such as teacher education might be, "The unexamined practice may not be worth repeating." The exhortation to examine one's thinking and practice has a deep history, permeating writings across the span of human thought. The Buddha introduced *vipassana*, a type of "insight meditation" with a goal not to calm or clear the mind, but to the "generation of penetrating and critical insight" (Keown, 1996). Looking within is also present in Christianity: "How can you say to your brother, 'Let me take the speck out of your eye,' when all the time there is a plank in your own eye? You hypocrite, first take the plank out of your own eye, and then you will see clearly to remove the speck from your brother's eye" (Holy Bible, Matthew 7:4). In 1929, John Dewey framed teaching as a reflective practice of professional decision-making, and asserted that learning to teach is not a matter of acquiring recipes for practice that "work," but is instead a matter of learning to see—to have greater professional insight about the events in the classroom that are then used to inform subsequent practice.

Reflection to inform practice sounds rather straightforward, but is in fact a very complicated act that requires knowledge, thinking, action, and the cognitive skills to make what is typically "subject" (in this case, the self) into an "object" of study. Outcomes for science teacher education often include terms such as knowledge, skills, reasoning, and sometimes judgment. These terms differ in complexity. Locke, for instance, distinguishes knowledge from judgment, with judgment related to the formation of opinions. In most cases, judgment requires "the capacity to deliberate about the advantages and disadvantages or other circumstances relevant to the action in question" (Adler & Gorman, 1952a, p. 835). Thus, the act of informing personal practice requires the possession of knowledge and skills to initiate and sustain practice in the first place, and a level of reasoning and accurate judgment

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about what occurred—coupling these with an understanding of other relevant circumstances and possibilities. Informing practice requires more than knowledge, self-reflection and judgment, however. We may form accurate and sophisticated opinions about our practice, yet fail to know how to take action that alters the current state toward improvement. What concept, then, captures the use of self-reflection, the making of informed judgments, and the conversion of such thought into action toward appropriate and productive ends? A term from the past that may express what our field needs is *prudence*. Before the reader's mind wanders to colloquial uses of the term *prude*, consider the term's historical roots. The term *prudence* in English dates to 1340 and relates to *foresight* and *practical wisdom*. Its Latin roots (*prudentia*) refer to *foresight*, *sagacity*, and *skill*. In 1382, the term became associated with being *wise* and *discerning* (Barnhart & Steinmetz, 2005). In their review of the treatment of prudence in western philosophy, Adler and Gorman (1952b) note that, "Of the qualities or virtues attributed to the intellect, prudence seems to be…most concerned with action" (p. 472). To summarize Aristotle, "What a man knows when he is prudent seems to be much less capable of being communicated by precept or rule. What he knows is how to deliberate or calculate well about things to be done" (Adler & Gorman, 1952b, p. 473).

This ASTE Monograph about self-study in science teacher education can be seen as an important contribution to a larger effort to develop science teacher educators who deliberately reflect on practice and use that information in conjunction with well-established research to move forward their practices—in essence, to develop prudence among ourselves while at the same time fostering that quality among the students and teachers with whom we work. Prudence is crucial because without it, reasoning and even judgment are insufficient.

For example, reasoning based solely on research in teacher education can be used to develop principles for practice that appear sound, but may not hold up well in practice. For example, Marble, Kamen, Naizer, and Weinburgh found evidence in practice that contradicts a commonly-held principle that preservice teachers will best learn science pedagogy in the context of science content and activities. Research on embodied learning and the research-practice gap so often lamented by preservice teachers certainly supports this principle, but self-study by these researchers is showing that far more appears to be involved—in their study, preservice teachers' focus on content appeared to suppress their ability to learn pedagogy. Nyamupangedengu also used self-study to test the principle of coupling content and pedagogy, but in the context of a science content course, and reached different results, finding that pedagogy was learned alongside science content. The findings of these two self-studies should open more investigations into this phenomenon so that our principle can be refined and our practices informed. Similarly, Bowen, Bartley, MacDonald, and Sherman challenge assumptions frequently made about prospective secondary teachers' understanding of data representation, even when they possess an undergraduate background in science. This need to "ground truth" theory in the realities of practice is essential if the research base in science teacher education is to be generalized more broadly to have a genuine impact on practice. While research findings are undeniably crucial to advance the field and improve practice, they must not be viewed in isolation and prescribed as a set of disjointed rules for practice; rather, they must be considered as a coherent whole (Clough, Berg, & Olson, 2009; Dewey, 1929) and tested in the complex environment of practice.

Through self-study, powerful judgments about our practices may make apparent that we are not as effective as expected (see, for example, the chapters in this volume from Bowen et al., Buck et al., and Quebec Fuentes and Bloom). Using such information to appropriately inform practice requires that those judgments translate to implications for practice that are then implemented and studied, a process that receives far less attention in the literature than making initial judgments and deriving implications (Eisner, 2002). An interesting example that studied the translation of self-study results to changes in classroom practice is the chapter in this volume by Marble et al. Furthermore, changes in practice are not only driven solely by data, reasoning and judgments, but also by goals, values, and experience, thus requiring prudence. Our goals, values, and experience should also be subject to reflection and study, and differences in these areas may partially account for varying patterns of implementation, even among experts.

Finally, in studies of classrooms and of our own practice, we cannot lose sight of the practices of the teacher. What occurs in the classroom is far more than a lesson plan and the behaviors of the students; the teacher plays an integral role in the interpretation of his/her lesson plan into a meaningful experience for the students. In this volume, few researchers turned the camera lens toward themselves. While much can be learned by studying classroom artifacts, interviewing students or looking at their work, or even examining the teacher's journal entries for his/her recollections and judgments about what occurred, few data sources are quite so revealing and so humbling as using video to assess what the teacher and students did when interacting in the classroom.

Perhaps due to the extensive time required to transcribe and/or code video events, video, if used at all, tends to be considered a supplement to verify claims that primarily are derived from print-based data sources, such as journals, assignments, or interview transcripts. My struggle with reliance on these more distal methods can be illustrated through the example of American football, and probably applies to most other team sports. In American football, much time is spent preparing for upcoming games, and this preparation occurs not only through physical practice of game skills (e.g., blocking, catching, running, rehearsal of various play options) and planning what plays to use and overarching strategy, but through reflection on past games of both one's own team, and those of the upcoming opponent. Players know that they will spend much time watching video, even in slow motion, to dissect particular behaviors and their outcomes, determine patterns of play of their opponents, and find strengths and weaknesses. Decades of research on teacher behaviors have made clear that certain teacher decisions and behaviors more likely promote desired goals for students (Balzer, Evans, & Blosser, 1973). These behaviors include the use of thought-provoking questions, responses that seek clarification and use students' ideas to carefully scaffold thinking, appropriate wait time 1 and 2, and nonverbal behaviors that convey an openness to students' ideas, such as eye contact, raised eyebrows, smiling, use of open hand gestures, standing with an upright posture, and moving throughout the room. This is equivalent to knowing what stances, head positions, hand position, etc. is ideal for an offensive tackle or a running back to play his/her position well on an American football team. While the football game as a whole is far more than simply those behaviors, without a mastery of those behaviors and the prudence to know when and how to use them, the quality of play suffers greatly and no amount of examination of the playbook will be sufficient to fix the underlying problem. So, too, when teacher educators only examine the students, or only examine what we think happened in a class, what actually happened on "game day" in our classrooms is can easily be lost or misunderstood.

Ultimately, central to the educational experience in a course is what occurs in space and time between the people in the classroom, including the teacher and students. And, if we are doing *self*-study, imperative is the examination of *self*—including not just our thoughts and reflections and the performance of our students, but our own actual practices in the time and space of our classroom. In doing so, we just might find a plank in our own eye, which can help us better improve our own practice through its removal, while advocating practices for others that are far more realistic, appropriate, and prudent.

Self-study is a crucial tool for science educators to ensure that our programs and practices reflect our goals and the research base in science education. We can learn much from the authors in this monograph who have made public their studies, findings, and insights. If we expect our graduates to become practitioners with high levels of knowledge and skill, insightful perception, accurate and informed judgments about their practice, and prudence to synthesize and apply these insights and research findings wisely toward desired ends, we would be wise to ensure that our practices do the same. Self-study, while revealing our weaknesses, helps us improve our practice and inform our research base, and it also reminds us of how very complex effective teaching is, enables us to better understand and empathize with our students when they struggle, and helps us avoid the hubris that can arise when we are unaware of our own shortcomings.

Iowa State University, Ames, IA, USA Joanne K. Olson

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