PROFESSIONAL IDENTITY DEVELOPMENT IN TEACHERS OF SCIENCE, TECHNOLOGY, ENGINEERING, MATH, AND SCIENCE AND MATH EDUCATION

Much of the science education community has advocated for a new vision of instruction emphasizing inquiry-based teaching (National Research Council, 1996). Unfortunately, as Anderson (2002) notes, many science teachers are not adopting inquiry-based teaching practices for a variety of reasons such as that teachers commonly favor text-book approaches to instruction. To facilitate the adoption of reformed teaching, Luehmann (2007) argues that teacher education must address the development of one's professional identity as a teacher. Unfortunately, little is known about the beliefs, values, experiences, and ways of acting and interacting that teachers in science and related fields use to form their professional teaching identity. Through repeated interviews with 18 graduate students who taught science and related disciplines, this study outlined generalizations defining the developmental trajectory of science educators' professional identity. In general, for less experienced teacher participants, one's own experiences as a student were particularly influential in learning how to teach, while for more experienced teacher participants, coursework, self-reflection, professional development experiences, and the review of professional journals were influential to skill development. Study results generally reflected the trajectory of teacher development (from teacher-centered concerns to student-centered concerns) put forth by Fuller and Bown (1975). More detailed findings indicated, however, that co-teaching experiences may have assisted teachers in moving from more teacher-centered concerns, including a focus on one's personality characteristics and ability to develop and implement engaging instructional activities, to more student-centered concerns, such as adjusting instruction to meet students' needs and facilitating student investigations. Therefore, in this study, participants' co-teaching experiences positively impacted their developing professional identities as inquiry-minded teachers.

Joanna Gilmore, University of South Carolina
Melissa Hurst, University of South Carolina
Michelle Maher, University of South Carolina

Introduction

The science education community has advocated for a new vision of science instruction emphasizing inquiry-based teaching (American Association of Advancement of Science, 1993; National Research Council, 1996). Inquiry-based teaching is defined here as engaging students in authentic scientific processes such as developing hypothesis, collecting, analyzing, discussing and interpreting data. Previous research indicates that the use of inquiry-based teaching improves scientific reasoning and achievement for all students (Schroeder, et al., 2007, Shymansky, et al., 1983).

Given previous research which indicates that prior beliefs about the nature of effective instruction, teacher affect, self-confidence, and ability to reconcile experience with theory influence one's likeliness to adopt theory-based practices, Luehmann (2007) argues that teacher education must address the development of professional identity (defined by Luehmann as including professional philosophy, passions, commitments, ways of acting and interacting, values, and morals) in addition to the cognitive aspects of teacher education such as knowledge. Research by Forbes and Davis (2007) supports Leuhmann's assertion that teacher identity has important implications for participation in reform efforts, specifically for how pre-service teachers engage with new curricula in the science classroom.

Numerous scholars have theorized about identity and identity development (e.g., Erikson, 1968; Mead, 1934) and specifically teachers' professional identity, presenting the research community with several ways of defining and investigating identity (see Beijaard et al., 2004 for a review). Common among teacher professional identity definitions is the notion that it is (1) a process involving ongoing reflection upon experience with the underlying questions "who am I?" and "who do I want to be?," (2) developed through the interaction between the individual and the context of their experiences, (3) multifaceted consisting of sub-identities which may correspond to different contexts and relationships, and (4) constructed through the activity of the learner (Beijaard et al., 2004). Luehmann (2007) more recently described five necessary processes in the development of a professional identity as a reformed science educator, including (1) reconciling prior beliefs with reformed teaching, (2) locating identity within a community of practice, (3) managing emotional aspects of identity formation, (4) integrating experiences and theory, and (5) developing a sense of self-confidence.

Though research on these five aspects of professional identity development as a teacher exists, as Adams and Krockover (1997) discuss, it is generally not specific to science or mathematics teachers. For example, Goodson and Cole (1994) explored identity development among new college instructors with no preparation, and Mawhinney and Xu (1997) studied foreign-trained teachers intending to teach in the UK. Some researchers, however, have specifically studied aspects of identity development among science educators, such as Maor and Taylor (1995), who examined science teachers' beliefs about the nature of learning as they related to incorporating technology during inquiry teaching. Although these exploratory studies provide some information for teacher educators, as Volkmann and Anderson (1997) note, specific knowledge of how science teachers construct professional identities is scarce.

One comprehensive view of teacher identity development, conceptualized over three decades ago, is based the work of Fuller and Bown (Fuller, 1969; Fuller & Bown, 1975). This view proposes that teachers undergo a series of developmental stages[1] characterized by unique concerns. In the first stage, *Fantasy*, which occurs prior to actual teaching, prospective teachers romanticize about the experience ahead. Fuller and Bown (1975) note that in this stage, the pre-service teacher can better identify with the students' perspective than the teachers. Thus, students in this stage are often overly critical of their own teachers, or of teachers who they observe during early field experiences. The *Survival* stage begins after entering the classroom and

[1]According to Fuller and Bown (1975) the changes that they investigated in teacher's concerns may be stages or may be better described as clusters of concerns. (p. 37).

encountering a crisis usually related to classroom management or mastery of content. During this stage, the teacher struggles to achieve a sense of worth and identity. This struggle usually translates into concerns about class control, being liked by students, or evaluation from other educators and administrators. The third stage, *Mastery*, occurs as teachers begin to develop mastery over their content and pedagogical knowledge adaptable to different situations. The teacher in this stage is able to engage in more systematic reflection about their instructional practices. As Fuller and Bown (1975) note, however, these stage indicators focus on the teacher's own performance, not on indicators of student learning. In the *Impact* stage, the somewhat more experienced teacher is better able to focus on individual students and their needs; rather than being concerned about the evaluation of others, he or she is mostly concerned with self-evaluation (Fuller, 1969).

The researchers of this current effort found it helpful to consider how Fuller and Bown's (1975) developmental trajectory was related to discussions of teacher-centered or student-centered instruction[2] where in student-centered instruction, students have considerable control over what they learn and how they learn. In the process, the researchers created Figure 1. As Figure 1 shows, beginning teachers are highly concerned with students. However, this concern decreases after entering the classroom. The teacher becomes focused initially on his or her own identity and knowledge (survival) and then becomes concerned about his or her teaching methods (mastery). After a fair amount of teaching experience, the teacher becomes less concerned with him or herself and is better able to focus on individual students and their learning outcomes. Though the authors were unable to depict the qualitative differences between stage 1 and stage 4 in this figure, it is important to remember that teachers' student-centered concerns of Stage 1 differ from those of Stage 4 in that these concerns are largely unrealistic; they are based on the pre-teacher's experiences as a student alone and expectations for student learning at this stage are not understood in terms of teaching practices.

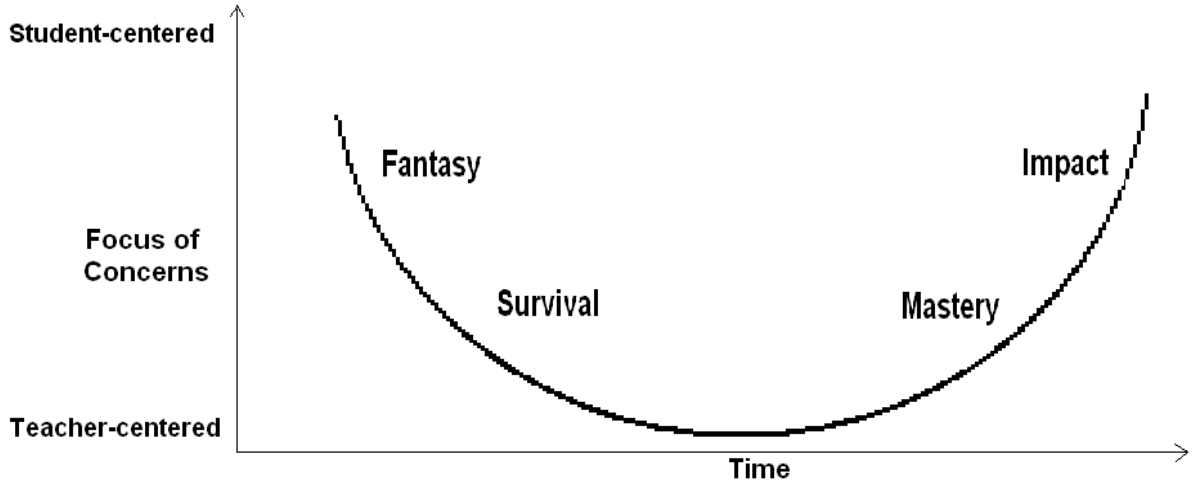

Figure 1. *Relationship Between Fuller and Bown's (1975) Stages of Teachers' Concerns and Notions of Student- and Teacher-Centered Instruction*

[2] Some researchers use the terms teacher-directed and learner-directed however, because as Ormrod (2006) notes, most instructional strategies "focus on the *student's* learning; the essential difference lies in who has control of the instructional activity" (p.435).

Although Fuller and Bown's work (1975) provides a framework for understanding how the concerns of teachers change with experience, their theory was formed based upon observations of pre-service educators, and the stages that these authors proposed are not specific to science educators. However, some research on teacher identity development has been conducted specifically with science educators. For example, the work of Volkmann and Anderson (1997) represented an initial contribution to understanding how science educators construct professional identities. The study used an in-depth phenomenological approach, which has become common in studies exploring teacher identity development (Carter & Doyle, 1996). Though the work of Volkmann and Anderson (1997) provided knowledge about the struggles encountered by a single beginning science teacher and her constructed personal narrative, these authors were unable to make generalizations about the developmental trajectory of science educators' professional identity though their study generally supported Fuller and Bown's framework. Thus the purpose of this study is to determine how well Fuller and Bown's framework could capture important aspects of teacher identity development among several teachers from STEM-ED disciplines.

Method

This study, part of a larger project investigating a multitude of factors affecting the development of graduate student research and teaching skills, explores how professional identity as teachers is shaped among graduate students who teach in science and related fields including technology, engineering, math, and math and science education (STEM-ED).

Given the need for instructors to conceive of themselves as inquiry-minded teachers (Leuhmman, 2007), it is important to understand the development of teaching identity as a reflection of values in the STEM-ED disciplines. It has been argued that part of the support necessary to encourage the adoption of inquiry teaching practices includes preparation that encourages students to reconsider and integrate their values, beliefs, and experiences, in the formation of a new professional identity (Forbes & Davis, 2007; Leuhmann, 2007). Unfortunately, this poses challenges to individuals who prepare future educators because little is currently known about the beliefs, experiences, values, commitments, and patterns of interaction that science educators, and specifically graduate students, bring with them to their studies.

This study will provide insights about STEM-ED teachers' identity development and formative experiences through examination of four research questions including:

(1) How do participants believe they learned how to teach/teachers learn how to teach?
(2) How do participants describe themselves as teachers and their strengths as teachers?
(3) What changes are observed in participants' identity as a teacher and teaching skills over the course of an academic year?
(4) What experiences contribute to changes in teaching skills or identity?

A fifth research question will determine how well the developmental trajectory put forth by Fuller and Bown describes the observed changes for a group of graduate students in STEM-ED

fields (Fuller, 1969; Fuller and Bown, 1975):

(5) How do responses to the previous questions compare for experienced vs. less experienced teachers?

Participants

The 18 graduate student participants were enrolled in either Masters or Doctoral programs in STEM-ED fields at a single large, Tier-I research university in the southeastern United States. More information about the degree that the 18 participants were seeking during 2007-2008, as well as the participants' gender, field of study, and year in the current degree program are shown in Tables 1 through 4. As table 5 shows, of the 18 participants, 11 participants were GK-12 and Pi Fellows[3] who co-taught with a partnering teacher in a K-12 setting as part of their fellowship programs. Three participants served as university teaching assistants which included teaching introductory-level undergraduate courses in their field of study. Four of the participants in this study had autonomous teaching positions which included working as a K-12 public school science teacher, teaching introductory science courses at a local teaching college, and teaching undergraduate courses as well as working as a liaison for a professional development school. Participants' prior teaching experience varied greatly, from veteran teachers with 30 years of experience to individuals who had never taught in a formal instructional setting.

Table 1.
Current Degree of Study Participants

Degree	Number
Masters	3
PhD	14
EdD	1
Total	18

Table 2.
Academic Field of Study Participants

Field	Number
Engineering	6
Physical/Biological Sciences	6
Education	5
Computer Sciences	1
Total	18

[3] GK-12 is a fellowship program funded by the National Science Foundation (NSF) designed to prepare future faculty in Science, Engineering, Computing, and Math. The Pi program is a University of South Carolina funded program that mirrors the NSF GK-12 program where graduate students and middle school science teachers are partnered for one academic year.

Table 3.
Year in Current Degree Program

Year in Current Degree Program	Number
First Year	5
Second Year	4
Third Year	4
Six Year	2
Eighth Year	1
Year Unknown	2
Total	18

Table 4.
Gender of Study Participants

Gender	Number
Male	9
Female	9
Total	18

Table 5.
Teaching Assignment of Study Participants

Teaching Assignment	Number
GK-12	7
Pi	4
University Teaching Assistant	3
Autonomous Teaching Position	4
Total	18

Data Collection

Students participated in semi-structured interviews in early fall of 2007 and late spring of 2008. Initial interview data served as a baseline to examine changes in these areas over an academic year. Interviews were about 30 minutes in length and examined participants' co-teaching experiences, mentoring experiences, identity as a teacher and researcher, teaching and research skills and views related to teaching and research. All interviews were audio recorded.

Data reported in this paper came from four interview questions including (1) How did you learn how to teach (or in the case of participants who did not feel they had learned how to teach, how do you think teachers learn how to teach?), (2) How would you describe yourself as a teacher?, (3) What are your strengths as a teacher?, and (4) What experiences have helped you become a better teacher? Considerable overlap emerged between the categories that resulted from coding responses to interview questions 2 and 3 as well as between the responses of each individual to

items 2 and 3. Since the authors did not feel that these items yielded unique, independent information, they decided to analyze the data to questions 2 and 3 jointly in order to gain a fuller picture of each teacher's preferences, skills, etc.

Analysis

The process of transcription served as a preliminary level of analysis of the semi-structured interviews. Following transcription, a domain analysis to explore for relationships between terms for inclusion in a category was conducted (Spradley, 1980). For example, statements such as "talking with students," "relating to students," and "caring about students" were all coded as "ways of building relationships with students." Numerous changes were made to the coding scheme as analysis unfolded, resulting in a grounded theory of similarities and differences among participants' experiences and views (Glaser & Strauss, 1967). All codes were then reviewed using the revised coding scheme.

All participants were categorized based on level of prior teaching experience. Ten participants were categorized as less experienced teacher (LET) participants and eight were categorized as experienced teachers (ET) participants. LET participants included five students who had not previously taught in a formal instructional setting and five students with some teaching experience, generally about one academic year in length. Participants categorized as ET participants had between three and 30 years of experience. The decision to analyze the data in light of previous teaching experience was informed by research (Fuller & Bown, 1975; Ryan, 1986) indicating that beginning teachers experience distinct challenges from experienced teachers. Examining participants' identity formation as a function of prior experience also highlighted differences between novice and experienced teachers, which may provide insights into the developmental trajectory of STEM-ED teachers' identity, and which may provide implications for differential professional preparation. According to Fuller and Bown's (1975) categorization, all participants in the LET group are in the *survival* stage, and participants in the ET group would likely be concerned with issues associated with the *mastery* or *impact* stages.

After all coding was finalized and all participants were categorized as either LET or ET participants, the frequency of each code was calculated for both groups. The process of data transformation allowed the researchers to capitalize on the strengths of both quantitative and qualitative research methods. Specifically, quantitizing qualitative data assisted in identifying patterns in the data and maintaining analytical integrity which are common reasons for engaging in data conversion (Teddlie & Tashakkori, 2009). In terms of identifying patterns in the data, quantification assisted the researchers in making inferences about the most commonly held views both within and across participant groups. In terms of analytic integrity, quantification assures that the researchers have not "discounted" important data which can occur when vivid responses are allowed to outweigh other accounts or when data are ignored, underweighed, or "cleaned up" (Sandelowski, 2000). The results of the analysis are presented in the following section. Tables that summarize participants' responses only include codes that were represented at least two times in the data.

Results and Discussion

Learning to Teach

At the initial interview, students described how they learned to teach. Overall, both LET and ET teachers tended to discuss learning to teach through informal methods such as through trial and error or experiences as a student rather than formal methods such as coursework. In part, this may reflect the nature of the participants included in this study, many of whom have not taken courses in schools of education. Table 6 displays emergent themes with associated frequencies.

Table 6.
Participants Beliefs about How they Learned to Teach

	LETs	ETs	Total N
Trial and error/practice	4	6	10
Observing my teachers/Experiences as a student	5	2	7
Course work/practicum experiences	2	5	7
Observing family member teaching	2	2	4
Collaborating with others	1	2	3
Tutoring siblings or peers at an early age	2	1	3
Observing teachers in the field (*not* my teachers)	0	2	2

Note. The sample size for LET and ET participants is 9. The frequency represents number of individuals rather than number of instances in which each code appeared.

Almost all of the participants in this study recognized learning to teach as a process and their responses as a whole depicted learning to teach as a cycle of implementation, feedback, and adjustment, or trial and error. One LET participant described learning to teach through practice in the following quote:

> Mostly going through it, doing it…[that is helpful in] just developing the skill and also making sure you maintain it because it's something if you, and there are times where it might be a year and a half before where I wasn't tutoring anyone or doing anything and try to pick that back up is always a little harder and so just maintaining some kind of education work is always important I think.

An ET participant explained,

> Where I really learned how to teach, that was on the job…I learned to teach after I got into teaching, not necessarily through a formal, well developed education program.

Both groups of participants talked about observing their own teachers as a source of information about learning how to teach. As one ET participant said:

> I had a Geology professor and my science methods instructor who were very hands-on teachers. They are the ones that really turned me on to wanting to teach science and so I think I've learned a lot from the way they taught and how they modeled.

Another LET participant stated, "I learned how to teach, I guess from my undergrad instructor and they were just an excellent example of what I think a teacher should be…" Overall, LET participants tended to discuss learning how to teach through observing teachers in the field much more frequently as compared with ET participants. This finding is consistent with Fuller and Bown's (1975) description of the process of learning to teach as well as previous research by Eraut (1985), Goodman (1988), and Bullough (1991) which indicates that educators are guided by powerful images from events experienced as a student which influence their desire to teach, desired teaching location and field, expectations, interpretations, and behaviors as a teacher. Bullough (1991) hypothesized that these images of self developed through experiences as a student are a necessary prerequisite to the development of teaching identity and skills.

Both LE and ET participants described drawing upon coursework or practicum experiences in learning how to be a teacher, although ET participants discussed the importance of these experiences more commonly. As one ET participant stated:

> Honestly, the courses that I'm taking, the courses I'm selecting, this program is a big, big help. Especially when I have courses like Social Class & Diversity, those things actually help me a lot. From last year to this year, I could see changes just based upon that one particular course.

The fact that more LET participants described ways in which coursework or practicum experiences have influenced their ability to teach may reflect the nature of the LET participants. Specifically, LET participants in this study were generally from Science, Technology, Engineering, and Mathematics backgrounds and had not had the opportunity to take courses in education.

Both LET and ET participants described how early experiences observing family members teach have impacted them. As one LET participant said:

> I watched my aunt, she was a teacher and she allowed me to grade papers for her and things like that." Similarly, LE and ET participants talked about how early experiences tutoring peers or siblings impacted their ability to teach. As one ET participant explained, "I have four brothers and my mother and father, neither graduated from college or high school…And I would help my brothers with their homework…So, I think it came naturally because I was the only girl and my brothers, they really needed help. I did that. Being grown up in a rural area, not too many things to do but play teacher. So, you know teach my little brothers about ABC's and things that I knew because three of them are younger than I am. That helped out a lot.

Two ET participants and one LET participant also identified collaboration as a strong influence on their ability to teach. As one of these ET participants explained:

> One thing I love to do is to share my experience with other teachers and try to learn a lot from other teachers. Every time I have to deal with a teacher that is successful, I get to learn. I always have to learn, tell me what is the secret. How he does it in class? What kind of plan can we use to deal with at this time, to touch our students?

Two ET participants also talked about the value of observing teachers in the field other than one's own instructors. As one of these ET participants explained:

> I think supervising student teachers has helped and watching people do things right or wrong, watching how it plays out, and then being able to analyze other people's teaching and then you see why it is good or bad to do a certain thing.

In part, ET participants may have cited interactions with other educators more frequently as compared with LET participants because ET participants may have had more opportunities to engage with other professional educators. Alternatively, ET participants may have been better able to make use of these opportunities for collaboration. Support for this hypothesis comes from previous research which suggests that critical examination of teaching is an essential element of improving instruction through teacher collaboration (as cited in Borko, 2004). Findings also suggest that critical assessment of teaching is rare and challenging to foster, requiring the establishment of trust, communication norms, mutual respect, and the ability to critique instruction (as cited in Borko, 2004). Thus, even when provided with opportunities that allowed them to engage in professional collaboration, LET participants may not have been as capable of critically assessing instruction and thus the collaboration may not have been as fruitful.

Identity and Strengths as a Teacher

All participants were asked to describe themselves as a teacher and describe their strengths as a teacher during both interviews. Emergent themes in response to these questions along with associated frequencies are presented in Table 7.

Table 7.
Self-reported Aspects of Participants' Identity and Strengths as Teachers

	Initial Interview		Final Interview	
	LETs	ETs	LETs	ETs
Engaging class in instruction	5	6	2	2
Adjusting instruction	1	3	3	4
Encouraging student discussions	2	3	2	2
Facilitating student investigations	1	3	3	2
Establishing relationships	3	1	1	3
Providing comprehensible explanations	3	1	4	0
Nurturing aspects of personality	3	1	1	1
Dynamic aspects of personality	3	2	1	0

Organization/Ability to plan for instruction	3	0	1	1
Providing feedback to students	1	1	1	2
Content knowledge	0	2	0	2
Identifying and addressing student misconceptions	1	1	1	1
Developing as a teacher	3	1	0	0
Patience/use of wait time	2	0	3	0
Positive image of self as teacher in general	0	1	1	1
Using a variety of approaches	0	0	1	1
Collaboration (with individuals other than students)	0	1	1	0
Encouraging multiple problem solving approaches	0	1	0	1

Note. The sample size for LE and ET participants is 9. The frequency represents number of individuals rather than number of instances in which each code appeared.

Participants in both the ET and LET participant groups noted that they excelled at engaging their class in instructional activities, although they neglected to identify specific instructional strategies used. Instead, participants who cited this ability generally emphasized utilizing techniques that spark and retain students' attention such as one LE participant who said*:*

> I like to get up and move around. I like to get the students involved. I like to do things they don't expect, trying to get their attention.

As compared with LET participants, ET participants more frequently cited the ability to adjust instruction to meet students' needs as a teaching skill or an aspect of their identity as a teacher. These individuals talked about adjusting instruction based on students' cultural background, level of prior knowledge, motivation, and rate of comprehension. As one ET participant stated at the final interview:

> so I think I present my information in the content of science in a way where students can understand. I like to refer to it as culturally relevant. I teach a lot of minority students at Kaplan and certain things in science are so hard to grasp and I like to tie things back to their home life or I love to make jokes, sometimes they laugh, sometimes they don't.

The fact that more ET participants cited this ability at the time of the initial interview is consistent with Fuller and Bown's (1975) theory in that these teachers are likely in the *mastery* stage in which teacher are becoming more knowledgeable about the tools to use in a given instructional situation or the *impact* stage of teaching in which they are hypothesized to be more concerned about the impact of teaching methods on students and more concerned about the needs of students. It is somewhat unexpected for the three LET participants to have reported this ability by the time of the final interview. For one of these participants, this finding could be reconciled by the fact that he had had a fair amount of teaching experience including serving as a teaching

assistant for three academic semesters. The other participants, however, had either no or minimal teaching experience prior to 2007-2008. Both of these participants, however, were GK-12 students: thus, they may have been able to develop the ability to adjust instruction due to the nature of the co-teaching experience. For example, the partner teacher with whom one of the two specified LET participants was paired may have provided assistance in terms of facilitating an effective learning climate and establishing classroom management procedures. In turn, this may have allowed the LET participant to more quickly shift his focus from behavior to instruction and specifically to adjusting instruction to meet students' needs.

Several participants in both groups also talked about engaging students in classroom instruction through encouraging discussion between students, between teacher and student, or both. Numerous theorists and scholars have emphasized the critical role of providing opportunities for discussions with and among students in the development of scientific reasoning skills, such as Vygotsky and Piaget. Vygotsky's cultural historical theory states that all higher psychological functions begin as social activities (Gredler, 2005). Thus collaboration between individuals and, specifically, interaction with highly capable individuals, generally the teacher, is essential to cognitive development in Vygotsky's theory (Gredler & Shields, 2007). Piaget also ascribed an important role to social interaction and collaboration among learners, indicating that "knowledge acquisition is in fact a co-construction in collaboration" (as cited in DeVries, 2006). In Piaget's theory, collaboration promotes advanced reasoning because individuals present alternate worldviews or perspectives. When the learner considers the other's point of view, they may experience cognitive conflict or disequalibration which Piaget theorized promotes cognitive development as the learner searches for logical coherence and equilibration.

One LET participant who did not talk about the ability to encourage student discussions at the time of the initial interview stated at the final interview:

> I am really open with my class this year I don't have so many behavioral problems to deal with so I can be really laid back and open and let the kids have kind of an open forum and we have a lot of class discussions so I guess more than a teacher I feel like I'm kind of a facilitator.

At the time of the final interview, this participant had just completed his first year of co-teaching, which represented his first formal teaching experience. Thus, the change in focus from an emphasis on classroom management to an emphasis on instructional practice is consistent with change in concern hypothesized by Fuller and Bown (1975). This participant, however, may have reached this stage somewhat more quickly than expected given that he had only had engaged as a course instructor twice per week for one academic year. This premature change, however, may reflect the benefits of co-teaching. Research by Eick, Ware, and Williams (2003) supports this notion. From their study of pre-service educators who engaged in co-teaching experiences with K-12 teachers, they concluded that:

> Greater assuredness in interacting with classroom students now is evidence of the beginning development of classroom management and discipline skills. This coteaching arrangement appears to have begun this process of development in a teacher-supportive environment. This earlier development of the experiential knowledge of managing

> students may allow student-teachers to move to other concerns or issue in their teaching sooner (p. 82).

Another strategy that several teachers reported using to increase student engagement was encouraging student problem-solving, exploration, and investigation. One LET and three ET participants discussed this ability during the initial interview. As one ET participant explained:

> I like to present problems to the students that let them discover the answers, and let them be the problem solvers. I have been fortunate in that's pretty easy for me to do teaching just math and science…my district uses the…delta science modules and even though I have those and I use those I don't go step by step with the teachers guide. I might present a lesson but then allow the children an opportunity to come up with their own investigations.

Although only one LET participant cited this ability during the initial interview, several LET participants discussed the importance of student investigations during the final interview, providing some indication that these participants have developed more inquiry-minded instructional practices. Comparison of the LET and ET participants' descriptions of facilitating student investigations revealed some important differences. Specifically, the three LET participants who were coded as placing importance on student investigations during the final interview discussed encouraging students to be hands-on and thinking of themselves as hands-off teachers. The ET participants who described this strategy at the final interview more comprehensively depicted inquiry teaching including a discussion of having a lesson objective in mind in terms of what students will learn from their investigations and having the children develop their own research questions. As one of these ET participants said,:

> In the classroom I see myself more as a facilitator and definitely not a teacher that sees herself just as a transmitter of the knowledge or the great knowledge holder that you give to all the children. My children tend to be very involved in discovery based learning, as much inquiry as I possibly can. I really work hard with them to get them to solve their own problems…allowing them the time to come up with a plan to investigate it or a plan of where are they going to go to find the information and then also giving them time to come back together and talk about what they found and start making connections. I am not the type of teacher who you are going to find in the front of the classroom just giving a lecture.

The ability to build relationships and relate to students was also discussed by several LET and ET participants. Interestingly, at the time of the initial interview, more LET participants identified this strength while more ET participants identified this ability at the time of the final interview. According to Fuller and Bown's (1975) theory, ET participants would be more likely to be concerned about establishing individual relationships with students. Analysis of these participants' responses, however, indicated that the ET participants who described the ability to establish relationships with students noted this ability in terms of going beyond classroom instruction. For instance, one ET participant whose response was coded as "good at establishing relationships with students" said:

> I am very approachable, and so therefore the students ask me whatever questions they have, they feel comfortable asking that question. They always spend time with me after class trying to get more – asking me, 'what would you do in this situation?'

while an LET participant who was identified as such stated:

> Well, I've think I got now where I can communicate with the students very well. I think I do a good job relating, they seem to, but, I mean, I just don't know. You don't get a whole lot of feedback about it. I think I relate well – they seem to know when I try to give examples or connect things. They seem to understand what I am saying.

LET participants commonly identified one of their teaching skills as the ability to provide understandable explanations including using multiple means to describe phenomenon, providing clear descriptions, using numerous examples, and providing analogies. One LET participant who was described this ability stated that:

> I am able to break down the information so they can understand it. I give a lot of examples so even if they don't see it they are able to relate it to things outside the classroom, I would say.

Three LET participants described this ability at the time of the initial interview and four LET participants noted this ability at the time of the final interview. This provides some indication that the teaching experiences of these LET participants facilitated their ability to communicate their subject matter. Other researchers who have studied the impact of participating in the GK-12 program have similarly reported that following participation, GK-12 participants are better able to communicate about their own research (as cited in Sevian & Gonsalves, 2008). The lack of ET participants reporting this ability was unexpected.

Several participants also identified nurturing characteristics of their personality that they felt were fundamental aspects of their professional identity (such as being helpful, caring, friendly, approachable, patient, kind, respectful, encouraging, or personable) or dynamic aspects of their personality which allowed them to get students' attention (such as being enthusiastic, captivating, goofy, or energetic). Almost all of the participants who discussed these personality characteristics were LET participants, and they generally only described personality characteristics as part of their identity as teacher during the initial interview. Fuller and Bown's (1975) theory of teacher development indicates that teachers in the *survivial* stage, which occurs during the first year of teaching, are experiencing serious crisis about their identity and sense of worth (Ryan, 1986). This concern with self may explain why many of these participants (particularly at the initial interview which occurred about one or two months into their teaching experiences) reflected on their personality and possibly were reconstructing or reconsidering their personality and personal identity as well as developing the professional teaching identity.

Only ET participants talked about mastery of their subject area as an aspect of their teaching identity and/or strengths as a teacher. The fact that no LET participants identified themselves as having expertise in their subject-matter may reflect the Fuller's (1969) finding that new teachers are often concerned about the adequacy of their subject-matter knowledge.

Organization or planning for instruction was a skilled that was almost exclusively discussed by LET participants. Rather than interpreting this finding as evidence of differential ability, the authors of this study believe that this difference reflects that LET teachers are much more concerned with planning for instruction as compared with ET teachers. This is consistent with the work of Adams and Krockover (1987) who found that beginning teachers were often highly concerned with preparing for instruction including concerns about organization, timing, sequencing, and presentation of content. Other qualities that participants described as primary components of their identity as teachers can be seen in Table 7.

Experiences that Improved Teaching

In both the initial and final interview, students described experiences they felt had improved their teaching during the academic year. Table 8 shows emergent themes with associated frequencies.

Table 8.
Participants' Experiences that Improved their Teaching

	Initial Interview		Final Interview	
	LETs	ETs	LETs	ETs
Co-teaching with my partner teacher	2	1	2	3
Interacting with students/ Feedback from students	3	2	2	2
Classroom-level challenges	0	0	2	3
Students who present challenges (academic and behavioral)	0	2	2	0
Observing my teachers/experiences as a student	2	0	1	0
Reflecting on one's own teaching experiences	0	2	0	1
Talking with peers/colleagues	1	1	1	0
Reading journals/books in field	0	1	0	1
Professional development experiences	0	2	0	0

Note. The sample size for LET and ET participants is 9. The frequency represents number of individuals rather than number of instances in which each code appeared.

The most commonly cited formative experience was co-teaching with a partnering teacher. Eleven of the students interviewed engaged in this experience as part of their graduate fellowships, seven[4] of whom identified this experience as particularly influential on their teaching skills during the initial and/or final interview. Many of the participants also described specific aspects of their co-teaching experience that were beneficial in the development of their teaching skills. LET participants discussed the benefits of being able to facilitate student investigation and experiencing challenges in doing so such as dealing with students who were not engaged in the lab which resulted in developing strategies for cooperative learning. Another student noted the challenge she experienced when implementing a lab which took more time than expected. This LET participant discussed how she learned to better plan for instruction and realized the need to be able to adjust instruction frequently. She contributed acquiring this knowledge, in part, to her co-teacher's willingness to allow her to make mistakes in the classroom. As she explained:

> [My partner teacher],…he basically let me screw up a couple of times and like there's one time where I roasted, ran over time and we didn't have time to finish about half the activities that we planned but he says "that's ok, that happens,"…I learned a lot working with [my partner teacher] – that just nothing tends to go as planned and that's going to be ok and …you just have to be able to adapt like ultimately the classroom as the responsibility of the teacher…

Similarly, two ET participants identified the benefits of addressing student and classroom challenges when facilitating student investigation. Other benefits cited among the four ET participants included being able to jointly reflect on teaching practice and outcomes, and development of new instructional activities and knowledge about a related content area and students' cultural background. Comments about the experience of teaching with partner teachers reveal some differences in the kinds of co-teaching experiences that the participants' found beneficial. For example, the ET participant who discussed developing new instructional activities and knowledge emphasized how important it was to her that her partner teacher "tells me the truth," while the LET participant who was previously quoted and one ET participant seemed to find their partner teacher's willingness to allow them to "try things out" and make mistakes as a benefit. Opportunities to try things out and "fail on occasion" were documented as important to beginning teachers in Fuller's (1969) study.

Both LET and ET participants discussed the benefits of interacting with and receiving feedback from students. Of the LET participants who noted the importance of feedback at the initial interview, only one identified adjusting instruction based on student input, which involved speaking more slowly. Both ET participants who discussed the importance of receiving student feedback at the initial interview discussed adjusting instruction accordingly. One ET participant who described using student input to adjust instruction explained:

[4] One of the ET participants cited co-teaching as particularly beneficial during both the initial and final interviews.

> The feedback from the students is I guess the most important because you have to cater to the students at the end. I usually talk to my students at the beginning of the semester, at the middle of the semester and then at the end of the semester so that I know what kind of students I am supposed to be teaching. For example, if I am teaching most non-biology students a biology course, then I orient my course that way…I would try to approach them from a different point of view.

Additionally, at the time of the initial interview, all three of the LET participants identified informal methods of gaining student feedback about instruction such as "Reading the student's faces and seeing where they are, if they are lost and if there is an interest in their eyes, in their attitude." ET participants who mentioned the importance of receiving feedback cited both formal and informal methods of gaining feedback about teaching.

Both LE and ET participants discussed improving their teaching as a result of addressing classroom-level challenges (such as unexpected interruptions, schedule changes, or when experiments go "wrong" or are more timely than expected) as well as challenges that individual students present (including academic and behavioral challenges). One ET participant described why she believes that these experiences can improve one's teaching. As she explained, "Usually the best experiences are things that go wrong because you are more likely to remember them and remember and learn from them."

Similar to findings related to learning how to teach, LET participants uniquely identified experiences as a student and the opportunity to observe their former and/or current teachers as an experience that has improved their teaching. Only one teacher (an LET participant) cited this experience as significant at the final interview, which may reflect changes in the experiences that these participants perceive as pivotal to their professional identities.

Both LE and ET participants cited professional experiences, such as talking with colleagues, reading professional journals or books, and professional development experiences as pivotal in the development of their teaching skills and/or professional teaching identity, although ET participants cited these experiences much more commonly. Similarly, ET participants uniquely identified reflection upon teaching as a method of improving their teaching abilities. This finding is consistent with that of Fuller (1969), who found that self-evaluation is of primary importance to experienced teachers.

Conclusion

Consistent with past studies demonstrating the positive impact of observing experienced science teachers using inquiry-teaching (Eick, Ware, & Williams, 2003), graduate students who participated in co-teaching experiences in middle school science classrooms in this study also viewed the experience as rewarding and, possibly as a result, the focus of their professional identities transformed. Specifically, several LET participants who had not mentioned encouraging student investigation during the initial interview described this practice as being a part of their identity as a teacher at the final interview. This change provide some indication that many of these teachers are reconciling their prior beliefs with views of inquiry-based teaching, which Leuhmann (2007) identified as an essential step in becoming a reformed teacher.

Findings of this study somewhat supported the trajectory of concerns depicted by Fuller and Bown (1975). Specifically, LET participants were more likely to describe their identity as a teacher in terms of personality characteristics (at the time of the initial interview) which is consistent with the identity crisis that occurs during the *survival* stage. ET participants more frequently recounted their ability to adjust instruction based on students' cultural and academic background, which is also consistent with Fuller and Bown's assertion that teachers in the *mastery* stage are more knowledgeable about the tools to use in a given situation. Given that some of the LET participants (such as the participant with minimal prior teaching experience who identified being able to adjust the pace and depth of instruction to meet students' needs) in this sample progressed to these concerns perhaps faster than predicted by Fuller and Bown (1975), further research should investigate if/how co-teaching experiences can assist student teachers in minimizing classroom management concerns and allowing them, instead, to focus on facilitating student investigation.

One of the primary tasks of teacher education is to assist students in integrating their personal experiences with their content and pedagogical knowledge. Thus, effective teacher educators and teacher education programs should provide opportunities for students with all levels of experience to reflect on their salient educational experiences. Unfortunately, this poses challenges to individuals who prepare future educators because little is currently known about the beliefs, experiences, values, commitments, and patterns of interaction that science educators, and specifically graduate students, bring with them to their studies. Though this study had several limitations, of which the most significant may be its exploratory nature, small sample size, and reliance on self-report, this study nevertheless provided key insights into STEM-ED teachers' identity development and formative experiences.

Overall, study findings indicate that one's personal experiences as a student may be important sources of identity and teaching skills for LET participants, while coursework, professional development, reading professional journals, and observation of teachers in the field may be more important to ET participants' identity and skill development. Findings also show that Fuller and Bown's (1975) model of teacher development is somewhat applicable to a sample of graduate student teachers, with some exceptions. Some of these exceptions may be attributable to the impact of co-teaching experiences. More research on teacher identity development, specifically among science teachers, may assist in improving the preparation of science educators and their willingness to participate in reform efforts. Additionally, more research on the nature and impact of co-teaching experiences is also warranted including an investigation of when, during teacher preparation and development, it is most productive for teachers to have opportunities to collaborate.

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