# An Exploratory Study of Factors Influencing the Development of STEM Graduate Students' Teaching Skills

Joanna Gilmore (jagilmor@mailbox.sc.edu)

Melissa Hurst

**Abstract:** Graduate students in the sciences, technology, engineering, and mathematics (STEM) fields, represent an important link in current reforms emphasizing inquiry-based learning and teaching, as they represent the future of the STEM professoriate. Although graduate students commonly hold teaching assistantships, they rarely receive training on how to teach (Prieto & Meyers, 1999) and even less frequently on inquiry-based teaching methods. Thus this study explored the factors that facilitate the development of inquiry-based teaching skills among 17 STEM graduate students. Graduate students who made gains in inquiry-based teaching skills across an academic year were more likely to regularly discuss their teaching with their mentors, graduate student peers, or practicing K-12 teachers. Graduate students who showed gains in inquiry-related teaching skills also emphasized the importance of having their students' develop their *own* research questions and engage in critical thinking when unexpected results arise during experimentation.

Paper presented at the National Association for Research on Science Teaching, Philidelphia, PA, March 24, 2010.

The work in this paper is supported by a grant of the National Science Foundation, NSF-0723686 to David Feldon, Briana Timmerman, Stephen Thompson, Jed Lyons, and Michelle Maher. The views in this paper are those of the authors and do not necessarily represent the views of the supporting funding agency.

# Introduction

The science education community has come to advocate for a new vision of science instruction based on psychological research that emphasizes inquiry-based teaching (National Research Council [NRC], 1996, 2000). Inquiry-based teaching is defined as engaging students in authentic scientific processes such as developing hypothesis, collecting, analyzing, discussing and interpreting data. Previous research indicates that inquiry-based teaching improves scientific reasoning and achievement for all students (Schroeder, et al., 2007; Shymansky, et al., 1983). Thus scientific inquiry has come to be viewed as “the heart of science and science learning” (NRC, 1996, p. 15) and it is an important instructional strategy for science teachers at all levels of education. In the same vein, the role of the teacher has been re-envisioned. The teachers’ focus is no longer the transmission of knowledge but rather the development of students’ curiosity, persistence, beliefs, and skills that will allow them to direct their own learning. New visions of science education prompt us to view teaching as a form of inquiry (e.g. Badley, 2002).

Graduate teaching assistants (GTAs) in the sciences, technology, engineering, and mathematics (STEM) fields, represent an important link in current science reforms emphasizing inquiry learning and teaching, as they represent the future of the STEM professoriate. Their early teaching experiences are of utmost importance because, during this time, teachers establish an enduring teaching style and set of teaching skills (Boice, 1996). Although graduate students commonly hold GTAs, they rarely receive training on how to teach (Prieto & Meyers, 1999) and even less frequently on inquiry-based teaching methods. Thus it is important to understand how STEM graduate students learn to be effective teachers and the factors that facilitate their development.

## Review of Literature

Researchers have identified several factors which may influence the development of teaching skills among graduate students. A first factor that is external to the student is instruction specifically targeted at the development of teaching skills which includes training or professional development provided by graduate programs. Often training is provided to graduate students as they engage in GTAs. Some research indicates that training programs can influence the teaching behaviors of GTAs. For example, from a review of research, Caroll (1980) found that studies examining the impact of semester or year-length training programs, geared toward teaching GTAs to facilitate class discussions or engage learners in problem-solving, generally resulted in substantial improvements in the teaching behaviors of the GTAs. In a later study, Prieto and Meyers (1999) surveyed GTAs in psychology across the US. They found that respondents who received training for their GTAs received, on average, 22 hours of instruction. Despite the shorter duration of the training provided, they found that respondents who had the opportunity to attend GTA training reported higher levels of teaching efficacy.

Though effective instruction has the potential to assist graduate students' in becoming effective teachers, some research suggests that few graduate students actually feel prepared to teach. Golde and Dore (2004) surveyed 4,114 graduate students and found that few reported being prepared by their programs to engage in basic teaching activities including facilitating discussion-based courses (57.9% of respondents reported being "very prepared" to do this), leading a laboratory section of a course (44.7%), and lecturing (36.1%). These findings may reflect the reality that the development of graduate students' teaching skills is often not the priority of graduate programs in designating teaching assignments or providing support structures for GTAs.  As Austin (2002) noted, teaching assistantships "sometimes are structured more to serve the institutional or faculty needs than to ensure a high quality learning experience for graduate students" (p.95).

Research also indicates that effective mentorship greatly contributes to successful completion of graduate school (Council of Graduate Schools, 2009). However, effective mentoring is "complex." Barnes and Austin (2009) conducted interviews with exemplary faculty mentors and found that there are a variety of important facets of effective mentoring. Effective faculty mentors in Barnes and Austin's (2009) study commonly reported assessing their graduate students skills', providing regular feedback to their mentees, promoting their growth as professionals and researchers, helping their mentees identify dissertation topics and effective dissertation committees, and encouraging them to persist in the face of unexpected results, in addition to being "professional," "collegial," "supportive," "accessible," and "honest" with their mentees.

Variability in the quality of mentorship received may, in part, explain discrepant findings regarding the relationship between mentoring and graduate student teaching outcomes. For example Prieto and Meyers (1999) did not find a relationship between ongoing mentor supervision regarding graduate students' teaching and teaching-efficacy. However, when Boyle and Boice (1998) provided funding to ensure that TAs received regular mentoring regarding their teaching, they found that GTAs reported learning more from their teaching experiences as a result of mentoring.

One problem that graduate students commonly cite with the mentorship that they receive regarding their teaching includes a "lack of developmentally organized and systematic professional development opportunities" (Austin, 2002, p.95). For example, teaching assistantships are often not planned in such a way as to encourage increasing levels of autonomy over time. Additionally, teaching assignments generally reflect departmental needs rather than the budding interests of GTAs. Other problems that graduate students commonly experience in terms of the mentorship that they receive from teaching include a lack of opportunity to discuss the teaching career, their development as teachers, and assumptions about learning and teaching (Austin, 2002).

Graduate programs have also attempted to facilitate the development of graduate students' inquiry-based teaching skills through programs such the National Science Foundation's (NSF) Graduate Teaching Fellows in K-12 Education (GK-12) program and Partners in Inquiry (Pi)[1] programs. To date, approximately 200 university-based GK-12 projects across the country with varying foci have been funded (NSF, 2009), including a project with a strong focus on inquiry-based teaching that forms the context for this study. The GK-12 and Pi programs follow an immersion model, in which a single Graduate Teaching Fellow works directly with one or two classroom teachers and their students for an entire school year (Mitchell, et al., 2003). GK-12 programs impact Graduate Teaching Fellows teaching skills, in part, because they provide opportunities for Graduate Teaching Fellows to receive feedback following the implementation of inquiry based lessons. Additionally, GK-12 provides opportunities for Graduate Teaching Fellows to reflect on their own teaching practices through weekly meetings with other graduate teaching fellows. Both of these mechanisms (practice with feedback and collaborative reflection) have been shown to impact the development of teaching skills in prior research (e.g. Martin & Double, 1998). Thus these programs provide systematic support for STEM graduate students to develop inquiry-based teaching skills as they act as resources for K-12 science and mathematics teachers.

[1] 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.

In addition to external factors that support the development of inquiry-related teaching skills, Leuhmann (2007) also indicates that teacher beliefs are important predictors of the extent to which teachers encourage inquiry-based learning. Research by Marshall et al. (2009) supports Leuhmann's assertion. Through surveying 1,222 K-12 teachers, Marshall et al. (2009) found that teachers' beliefs about inquiry are highly related to the extent to which their students engage in inquiry.

These beliefs about inquiry are developed, in part, through events experienced as students (Bullough, 1991; Eraut, 1985; Goodman, 1988; Hollingsworth, 1989; Lortie, 1975; Selden & Selden, 1997). These experiences influence teachers' desire to teach, desired teaching location and field, expectations, interpretations, and behaviors.  Lortie (1975) referred to this situation in which educators teach in the way they were taught as an *apprenticeship of observation*. However, as Meyborn and Tyminski (2006) note, the cycle of behaviors can be broken through critical examination and reflection upon one's beliefs.

Teaching efficacy may be one factor that may influence teachers' willingness and ability to break such a cycle. Prior research indicates that teaching efficacy (or the extent to which teachers believe they are capable of brining about positive student outcomes; Tschannen-Moran & Hoy, 2001) has a substantial impact on teachers' instructional practices. For example, Gibson and Dembo (1984) found that teacher efficacy was highly related to the extent to which teachers use small vs. whole group instruction and use of criticism. Allinder (1994) found that teachers with high teaching efficacy exhibit more planning and organization and are more likely to try innovative teaching approaches. Less research has investigated the link between teacher efficacy and the use of inquiry-based teaching practices. Marshall et al. (2009), however, found that teaching efficacy was significantly correlated with the amount of time K-12 teachers spent on inquiry.

Experiences in which teachers engage in authentic scientific inquiry may also be pre-requisite for implementing inquiry-based teaching methods. Windschitl (2003) supported this contention. Specifically, in a study of 12 pre-service science teachers, Windschitl (2003) found that engaging in authentic research experiences impacted the ways in which pre-service teachers *planned* to use inquiry in the classroom. To the author's knowledge, however, no previous studies have systematically examined the relationship between teachers' research experience and their use of inquiry-based teaching in the classroom.

Theories of teacher development suggest that the amount of prior teaching experience that teachers possess will also likely impact the extent to which they use inquiry-based teaching methods. Specifically, models of teacher development commonly posit that beginning teachers focus on developing "survival" skills such as classroom management and the ability to transmit basic information (Fuller & Bown, 1975; Zuljan, 2007). These models suggest that the ability to effectively engage in student-centered instruction emerges later in the teacher's development.

## Study Purpose

These studies have contributed to our understanding of the development of graduate students' teaching skills, however, many of these studies have not been conducted specifically with STEM graduate students and many have not focused specifically on the development of inquiry-related teaching skills. Additionally, researchers have usually relied upon self-reported measures of teaching skills. Thus this study will connect mechanisms by which STEM graduate students develop inquiry-related teaching skills. Specifically, this study will explore the impact of personal factors (e.g. prior teaching and research experience, teaching goals, and beliefs about inquiry teaching) and environmental factors (e.g. training provided, ongoing supervision/mentorship, interaction with peers regarding teaching) on changes in graduate students' inquiry-based teaching skills.

## Method

All data used in this study were collected as part of a larger project investigating the development of graduate students' teaching and research skills. Participants were recruited from a research university in the Southeast and a liberal arts college in the Northeast. The study reported in this paper included 17 participants who taught in a formal instructional setting during the academic year in which they participated in this study. Only participants for whom complete data was available were selected for this study.

Of the 17 participants, 2 were seeking a master's degree while 15 participants were seeking a Ph.D. Three of the participants were seeking degrees in Biology, 4 in Chemical Engineering, 2 in Mechanical Engineering, 2 in Marine Science, 2 in Mathematics, 1 in Geology, 1 in Statistics, 1 in Science Education, and 1 in Instruction and Teacher Education with an emphasis on Science Education. Ten of the participants were GK-12 or Pi fellows. Thus these participants co-taught inquiry based science lessons to middle school students weekly. Five of the participants taught courses through GTAs.  Two of the participants worked as full-time teachers; one as a junior faculty member at a small nearby college and the other as a full-time public high school science teacher.

All participant interviews were conducted in the fall and late spring. Relevant interview questions include:

1. *Tell me about your prior teaching experience. (fall only)*
2. *Tell me about your prior research experience. (fall only)*

3. *What are  your academic and professional goals (fall only)*
4. *What experiences have helped you become a better teacher? (fall and spring)*
5. *What is inquiry teaching? Can you provide an example of inquiry teaching? (fall only)*
6. *If you were teaching a lab and students were finding results that were unexpected, what would you do and what would you tell your students to do? (fall only)*
7. *How would you describe your relationship with your advisor? (fall and spring)*

This study also drew upon information gained from advisor interviews which were conducted twice during the year. Relevant interview questions include *How would you describe your relationship with the participant?* and *To what extent are you involved in the participant's teaching activities?*

All interviews were recorded and transcribed. A domain analysis, which explores relationships between responses for inclusion in a category, was then conducted for all participant responses to each interview question (Spradley, 1980). Each response was coded and tallied in order to identify similarities and differences in participants' experiences and points of view. Information obtained from faculty advisor interviews was also used to supplement and triangulate the data that participants provided concerning their relationship and interactions with their advisors.

In addition to interviews, participants' teaching skills were evaluated using the Learning Environment Inventory (LEI). The LEI is an informative and accurate way to gather information about classroom practices along with student and teacher opinions and perceptions of that environment (Haney & McArthur, 2002; Lee & Fraser, 2000).  The LEI instrument used in this study was employed in order to capture teachers' ability to establish a productive learning environment and includes elements of inquiry teaching such as making learning personally relevant and exploring the nature of science with students. The LEI instrument used in this study is a combination of two previously validated instruments: 1) *The Constructivist Learning Environment Survey* (CLES) (Taylor, P.C., Fraser, & Fisher, 1997) and 2) *What is Happening in this Class?* (WIHIC) (Aldridge, Fraser & Huang, 1999). The LEI was administered to the students that the participants taught in the early fall and late spring. All student actual responses were averaged for each item and a total average LEI score was computed for each graduate student participant.

All participants were then categorized in terms of the level of change they exhibited in their teaching skills across an academic year. Five participants were categorized as showing a decline (SD) in inquiry-based teaching practices (loss between -.259 to -0.69), five participants were categorized as showing little or no change (NC) (change between -.29 and .38), and seven participants were categorized as showing substantial improvements (SI) in their use of inquiry-based teaching practices (gains between .75 and 2.27). Findings will be presented by the level of change captured in participants' inquiry-based teaching skills as measured by the LEI. Appropriate statistical analyses were conducted in order to determine if there were significant differences between the groups.

## Results

Three out of 5 (60%) of the SD participants were involved in GK-12 or Pi while 2 out of 5 (40%) NC participants and 5 out of 7 (71.4%) SI participants were involved in this program. Participants in the NC group had the greatest length of prior teaching experience (mean=5.4 years) and participants in the SD and SI groups had similar amounts of teaching experience (mean=1.3 and 1.4 years, respectively). However, a one-way between-subjects ANOVA showed that differences between the 3 groups in terms of prior teaching experience were non-significant, $F(2, 14)=1.27$, $p=.311$. NC and SI participants more frequently reported the desire to teach in the future. Three participants in each of these groups wanted to work at a research university or a teaching college after finishing their degree while only 1 SD participant shared this goal. However, a chi-square revealed that these differences were non-significant, $X^2(2) = 1.665$, $p=.435$.

SI participants had the greatest amount of prior research experience (mean=5.7 semesters). SD participants had 4 semesters of prior research experience, on average, and NC participants had about 2 semesters on average. A one-way ANOVA showed that differences between the 3 groups in terms of prior research experience were non-significant, however $F(2, 14)=2.54$, $p=.115$.

Participants described experiences that have helped them become a better teacher in fall and spring. Several participants in all groups commonly identified the opportunity to work with students who present academic or behavioral challenges as pivotal in their development (Fall - SD=3, NC=2, SI=2; Spring - SD=1, NC=0, SI=1). Participants in the SI group also commonly reported benefiting from classroom-level challenges, such as when experiments take longer than planned, in the Spring (SD=0, NC=1, SI=2). NC and SI participants also commonly reported improving their teaching as a result of interacting with and receiving feedback from their students (Fall - SD=1, NC=0, SI=2; Spring – SD=0, NC=2, SI=1). At the time of the fall interview, many participants also reported that observing their own teachers and professors helped them improve as a teacher (SD=2, NC=0, SI=2). Several SD participants talked about the benefit of observing practicing K-12 teachers in the Spring (SD=3, NC=1, SI=0). Participants also commonly identified the opportunity to interact and collaborate with other teachers (including other graduate students, faculty members, and their mentors) regarding their teaching as important in their development (Fall - SD=0, NC=2, SI=2; Spring – SD=1, NC=0,SI=1). Participants also commonly reported learning how to teach through trial and error in the fall (SD=1, NC=0, SI=2). A Chi-square was conducted for each of these themes. The only significant difference between the 3 groups of participants occurred for observing K-12 teachers, $X^2(2) = 6.650$, $p=.036$.

In terms of participants' beliefs regarding inquiry teaching, participants in all 3 groups commonly talked about the teacher setting up a thought provoking activity in order to guide students' discussions and investigations (SD=1, NC=2, SI=4) and discussed the importance of allowing students time to explore ideas and construct their own knowledge, (SD=2, NC=3, SI=4), however, SI participants talked about these issues slightly more frequently. Participants also frequently identified that inquiry teaching involves asking students questions about a given topic (SD=3, NC=2, SI=3), however, NC and SI participants more often described inquiry teaching as encouraging their students to develop their own research questions (SD=0, NC=2, SI=2). SI participants also more commonly reported that, in their view, teachers should provide time for their students to discuss or interpret their findings as a class (SD=1, NC=1, SI=3). A Chi-square was conducted for each of these themes and there were no significant differences between the 3 groups.

When asked how they would deal with a lab in which students found unexpected results, participants in all groups commonly reported that they would encourage their students to replicate the experiment (SD=2, NC=3, SI=3), that they would invite their students to discuss differences in the conditions under which the study was conducted or the method by which the data was obtained (SD=1, NC=2, SI=2), and that they would explain that experimentation includes measurement error (SD=2, NC=3, SI=3). The most notable difference between the groups was that SI participants more often identified (SD=2, NC=1, SI=5) that they would encourage their students to generate a hypothesis that could explain the discrepancy. Fewer participants reported that they would determine the reason for the unexpected results and explain this to their students (SD=1, NC=2, SI=1). A Chi-square was conducted for each of these themes and there were no significant differences between the 3 groups.

SI participants and their advisors commonly identified (n=4) that they met regularly with each other regarding the participants' teaching while no NCs and only 1 SD reported this experience. Additionally advisors of SI participants were more frequently (SD=2, NC=4, SI=6) coded as being highly knowledge about the participant that they advise including knowing about the participants' teaching (e.g. teaching activities, identity, and skills), research, and personal life. A Chi-square revealed, however, that differences in terms of mentoring between the 3 groups were not significant.

## Discussion

Overall, participants whose inquiry-related teaching skills increased generally had a moderate level of prior teaching experience. This may be explained, in part, by models of teacher development (e.g. Fuller & Bown, 1975; Zuljan, 2007) which indicate that teachers may need to acquire basic teaching skills and a sense of confidence before engaging in student-oriented teaching practices.

This study also provided some information about important beliefs and experiences of STEM graduate students that may explain why these graduate students improved in their ability to facilitate student inquiry.  Specifically, participants who reported frequently interacting with their peers and non-mentoring faculty regarding their teaching were more likely to show gains in their inquiry-based teaching skills. The role of peers in the development of GTAs teaching skills has rarely been investigated (but see Austin, 2002; Puccio, 1988). Given this evidence, it warrants further attention in future studies.

Results from this study also emphasize the importance of graduate students recognizing the value of encouraging their students to develop their *own* research questions as opposed to posing questions to students. This is an important insight in implementing inquiry-based teaching as, “Helping students identify a question produces significant improvement in the remaining phases of inquiry,” (as cited in Kuhn & Pease, 2008, p. 516).

As Murray and Mike (1999) noted, when unexpected results arise during experimentation, it represents a learning opportunity. Participants who showed gains in inquiry teaching skills in this study were more likely to view unexpected results in this manner. Specifically, when their students achieve unexpected results, they believed they should encourage them to find the reason why the result was obtained rather than determining the reason themselves and providing their students with this explanation. Thus participants who improved their inquiry-related teaching skills recognized that when learners achieve unexpected results, this is a valuable experience that can be used to promote students’ critical thinking.

This study also showed that graduate students who had advisors who were knowledgeable about them and were involved in their teaching were more likely to make gains in their inquiry based teaching skills. This supports previous research (e.g. Boyle & Boice, 1998) which indicates that mentors play an important role in the development of graduate students’ teaching skills.

## Conclusion

Overall this study contributes to knowledge about how graduate students learn to use inquiry-based teaching methods. This study provides support for programs which provide opportunities for graduate students to interact regularly with their mentors, graduate student peers, and other faculty members and teachers regarding their teaching. Information gained from this study can be used to create professional development opportunities and programs, such as the GK-12 and Pi programs, that address graduate students' experiences and beliefs.

## References


Aldridge, J., Fraser, B.J., & Huang, T.-C. (1999). Investigating classroom environments in Taiwan and Australia with multiple research methods. *Journal of Educational Research,* 93, 48-57.

Allen, D., & Fraser, B.J. (2002). *Parent and Student Perceptions of the Classroom Learning Environment and Its Influence on Student Outcomes*. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Allinder, R.M. (1994). The relationship between efficacy and the instructional practices of special education teachers and consultants. *Teacher education and special education, 17*(2), 86-95.

Badley,G. (2002). A really useful link between teaching and research. *Teaching and Higher Education, 7*(4), 443-455.

Boice, R. (1996). First-order principles for college teachers: Ten basic ways to improve the teaching process. Bolton, MA: Anker Publishing.

Boyle, P. & Boice, B. (1998). Systematic mentoring for new faculty teachers and graduate teaching assistants. *Innovative Higher Education, 22*(3), 157-179.

Bullough, R.V. (1991). Exploring personal teaching metaphors in preservice teacher education. *Journal of Teacher Education, 42*(1), 43-51.

Carroll, J.G. (1980). Effects of training programs for university teaching assistants: A review of empirical research. *The Journal of Higher Education, 51*(2), 167-183.

Chionh, Y.H. & Fraser, B.J. (1998, April 1998). *Validation of the 'What is Happening in this Class' questionnaire.* Paper presented at the Annual meeting of the National Association for Research in Science Teaching, San Diego, CA.

Council of Graduate Schools. (2009). http://www.phdcompletion.org/information/Executive_Summary_Exit_Surveys_Book_III.pdf

Dharmadasa, I. (1999). Preservice and inservice teachers perceptions of skills in science teaching for primary grades. Paper presented at the Mid-South Educational Research Association, Pt. Clear, Alabama. (ERIC Document Reproduction Service No. ED 436 499). Retrieved from http://www.eric.ed.gov/

Eraut, M. (1985). Knowledge creation and knowledge use in professional contexts.

*Studies in Higher Education.*, *10*, 117-133.
Feldman, A., Divoll, K., & Rogan-Klyve, A. (2009). Research education of new scientists: Implications for science teacher education. *Journal of Research in Science Teaching, 46*(4), 442-459.
Fraser, B. J. (2002). Learning environments research: Yesterday, today and tomorrow. In S. C. Goh & M. S. Khine (Eds.), Studies in educational learning environments: An international perspective. Singapore: World Scientific Publishing.
Fuller, F.F. and Bown, O.H. (1975). Becoming a teacher. In K. Ryan (Ed.), *Teacher education 74th yearbook of the National Society for the Study of Education, part II* (pp. 25-52). Chicago: University of Chicago Press
Gibson, S. & Dembo, M.H. (1984). Teacher efficacy: A construct validation. *Journal of Educational Psychology, 78*(4), 569-582.
Golde, C. M. & Dore, T.M. (2001). "At Cross Purposes: What the experiences of doctoral students reveal about doctoral education." Report prepared for The Pew Charitable Trusts, Philadelphia, PA. Retrieved online from www.phd-survey.org
Golde, C. M. and Dore, T. M. (2004). "The Survey of Doctoral Education and Career Preparation: The Importance of Disciplinary Contexts," in Path to the Professoriate: Strategies for Enriching the Preparation of Future Faculty, Donald H. Wulff, Ann E. Austin, & Associates, eds. San Francisco: Jossey-Bass.
Goodman (1988). Constructing a practical philosophy of teaching: A study of preservice teachers' professional perspectives. *Teaching and Teacher Education, 4*, 121-137.
Haney, J.J.. & McArthur, J. (2002). Four case studies of prospective science teachers' beliefs concerning constructivist teaching practices. *Science Education*, 86(6), 783-802.
Hollingsworth, S. (1989). Prior beliefs and cognitive change in learning to teach. *American Educational Research Journal, 26*(2), 160-189.
Huang, T.-C., Fraser, B.J., & Aldridge, J.M. (1998, April 1998). *Combining Quantitative and Qualitative Approaches in Studying Classroom Climate in Taiwan and Australia*. Paper presented at the Annual meeting of the National Association for Research in Science Teaching, San Diego, CA.
Irish Universities Association. (2008). Irish universities graduate student skills statement. Retrieved from http://www.iua.ie/iua-activities/documents/SkillsStatementiteration28-05-2008.doc in July, 2009.
Kuhn, D., & Pease, M. (2008). What needs to develop in the development of inquiry skills? *Cognition and Instruction*, 26, 512-559.
Lee, S.S.U., & Fraser B.J. (2000, June 29-July 1, 2000). *The Constructivist Learning Environment of Science Classrooms in Korea.* Paper presented at the Annual meeting of the Australian Science Education Research Association, Fremantle, Western Australia.
Lieberman, A. (1987). *Documenting professional practice: The vignette as a qualitative tool.* Paper presented at the annual meeting of the American Educational Research Association, Washington DC. (Retrieved from ERIC Document Reproduction Service ED 287 866).
Lortie, D.C. (1975). Schoolteacher: A sociological perspective. Chicago, IL: University of Chicago Press.
Luehmann, A.L. (2007). Identity Development as a Lens to Science Teacher Preparation. *Science Education*, *91*(5), 822-839.

Martin, G.A. & Double, J.M. (1998). Developing higher education teaching skills through peer observation and collaborative reflection. *Innovations in Education and Training International, 35* (2), 161-170.

MacIsaac, D., & Falconer, K. (2002). Reforming physics instruction via RTOP. *The Physics Teacher, 40,* 479-485.

Marshall, J.C., Horton, R., Igo, B.I., & Switzer, D.M. (2009). K-12 science and mathematics teachers' beliefs about and use of inquiry in the classroom. *International Journal of Science and Mathematics Education*, 7, 575-596.

Mewborn, D.S. & Tyminksi, A. M. (2006). Lotrie's apprenticeship of observation revisited. *For the Learning of Mathematics, 26*(3), 30-33.

Mitchell, J., Levine, R., Gonzalez, R., Bitter, C., Webb, N. & White, P. (2003). *Evaluation of the National Science Foundation Graduate Teaching Fellows in K-12Eeducation (GK-12) Program.* Paper presented at the American Education Research Association, Chicago, IL, April, 2003.

McClure, R., Johnson, B., & Jackson, D. (2003). Assessing the Effectiveness of a Student-Centered College Classroom.

McClure, R., Johnson, B., Jackson, D., & Hoff, J. (2000). Assessing the Constructivist Classroom (pp.17): ERIC, Resources in Education (RIE), Accession Number ED443459.

Murray, J.S. & Mike, S.U. (1999). What to do when the mice die: Turning a lab wreck into a productive learning experience. *American Biology Teacher, 61*(9), 655-661.

National Research Council. (1996). National Science Education Standards, Washington, DC: National Academy Press.

National Science Foundation (2009). *NSF Graduate Teaching Fellows in K-12 Education (GK 12)*, retrieved June 10, 2009 from http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5472&org=NSF

Pickett, L.H., & Fraser, B.J. (2002, April 2002). *The Role of Learning Environment, Achievement, and Student and Teacher Attitudes in a Science Mentoring Program for Beginning Elementary School Teachers.* Paper presented at the Annual meeting of the America Educational Research Association, San Diego, CA.

Prieto, L.R. & Meyers, S. A. (1999). Effects of training and supervision on the self-efficacy of psychology graduate teaching assistants. *Teaching of Psychology, 26*(4), 264-266.

Puccio, P. (1988). Graduate instructor representation in writing programs: Building communities through peer support. Paper presented at the annual meeting of the Conference on College Composition and Communication, St. Louis, Missouri. (ERIC Document Reproduction Service No. ED 297 333). Retrieved from http://www.eric.ed.gov/

Richardson, G.M. & Liang, L.L. (2008). The use of inquiry in the development of preservice teacher efficacy in mathematics and science. *Journal of Elementary Science Education, 20*(1), 1-15.

Schroeder, C.M., Scott, T.P, Tolson, H., Huang, T, Lee, Y. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching, 44*(10), 1436-1460.

Selden, A. & Selden, J. (1997). Preservice teacher's conceptions of mathematics and how to teach it. Retrieved from http://www.maa.org/t_and_l/sampler/rs_3.html on November 2, 2009.

Shymansky, J.A., Kyle, W.C. Alport, J.M. (1983). The effects of new science curricula on student performance. *Journal of Research in Science Teaching*, *20*(5), 387-404.

Spinner, H., & Fraser, B.J. (2002). *Evaluation of an Innovative Mathematics Program in Terms of Classroom Environment, Student Attitudes, and Conceptual Development.* Paper presented at the Annual meeting of the American Educational Research Association, New Orleans, LA.

Spradley, J.P. (1980). *Participant Observation.* Hartcourt College Pubishers: Fort Worth.

Taylor, P.C., Fraser, B.J., & Fisher, D.L. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research*, 27, 293-302.

Tschannen-Moran, M. & Hoy, A. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education*, *17*(7), 783-805.

Windschitl, M. (2000). *Preservice science teachers and the independent inquiry experience.* Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA. (Retrieved from ERIC Document Reproduction Service ED 441 703)

Zuljan, M.V. (2007). Students conceptions of knowledge, the role of the teacher and the learner as important factors in a didactic school reform. *Educational Studies,* *33*(1), 29-40.