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MULTILEVEL ANALYSIS OF FIFTH GRADE TEACHER QUALIFICATIONS
AND THEIR STUDENTS' SCIENCE ACHIEVEMENT

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Bachelor of Science in Biology

Cleveland State University

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degree

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at the

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2014

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NIGEL NOLL

ABSTRACT

The No Child Left Behind Act mandated every student be taught by a highly qualified teacher (HQT). Criteria to determine if teachers meet the HQT mandate fail to account for differences in grade levels, subject areas, and student demographics. This study posited that the relationship between measures of teacher quality and student achievement vary according to contextual factors.

Fifth grade is unique in that it marks students' transition from upper elementary to middle school grade levels; thus, fifth grade may be classified as either an upper elementary grade or middle grade. This classification determines HQT requirements; specifically, classification affects the level of content knowledge teachers must demonstrate to satisfy the HQT mandate. Middle level teachers are specialists and required to demonstrate content knowledge (CK) in the subjects they teach. However, the relationship between teachers' level of content knowledge and fifth grade student science achievement is poorly understood.

This study examined measures of teachers' qualifications as predictors of average student achievement. In addition, examination of gender and socioeconomic status (SES) explored how teacher qualifications differentially impact various student subgroups and impact achievement gaps.

A multilevel analysis examined student gender and SES as level-1 predictors of science achievement; aggregated teacher characteristics at level-2 predicted changes in gender and SES achievement gaps.

Findings revealed teacher qualifications that predicted fifth grade science achievement differed from qualifications that predict student achievement in other subject areas. Teachers' time spent at professional development and level of job enjoyment significantly predicted changes in student science achievement. The relationship between professional develop and achievement implicated the need for fifth grade teachers to possess content knowledge. The unanticipated finding of a strong correlation between teachers' job enjoyment and student achievement evidenced a teacher characteristic that warrants future research.

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CHAPTER I

INTRODUCTION

Measures of teacher quality are often based on what Harris refers to as “pieces of paper teachers hold—mostly before they enter the classroom” (2011, p. 19). These measures used to evaluate teacher quality are not based on direct measures of teachers’ abilities to increase student performance, many times bearing no relation to student achievement whatsoever. These pieces of paper—certifications, postsecondary education, documentation of professional development, and years of teaching experience—weakly predict teacher quality (Harris, 2011; Huang & Moon, 2009). However, the efficacies of these measures of teacher quality vary by grade level and content being

taught. Consequently some of these paper-based measures of teacher quality retain their merit in delimited settings and in delimited contexts.

Because the efficacies of paper-based determinations of teacher quality depend on contextual factors, policy makers and researchers need to exercise caution when attempting to generalize characteristics of effective teachers in one setting to a larger population of teachers. A set of teacher characteristics identified as indicators of teacher quality in suburban settings do not necessarily translate in to higher student achievement in urban settings. Likewise, this lack in transferability applies to socioeconomic status, gender, and racial achievement gaps (Blank, 2013; Bolshakova, Johnson, & Czerniak, 2011; Johnson, 2009). Simply put, one size does not fit all.

Researchers demonstrated an unquestionable need to address achievement gaps early in children's schooling. Achievement gaps emerge early on in elementary school (Chapin, 2006; Sack, Trundle, Bell, & O'Connell, 2011). These early achievement gaps, if not remediated, compound over the course of students' schooling and continue to increase through high school (Bolshakova et al., 2011). Fortunately, a quality education narrows these achievement

gaps, and quality teachers are vital for the narrowing of achievement gaps (Johnson, Kahle, & Fargo, 2006; Johnson, 2009; Kanter & Konstantopoulos, 2010). Because of the indispensable role of teachers, researchers must identify characteristics of quality teachers with a focus on contextual factors.

The Problem

Policy makers attempted, though unsuccessfully, to define characteristics of quality teachers (Lewis & Young, 2013). The No Child Left Behind Act, passed in 2001, mandated that every student receive instruction from a highly qualified teacher (HQT). As of yet, no universally accepted set of standards clearly and concretely delineates a definition of highly qualified teacher nor delineates a means of assessing whether or not teachers satisfy the HQT mandate (Harris, 2011; Lewis & Young, 2013; Marx & Harris, 2006). Much of the focus on assessing HQT centered on teacher preparation programs and teacher certifications. Among the most prevalent points of contention in establishing HQT requirements remains the need for teachers to develop content knowledge in the subject matter they teach.

Methods for determining HQT status routinely proved both controversial and ambiguous, with HQT requirements varying greatly by state (Lewis & Young, 2013; Marx & Harris, 2006). However, there exist some generalizable consistencies across states' methods of assessing HQT status. All teachers must possess valid certifications in the state in which they teach. Elementary teachers must attain certification in elementary education, and secondary teachers must attain certification in secondary education plus certification in the content area that they teach. While these requirements at the elementary and secondary levels appear seemingly straightforward, requirements for certification at the middle school level remains less well defined. The nebulous certifying and classifying of middle school teachers resulted in some states certifying middle school teachers with secondary level certifications while others certify these teachers as elementary teachers. Moreover, issuing of middle level teaching certifications added another dimension to the ambiguity. Middle level teachers must possess subject matter knowledge (Bolyard & Moyer-Packenham, 2008), but interpretations of this requirement vary greatly across states (Neill, 2006). Often, middle school teachers possess less content knowledge than that required of secondary teachers, but

middle school teachers possess more content knowledge than that required of elementary teachers. Furthermore, classifying grades such as fifth grade, a grade level that straddles the divide between upper elementary and middle grade levels, further complicates the evaluation of teachers' qualifications (Epstein & Miller, 2011). In short, this system of certifying teachers by grade level directly impacts the level of content knowledge required to meet the HQT mandate (Epstein & Miller, 2011).

Research attempts at analyzing the relationship between paper-based qualifications and student achievement primarily focused on elementary and secondary grade levels, with less emphasis on the middle school grades. Moreover, studies at the elementary grade levels focused primarily on reading and math achievement with little attention given to science achievement. However, adoptions of new and more rigorous science academic content standards for student learning resulted in growing concern over science teacher quality (Epstein & Miller, 2011; Foster & Jasper, 2010). Increased emphasis on STEM education and increased government spending on STEM education failed to yield anticipated levels of increased student achievement

(Epstsein & Miller, 2011). Instead, achievement levels tended to stagnate.

The relationship between science teacher qualifications and student achievement at the upper elementary grade levels remains unauthenticated. This poor understanding results from lower frequency of standardized testing in science. Conversely, more frequent testing in math and reading facilitated a greater understanding of math and reading teacher qualifications. Nonetheless, research examining teacher qualifications in math and reading focused primarily on lower elementary grades and upper middle school grades.

Although researchers conducted numerous studies on elementary level teacher qualifications in the subject areas of math and reading, generalizing research findings from these content areas to science fails to account for differences between math, reading, and science education. Best instructional practices in science are not congruent with best instructional practices identified in other content areas. Because science instruction typically requires a more hands-on approach and because science requires teaching through inquiry wherein students take a distinctly active role in the construction of knowledge,

teachers must possess pedagogical knowledge unique to science education. Typically, elementary teachers possess limited science CK, impeding the implementation of effective science instruction.

The current lack in research on science teacher qualifications presents a two-fold conundrum. At the policy level, requirements for fifth grade teacher preparation vary greatly across states, and no empirical research evidences the best means of training upper elementary level teachers. This deficiency not only affects student learning, it results in wider societal economic implications because higher quality teachers increase students' lifetime earnings (Hanushek, 2011). Secondly, better teacher preparation promotes teacher retention, diminishing early career attrition.

The utter lack of focus on differences in educational settings and contexts evidences a greater problem in the HQT debate. Routinely, policy makers regarded all subject areas as the same. They failed in differentiating between school settings and student demographics. Rigid policies arbitrarily lumped grade levels into similar groupings as if discrete grade bands existed in the grade level continuum. Policy makers focused on how to best fit one

system of assessing HQT to meet the demands of all schools, all teachers, and all students. Instead, a refocusing must examine the best means of meeting the needs of all students as individuals.

The Purpose

With the intention to guide educational policy, this study identified teacher qualifications that best predicted student achievement in fifth grade science, and teacher characteristics that best predicted teachers' abilities to close achievement gaps. This study posited that characteristics of effective fifth grade science teachers differed from characteristics identified as predictors of effective teachers in other content areas and at other grade levels. Three research questions were explored:

1. Which teacher characteristics best predict fifth grade student science achievement?
2. Which teacher characteristics best predict teachers' abilities to close gender and SES fifth grade student science achievement gaps?
3. Do content specific teacher qualifications predict student science achievement in fifth grade?

The Significance

Ensuring every student receives access to qualified teachers is an amiable goal. However, as of yet, no consensus delineates what constitutes a highly qualified teacher (Lewis & Young, 2013). The No Child Left Behind Act affirmed the need for HQT, but left the states with the task of defining most HQT requirements. Consequently, HQT state policies vary greatly. As a result, a qualified teacher is not necessarily a quality teacher. To this end, this study identified teacher qualifications that corresponded with teacher quality to inform HQT educational policies. A primary purpose of this study was to investigate if predictors of science teacher quality concurred with previously found predictors of math and reading teacher quality. Thus, beyond identifying predictors of teacher quality, this study attempted to identify whether or not differences exist between what constitutes a quality science teacher and what constitutes a quality teacher in other subject areas. Findings provide insight into the task of discerning fifth grade science teacher quality. Moreover, findings guide the task of developing qualification requirements through assessing whether a uniform set of qualifications can appropriately assess the quality of all teachers of all subjects in all schools, or must differentiation allow for policies to

maximize effectiveness by accounting for differences across subjects and educational contexts.

CHAPTER II

LITERATURE REVIEW

Fifth grade is a transition year for many students. This year straddles the transition between the upper elementary school and the middle school grade levels. Thus, how to best classify fifth grade teachers resulted in differences between documents that attempted to classify this grade level. While the National Science Teacher Association (NSTA) included fifth grade in their position statement on middle level science education (NSTA, 2003), the Next Generation Science Standards positioned fifth grade standards in elementary level science (Achieve, 2013). Because of this indeterminacy, the terms upper

elementary level and middle level grades are used somewhat interchangeably.

At the elementary level, unlike secondary education, teachers often teach multiple subjects, and, consequently, must possess a breadth of generalized pedagogic and content knowledge applicable across disciplines (Alake-Tuenter, Biemans, Tobi, & Mulder, 2013). Whereas highly qualified secondary education teachers specialize in the content they teach, a truism mandated by No Child Left Behind (No Child Left Behind [NCLB], 2002), an under-emphasis on specialized content knowledge and development of content specific pedagogical knowledge typifies the elementary and middle grade levels (Bolyard & Moyer-Packenham, 2008; Epstein & Miller, 2011); interestingly, in generalizing this de-emphasis on content, requirements for teacher preparation programs and teaching certifications vary greatly from state to state (Darling-Hammond, 1999). Moreover, despite an advocated need for content specialization at the secondary level, no empirical evidence supports the need for a high degree of specialization at the elementary level (Bolyard & Moyer-Packenham, 2008). Likewise, little evidence exists to support greater effectiveness in utilizing elementary teachers in the role of cross-content

generalists. Research yielded conflicting findings. Some studies resulted in support for the elementary teacher as a content specialist (Copur, Hug, & Lubienski 2014; Goldhaber, Cowan, & Walch, 2013), and other studies found utility in training elementary teachers as generalists in elementary education (Bolyard & Moyer-Packenham; Juttner, Boone, Park, & Neuhaus, 2013). While it may seem inherently logical to develop both extensive content specific pedagogical knowledge and content knowledge in addition to generalized pedagogical knowledge on teaching at the elementary level, teacher education programs are confined by limits in the amount of total coursework that can be required of pre-service teachers (Foster & Jasper, 2010; Darling-Hammond, 1999).

Limited learning of science specific pedagogy results in lack in ability to implement best instructional practices. Researchers advocated inquiry-based science instruction (Capps & Crawford, 2013; Morrison, 2013), but teachers must possess PCK in order to teach science through inquiry. Elementary teachers poorly understand science content and science instructional strategies, thus, resulting in deficient science PCK (Appleton, 2003; Davis, Petish, & Smithey, 2006). Lack of PCK limits teachers'

understanding of inquiry-based instruction, thus leading elementary science teachers to misinterpret the purpose of inquiry-based instruction (Davis & Smithey, 2009; Kim & King, 2012). Inquiry-based instruction provides a means of conveying content and helping students develop an understanding of the nature of science; however, elementary teachers often interpret inquiry as a means of arousing student interest (Davis & Smithey, 2009). Certainly teachers must arouse student interest in science, and NSTA's position paper on middle level science education iterated this need (NSTA, 2003). However, teachers must also understand that the role of inquiry extends beyond merely facilitating student engagement; it is both a product and process of science instruction.

Time allocated for instruction compounds difficulties in delivering quality upper elementary level science instruction. As accountability policies increased the emphasis on reading and math, elementary and middle school science teachers frequently expressed concern about the amount of time allocated for science instruction (Copur-Gencturk et al., 2014; Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012). Even in grade levels subjected to state mandated high-stakes testing in science, teachers still

felt they lacked the time required to teach science due to the persistent focus on reading and math. Research found this lack of time for science prevented teachers from developing and implementing new science instructional strategies (Appleton, 2003; Copur-Gencturk et al., 2014). Further exacerbating the problem of deficient instructional time, Appleton (2003) reported that some teachers attempted to actively avoid teaching science due to their limited understanding of science content and science pedagogic strategies.

Equity

Early elementary level science education predicts students' science achievement in upper elementary grade levels (Kumtepe, Kaya, & Kumtepe, 2009). Differences in science achievement between genders and races begin to manifest in the elementary grades (Chapin, 2006; Sackes et al., 2011). Without intervention these achievement gaps continue to widen through the duration of students' schooling (Bacharach, Baumeister, & Furr, 2003). Nonetheless, middle school teachers can effectively diminish science achievement gaps through standards-based instruction (Johnson, 2009; Johnson et al., 2006).

Gender. In middle school, males significantly outperform females in science (Vijil, Combs, & Slate, 2012), and that gap continues to widen as students progress through adolescence (Neild, Farley-Ripple, & Byrnes, 2009). Interestingly, using performance based assessments to compare male and female fifth grade science achievement, Shaw and Nagashima (2009) reported that females significantly outscored males. In their discussion of these findings, Shaw and Nagashima cited the use of performance based assessments as the reason why females outperformed males. They concluded that while males perform better on traditional standardized tests, females better demonstrate their abilities when completing performance based assessments. Consequently, the type of assessment administered to students may significantly bias assessment scores.

SES. An SES achievement gap exists in fifth grade science wherein SES positively correlates with science achievement (Noble, Saurez, Rosebery, O'Conner, Warren, & Hudicourt-Barnes, 2012; Shaw & Nagashima, 2009). Attempts to diminish this gap demonstrated that no simple means exists to facilitate equity in achievement. Blank (2013) examined the implications of the amount of time spent on

science instruction per week. While he found an overall positive relationship between instructional time and achievement, the SES achievement gap persisted despite the increased overall achievement. In part, students in urban schools needed more time to achieve mastery than students attending schools in more affluent settings (Li, Klahr, & Siler, 2006). In one study, urban students required three weeks to master topics that their peers in more affluent schools mastered in two days (Li et al., 2006). Consequently, a large portion of the achievement gap resulted from a lack of content coverage in urban classrooms. Further exacerbating the achievement gap, even when low SES students possessed the requisite knowledge required to answer test questions, students frequently failed to properly apply their knowledge, providing incorrect answers (Noble et al., 2012). However, although most interventions intended to decrease the SES achievement gap proved minimally effective, project-based and inquiry-based instruction proved moderately effective (Geier et al., 2008; Kanter & Konstantopoulos, 2010; Thadani et al., 2010). Unfortunately, most students attending less affluent schools received direct didactic instruction (Thadani et al., 2010). Inquiry-based instruction requires teachers possess science PCK (Appleton, 2003; Davis et al.,

2006), but teachers teaching in primarily low SES schools tend to possess lower levels of science PCK in comparison to teachers serving in more affluent schools.

Examining the relationship between teachers and SES, Lankford, Loeb, Wyckoff (2002) reported a significant difference in teacher qualifications across varying levels of SES, with less qualified teachers teaching in schools with lower average SES. Lankford et al. attributed this uneven distribution of teacher qualifications to teacher attrition in urban schools and more experienced teachers transferring out of urban schools to move to more suburban settings. This uneven distribution remained relatively stable over a 15 year period starting in the mid 1980s. Yet, in more recent years, in some areas of the United States, this disparateness in distribution declined substantially (Boyd, Lankford, Loeb, Rockoff, & Wyckoff, 2008; DeAngelis, White, & Presley, 2010).

Measures of Science Teacher Qualifications

In general, though enigmatic, research on science teacher qualifications demonstrated several trends. Teachers' undergraduate educations impact student learning. However, graduate degrees fail to increase student achievement in science. The body of research on teacher

certifications remains inconclusive. Teachers' years of teaching experience correlates with student achievement, but only to a limited extent. In addition, well planned professional development improves science instruction.

Teachers' college coursework. Due to generalist elementary teachers teaching multiple subjects, elementary science teachers received limited content specific pedagogy coursework in their respective teacher education programs. Similarly, limited general content knowledge resulted from minimal college coursework in science (Yilmaz-Tuzun, 2008). Furthermore, when teachers were required to complete coursework in science, introductory freshmen-level content courses often satisfied this requirement (Foster & Jasper, 2010).

The lack of coursework in science content systemically pervades the population of elementary and middle level teachers. In a study of pre-service teachers, many pre-service middle school-level science teachers expressed willingness to eventually transition into teaching at the secondary level. However, these middle level pre-service teachers viewed the content course requirements for teaching at the secondary level as a significant deterrent to pursuing secondary level certification (Westerlund,

Radcliffe, Smith, Lemke, & West, 2011). Teachers' disposition towards their own learning of science content knowledge indicates a wider reaching problem. Arousing enthusiasm and interest in science determines future student science success (NSTA, 2003); however, teachers' dispositions toward their own learning of content demonstrated that some teachers lacked the interest and enthusiasm that they must instill in their students. An inability to arouse student interest leads to long-term deficits in student science achievement (Leibham, Alexander, & Johnson, 2013).

Short-term, in spite of a clear relationship between teacher coursework and student science achievement at the secondary level, no research conclusively evidenced the existence of such a relationship at the elementary level (Boyland & Moyer-Packenham, 2008). No definitive correlation between coursework in science content and student achievement exists. However directly teaching science pedagogy to pre-service teachers resulted in improved understanding of the nature of science, scientific inquiry, instructional practices, lesson planning, and the goals of science education (Davis & Smithey, 2008; Goodnough & Hung, 2009; Yilmaz-Tuzun, 2008).

Pragmatic limitations hindered researchers' attempts to study the summation of coursework completed in teacher education programs. Consequently, some researchers substituted teachers' college majors as a benchmark for analysis. A comparison of college majors to science achievement indicated that elementary teachers who possessed a degree in either science education or generalist elementary education produced higher levels of student academic achievement in comparison to other populations of teachers. The correlation between a generalist elementary education degree and academic achievement only existed at the elementary level; at the secondary level, no correlation existed between a general education degree and student science achievement. Thus, findings showed that the value of preparation in general pedagogy is greatest at lower grade levels.

Beyond the undergraduate level, research failed to demonstrate that a graduate degree resulted in increased student achievement. Examining fourth and fifth grade math and reading, researchers found no relationship between graduate degrees and student achievement (Chingos & Peterson, 2011; see also Clotfelter, Ladd, & Vigdor, 2007). Buddin and Zamarro (2009) reported that advanced degrees

resulted in no significant increase in value-added reading and math achievement scores among California elementary students. Concurring findings demonstrated no correlation between graduate degree and second grade student achievement (Huang & Moon, 2009). In another study examining secondary level student achievement, masters' degrees failed to increase student achievement, and doctoral degrees negatively correlated with student achievement—though the authors of this study noted the limitation of small sample size of teachers possessing a doctoral degree (Clotfelter, Ladd, & Vigdor, 2010).

Certification. In the NSTA's (2003) position statement on science education at the middle school level, NSTA advocated that teachers be fully qualified to teach science in their respective states. While a well intentioned recommendation, certifications vary greatly across states, and the credentials required to teach fifth grade science in one state may be very different than credentials required in another state. A survey of state departments of education illuminated this ambiguity in credentialing of fifth grade teachers (McEwin, n.d.), specifically, variations in certifications existed in grade level specializations and requirements for subject area

specializations. As a result, some state policies required fifth grade teachers possess elementary level certifications, encompassing grades as low as kindergarten; other states, such as Montana, credentialed fifth grade teachers with secondary level certifications encompassing all fifth through twelfth grades. More commonly, many states issued certifications specific to the middle school grade levels. Given variations in grade level credentialing, state policies specifying the required amount of content area specialization for fifth grade teachers also varied greatly with some states mandating teachers specialize in specific content areas while other states required no content area specialization. Additionally, alternative certifications, emergency certifications, and similar exemptions to traditionally required certifications further obscured certification requirements. Finally, increasing the abstrusity in fifth grade certifications, states differed in pre-service requirements for obtaining certifications such as requisite college coursework and teacher certification examinations (Buddin & Zamarro, 2009; Clofetter et al., 2010; Lewis & Young, 2013).

No empirical evidence delineated the most appropriate and beneficial means of certifying upper elementary and middle level teachers. Comparing elementary and secondary certifications as predictors of middle school students' math and science achievement, Neild et al. (2009) found a weak positive correlation between secondary certification and middle level student math achievement; in science, they observed a strong positive correlation between secondary certification and student achievement. Nonetheless, while research indicated a positive relationship between achievement and secondary certification, only a small sample of teachers possessed secondary certifications. Thus, future research needs to further explore the academic performance of middle school students taught by secondary certified teachers.

The linkage of secondary certification to specific content areas hallmarks the difference between elementary and secondary certifications. This linkage of secondary certifications to specified content areas may explain the increased middle school student science achievement for students taught by teachers possessing secondary certifications (Neild et al., 2009). The theory that content specialization explains this increased achievement

coincides with findings demonstrating a positive correlation between undergraduate teacher preparation in science and student achievement.

Research demonstrating teachers' need for strong content knowledge in conjunction with research on undergraduate education demonstrating teachers' need for understanding elementary pedagogy supports the need for middle school level certifications. In general, middle level certifications attempted to balance and synthesize content and pedagogical knowledge. Research on middle school level certifications demonstrated that this concatenation of content and pedagogy positively increased the likelihood of teachers engaging in best instructional practices (Mertens, Flowers, & Mulhall, 2005; White, Ross, Miller, Dever, & Jones, 2013). However, despite evidence supporting middle school certifications, some states recently enacted contrary policies. Texas expanded the state's early childhood through fourth grade certification to include fifth and sixth grades, eliminating the requirement for middle level certification to teach at these grade levels (Foster & Jasper, 2010). This change in certification allowed teachers of the middle grades to teach under elementary certifications, resulting in

teachers needing fewer undergraduate content courses in order to meet HQT status (Neill, 2006). Essentially, by teaching under an elementary certification, fifth and sixth grade teachers need only attain the CK required of an elementary teacher. Such policy shifts diminished content specific requirements needed for teachers to meet HQT status, thus reducing challenges of ensuring the staffing of a highly qualified science teacher in every classroom (Foster & Jasper, 2010; Sanchez, 2001). This redefining of HQT requirements, while perhaps unintentional, adversely affects student achievement.

In short, evidence indicates that certification impacts student achievement; however, given pragmatic research constraints, the exact nature of this relationship remains unknown.

Teaching experience. Creating dialog among experts in primary education, Alake-Tuenter et al. (2013) reported a consensus for the necessity for teachers to possess PCK in order to create and deliver inquiry-based science lessons. However, experts held lower expectations for inexperienced teachers' levels of science PCK, instead stressing the need for inexperienced teachers to possess a more generalized knowledge and skill set applicable across all subject

areas. When elementary teachers take on the role of generalists, the need to develop the knowledge required to teach multiple subjects supersedes the need to develop science specific PCK, thus relegating science PCK to develop through teaching experience.

In spite of the proposed reliance on elementary teachers' teaching experience as a primary mechanism to develop subject area PCK, research on teaching experience at the elementary level failed to empirically support this contention. In Bolyard and Moyer-Packenham's (2008) review of literature on math and science teacher quality, they found that, in general, across grade levels, years of teaching experience correlated with student achievement. However, research showed a stronger relationship between teaching experience and student achievement at the secondary level. Buddin and Zamarro (2009) noted that teaching experience corresponded with only small increases in second through fifth grade math and reading achievement. The limited, weak correlation between teaching experience and student achievement resulted from diminished returns of experience on student achievement as teachers progressed beyond their first five years of teaching (Chingos & Peterson, 2011; Kane, Rockoff, & Staiger, 2008). That is,

amount of teaching experience correlated more strongly with student academic performance during teachers' first five years of teaching, and experience beyond the first five years resulted in only negligible increases in student achievement (Clotfelter et al., 2010).

It should be noted that researchers need to exercise caution when attempting to interpret findings on teacher experience; Chingos and Peterson (2011) warned that attrition of less effective teachers may explain some of the observed correlation between experience and student achievement.

Professional development. Concurring with research on teacher preparation, enhancement of science CK served as a primary motivator for science teachers to participate in professional development (Fields, Levy, Karelitz, Martinez-Gudapakkam, & Jablonski, 2012; Zwiap & Benken, 2013). Findings on motivation for seeking science PD contrasted with motivators expressed by teachers of other subject areas; Zwiap and Benken (2013) observed that math teachers expressed less concern about developing CK when seeking out PD opportunities.

Numerous studies examined the role of PD in increasing teachers' levels of PCK (Fields et al., 2013; Goodnough &

Hung, 2009; Smith & Neale, 1989; Zwiap & Benken, 2013). On the whole, research demonstrated PD increased teachers' levels of science PCK, improving teachers' delivery of classroom instruction. In addition to instructional implications, Fields et al. (2013) found a positive relationship between teachers' professional development and students' achievement scores on high-stakes state science tests. However, despite these findings, science teachers pursued fewer PD opportunities and expressed greater pessimism than other groups of teachers when surveyed to discern teachers' perceived utility of PD (Torff & Byrnes, 2011).

Job Enjoyment

Research demonstrated teachers' levels of job enjoyment and job satisfaction directly impacted instructional practices and student learning (Bolshakova et al., 2011; Opdenakker & Damme, 2006). Job frustration hindered positive student-teacher relationships and diminished student engagement in science learning (Bolshakova et al., 2006). Furthermore, in math, job enjoyment correlated with teacher efficacy (Opdenakker & Damme, 2006); students of all ability levels received the same level of instructional support when taught by teachers

with high levels of job enjoyment, while teachers with low levels of job enjoyment disproportionately focused their attention on higher achieving students.

Because elementary teachers often teach multiple subjects, teachers' levels of enjoyment varies according to the subject being taught. Wilkins (2010) surveyed k-5 elementary teachers' to discern teachers' levels of enjoyment of teaching and teachers' favorite subjects to teach. Wilkins surveyed teachers by asking teachers to ordinally rank their favorite subjects to teach. Among fifth grade teachers, reading and then social studies received the highest rankings. Math ranked least favorite with science ranked only slightly higher, and this difference in math and science rankings failed to prove statistically significant. In addition to ranking favorite subjects to teach, teachers rated degree of enjoyment when teaching given subjects. Surprisingly, while fifth grade teachers ranked math as their least favorite subject to teach, teachers chose math as the most enjoyable subject to teach. Enjoyment of teaching science remained relatively low in comparison to other subject areas. Science consistently ranked as one of the least preferred and least enjoyable subjects to teach.

Investigating factors that contributed to lower job satisfaction ratings among science teachers, Southerland, Sowell, and Enderle (2011) found that teachers' with less CK expressed greater discontent. Moreover, the challenges of teaching a diverse set of learners contributed to teacher dissatisfaction. This source of dissatisfaction compounded in urban schools where repetitious patterns of low student achievement disenfranchised more experienced teachers (Bolshakova et al., 2011).

Synthesizing enjoyment factors to explore the SES achievement gap, a clear pattern emerges. Job dissatisfaction correlated with poorer instruction and poorer student outcomes. Teachers' CK predicted job enjoyment, and researchers found an uneven distribution of qualified teachers when comparing schools in high SES and low SES settings. Teaching experience in urban schools correlated with decreased job enjoyment, counteracting the typically observed relationship between teaching experience and increased student achievement. In summation, given the relationship between job enjoyment and student learning, job enjoyment may directly contribute to the SES achievement gap.

CHAPTER III

RESEARCH METHODOLOGY

This study examined student science and math achievement in relation to fifth grade teacher preparation and teacher qualifications. Concurrently the study explored how differences in teacher qualifications differentially impacted students of varying socioeconomic statuses and genders. For analysis, a two level hierarchical statistical model examined student demographics at level-1 and aggregated teacher characteristics as level-2 predictors of student level-1 coefficients.

Although this study centered on science teacher characteristics, two separate statistical models analyzed

both science and math achievement separately. Analysis of math education provided a means of assessing the goodness of the statistical modeling. Because of the extensive body of research on math teacher characteristics, this study attempted to replicate previous research findings on math teacher characteristics as a means of strengthening current findings. Replicating results consistent with previous research on math education provided a means of testing the validity of the statistical modeling used to analyze science teacher characteristics.

This study analyzed three components of teacher qualifications to determine efficacy in predicting student achievement: first, teachers' teaching experience; second, teachers' professional development activities; and third, teacher preparation and teachers' college education. This study examined three dimensions of teacher preparation. Exploration of undergraduate coursework investigated teachers' number of courses in elementary education and number of courses in subject specific pedagogy, thus analyzing teacher training in both general pedagogy and content area pedagogy. Additionally, the analysis evaluated content area certification. Lastly, the utility of a

graduate degree furthered exploration of teacher preparation.

In addition to teacher qualifications, this study examined frequency of instruction and teachers' levels of job enjoyment. Frequency of instruction served primarily as a control to account for differences in time spent on science instruction across schools. Job enjoyment allowed for exploration of an additional dimension of teacher characteristics.

Data Source

Data analysis used data obtained from the National Center for Education Statistics's Early Childhood Longitudinal Study of the Kindergarten Class of 1998-99 (ECLS). The ECLS study followed a cohort of kindergarten students for 9 years, collecting data over 7 waves. Researchers collected two waves of data during the kindergarten base year, one in the fall and one in the spring. Similarly, two waves of data collection ensued in the subsequent first grade school year. The final 3 waves of collection occurred in the springs of third, fifth, and eighth grades.

Cross-sectional analysis utilized the ECLS fifth grade, sixth wave, round of data collection. The ECLS fifth grade dataset included information about teachers and schools not collected during earlier waves, thus inhibiting longitudinal analysis. As the participant cohort advanced to higher grade levels, ECLS altered sampling instruments to reflect changes in schooling that occur as students progress through the higher elementary grades. As a result, direct surveying of students' science and math teachers did not begin until the fifth grade round of sampling.

In the base year of the ECLS study, sample weight calculations allowed researchers to generalize data to the national population of students, teachers, and schools. However, data collected in later rounds, including fifth grade, lacked this national generalizability due to participant attrition over the course of the study. Instead, as a result of the constraints imposed by attrition, cross-sectional sample weights for subsequent sample waves allowed for generalizability to the cohort population only.

Variables

Dependant. Science and math IRT scale scores measured science and math academic achievement.

Student-level. Using students as the unit of analysis, the HLM model incorporated the subsequent variables in the level-1 regression:

- Gender: This composite variable coded gender dichotomously such that female=0 and male=1.
- SES: This normalized continuous measure calculated SES using measures of household income, guardians' highest levels of education, and guardians' occupations.

School-level. Although this study examined teacher characteristics, limitations arising due to sample size necessitated aggregation of teacher characteristics to the school level—methodology used for aggregation is detailed in the subsequent section on the preparation of data. Using schools as the level-2 unit of analysis, the HLM model included the subsequent variables predictors of level-1 coefficients. Descriptive statistics and correlation matrices for level-2 predictors are reported in Tables I, II, and III below.

- Frequency of instruction: On the teacher questionnaire, teachers indicated the number of days per week that science or math instruction occurred. Ordinally coded responses represented: 0=never, 1=less than once per week, 2=once or twice per week, 3=three or four times a week, 4=daily.
- Workshops: Teachers reported the number of hours spent in staff development workshops during the past year. This continuous variable is content area specific. That is, science teachers reported time spent in science PD and math teachers reported time spent in math PD.
- Enjoyment: A 5-point Likert-type scale collected teachers' reported levels of enjoyment at their present teaching jobs.
- Teacher coursework: Teachers indicated the amount of college coursework completed in a given area of study. The survey instrument allowed for teachers to ordinally report number of courses taken by selecting one response, either a number 0-5 or "6+" courses (see NCES, 2005). Both hierarchical models included 2 college coursework variables, coursework in elementary education and

coursework in teaching methods in the respective content area analyzed.

- Graduate degree: This dichotomous variable indicated attainment of any graduate degree. This study did not disaggregate graduate degree by level of degree, making no distinction between masters' degrees and doctoral degrees.
- Certification: On the teacher questionnaire, teachers reported whether or not they possessed a given type of certification. The questionnaire surveyed a broad range of certification types, and the instrument permitted teachers to select multiple responses, allowing teachers to report all attained certifications. This study limited analyses to content specific certifications, analyzing science certification in conjunction with science achievement and math certification in conjunction with math achievement. Dichotomously dummy coded responses indicated yes or no to possession of a given certification.
- Veteran teacher: This variable indicated five or more years of teaching experience (0=new teacher, 1=veteran teacher). This variable was generated from teachers' reportings of total number of

years of teaching experience. In lieu of a continuous measure of total teaching experience, this dichotomous variable inhibited bias arising from a lack in linearity between total years of experience and student achievement. Several studies observed this lack in linearity, finding diminished returns in student achievement gains as years of teaching experience increased (Clotfelter, Ladd, & Vigdor, 2010; Clotfelter, Ladd, & Vgdor, 2007; Croninger et al., 2007).

Table I

Descriptive Statistics for Level-2 Variables

Teacher Qualification	Science (<i>n</i> =1268)		Math (<i>n</i> =1294)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Frequency of instruction	3.05	0.86	3.93	0.28
Workshops	6.76	13.22	10.44	17.48
Enjoy present job	3.31	0.72	3.31	0.72
Elementary courses	5.39	1.41	5.40	1.43
Content courses	2.24	1.62	2.69	1.65
Graduate degree	.43	.46	.42	.45
Content certification	.38	.44	.38	.44
Veteran teacher	.80	.36	.80	.36

Note. Content courses and content certification represent the content areas of science or math respective to the content area being analyzed.

Table II

Correlation Matrix for Science Model Predictor Variables

	1	2	3	4	5	6	7	8
1. SES								
2. Frequency of instruction	.078**							
3. Workshops	-.071*	.129**						
4. Enjoy job	.137**	.068*	0.033					
5. Elementary courses	-.078**	0.041	-0.022	0.012				
6. Content courses	-0.001	.144**	.137**	.120**	.227**			
7. Graduate degree	.105**	0.012	0.007	0.034	.127**	.161**		
8. Content certification	0.003	0.026	.069*	-.057*	0.056	.166**	.069*	
9. Veteran teacher	.101**	0.003	-0.035	.072*	.132**	.206**	.266**	.081**

Note. SES is the aggregate SES of all sample students nested within each level-2 case.
* $p < .05$. ** $p < .01$

Table III

Correlation Matrix for Math Model Predictor Variables

	1	2	3	4	5	6	7	8
1. SES								
2. Frequency of instruction	-0.03							
3. Workshops	-.079**	0.041						
4. Enjoy job	.166**	0.031	-.083**					
5. Elementary courses	-.068*	0.012	0.009	-0.027				
6. Content courses	-0.046	0.005	.158**	0.027	.287**			
7. Graduate degree	.083**	0.016	.065*	.067*	.105**	.138**		
8. Content certification	-0.007	-0.018	0.028	0	0.04	.177**	-0.027	
9. Veteran teacher	.089**	0.018	-0.024	0.04	.106**	.173**	.205**	0.028

Note. SES is the aggregate SES of all sample students nested within each level-2 case.
* $p < .05$. ** $p < .01$

Instrumentation

Academic assessment. In fifth grade, students completed academic assessments in science and math. The science assessment covered a range of science content including concepts in physical science, life science, and earth science. Likewise, the math assessment covered a diverse set of content. Converted scale scores, based on raw scores, reported student achievement using Item Response Theory (IRT) providing a more accurate measure of student ability level. IRT scale scores reported a criterion-referenced measure of achievement. Although ECLS also calculated norm-referenced and proficiency probability scores, IRT scale scores provided the most appropriate measure for cross-sectional analyses (NCES, 2009).

IRT scale scores allowed for comparison of student performance across students within a given content area. However, different scoring scales inhibited direct comparison between science achievement ($M=66.27$, $SD=14.81$) and math achievement ($M=126.34$, $SD=23.21$).

Teacher questionnaire. In each round of ECLS data collection, students' teachers completed questionnaires. The fifth grade teacher questionnaires collected two forms of data, teacher reported data on the individual student

and teacher reported data on the teacher's own personal characteristics. This current study utilized only teacher characteristic data—reported on teacher questionnaire Form B—omitting all teacher survey responses pertaining to individual students (NCES, 2005). Limiting data to teacher characteristics allowed for the use of more generalizable sample weights, diminishing the potential for bias and allowing for a greater number of student level cases nested within each school (NCES, 2009).

The ECLS fifth grade wave of data collection surveyed two teachers per student. ECLS surveyed every student's primary reading teacher surveyed and surveyed either the primary science or primary math teacher. ECLS randomly linked students to either a science teacher or a math teacher resulting in half of students linked to a science teacher and half of students linked to a math teacher. Consequently, due to this either-or method of science or math teacher linkage, this study is comprised of two separate subsamples, a subsampling of students linked to a science teacher and a subsample of students linked to a math teacher.

Data Preparation

Data preparation preceded data analysis, and preparation occurred in three stages. First, data restriction eliminated student level cases that failed to meet predefined criteria necessitated for inclusion in this study. Next, when appropriate, data recoding ensued. Finally, data were split into hierarchical levels prior to building the statistical models.

Restriction of student level cases eliminated cases not meeting predetermined criteria for inclusion in analyses. Case removal eliminated cases to those students with questionnaires completed by their corresponding science or math teachers, removing cases linked to nonrespondent teachers. Next, following the methodology used in the Croninger et al. (2007) study which similarly analyzed ECLS data to examine teacher qualifications at the first grade level, students receiving special education services were eliminated from the datasets. Additionally, the data were limited to those teachers that reported that they were a regular classroom teacher. Finally, data restriction removed cases with missing values in level-2 variables. Pairwise exclusion at the time of analysis accounted for missing values in level-1 variables.

Next, recoding of existent variables restructured variables to facilitate analysis. Elimination of missing value codes simplified missing values simply as missing. Recoding of dichotomous variables resulted in dummy values equaling 0 or 1.

Creation of new variables occurred as necessitated. Originally, ECLS collected content area certifications as two separate variables; one variable represented elementary content certification and the other represented secondary content certification. Aggregation of certification variables resulted in single variables to represent the teacher possession of any level of certification in the given content area analyzed.

Creation of the graduate degree variable consolidated a categorical variable that reported teachers' highest levels of education. The original categorical variable differentiated between level of graduate degree, making a distinction between masters degree and doctoral degree. Aggregation created a new single variable to indicate the possession of any level of graduate degree.

Finally a variable was created to represent veteran teacher status. Recoding of a continuous variable that reported total years of teaching experience resulted in

classifying teachers with five or more years of teaching experience as veteran teachers.

Lastly, data separation split level-1 and level-2 variables into 2 separate files. Level-2 variables aggregated teacher qualifications to the school building level. This aggregation, while not ideal, allowed for an increased number of students nested within each level-2 case. This method of aggregation differed from the methodology used by Croninger et al. (2007) in their analysis of a similar set of ECLS data. Croninger et al. restricted their study to teachers with at least two participating students nested within. Because of differences between data collected in earlier rounds in the ECLS study and data collected in the fifth grade wave, this method of restriction was found to be inappropriate herein because it necessitated the removal of a significant number of cases. Consequently, level-2 consisted of the composite of teacher qualifications, aggregated directly from the student level. As a result, given that the number of level-1 student cases for science and math were $n=4086$ and $n=4087$ respectively, the mean number of students nested within in each level-2 school were $M=3.22$ and $M=3.16$ respectively.

The number of level-1 cases nested within level-2 groups was relatively small, and the small within group sample sizes reduced statistical power. However, Raudenbush and Liu (2000) noted that statistical power is most vulnerable to small sample sizes at the level-2 between-groups. Furthermore, large sample sizes at level-2 mitigate the loss of power arising due to small sample sizes at level-1 (Kim, Solomon, & Zurlo, 2009). Therefore, although there was a loss of statistical power arising from the level-1 sample sizes, the reported findings still retain a degree of power.

Data Analysis

To investigate the relationship between student achievement and teacher qualifications, a nested random intercepts two level hierarchical linear model was created using HLM 7 statistical software. At level-1, student demographics predicted academic achievement. Level-2 variables modeled aggregated teacher qualifications as predictors of level-1 coefficients.

Use of hierarchical models provided several advantages over a traditional ordinary least squares analysis approach. Because each level of a multilevel analysis allowed for a different unit of analysis, a multilevel

model decreased the potential for ecological fallacies that may arise in traditional methods, a potential consequence resulting from failure to define a single unit of analysis (Teo, 2012).

For this study, analysis required the construction of two separate hierarchical models. One model measured the effect of teacher characteristic coefficients on science achievement and one model to similarly analyzed math achievement.

Level-1 model. The student-level model utilized two student characteristics, gender and SES. Inclusion of gender in the model facilitated analysis of gender achievement gaps at the school-level. The SES variable allowed for analysis of achievement differences across a normalized continuum of SES. Equation 1 and Equation 2 below provided the means for level-1 analysis. It should be noted that SES was mean centered.

$$IRT_{ij} = \beta_{0j} + \beta_{1j}(GENDER_{ij}) + \beta_{2j}(SES_{ij}) + \varepsilon_{ij} \tag{1}$$

$$Y_{ij} = \beta_{0j} + \sum_{q=1}^Q \beta_{qj} X_{qij} + \varepsilon_{ij} \tag{2}$$

Equation 2 represents a generalized form of Equation 1, where β_{qj} for $q=1,2,\dots,Q$ were coefficients of level 1 predictor q in school j . The parameter X_{qij} represented the value of the student characteristic q for student i in school j . Averaged student achievement scores in school j were represented by β_{0j} . The dependent variable in this model, Y_{ij} , was the achievement test score for student i in school j . Finally, ε_{ij} represented the random error in the equations and was assumed to be normally distributed.

Level-2 model. The school level model comprised of eight predictor variables, used as predictors of β_{0j} and β_{qj} obtained in Equation 2 in level-1 of the model. With the exception of the aggregated frequency of instruction in the given content area, all variables measured aggregated teacher characteristics. These variables assessed the relationships between students' achievement and respective teachers' qualifications. Equations 3, 4, and 5 show the modeling used at level-2.

$$\beta_{0j} = \gamma_{00} + \sum_{s=1}^S \gamma_{0s} W_{sj} + u_{0j} \tag{3}$$

$$\beta_{1j} = \gamma_{10} + \sum_{s=1}^S \gamma_{1s} W_{sj} + u_{1j} \tag{4}$$

$$\beta_{2j} = \gamma_{20} + \sum_{s=1}^S \gamma_{2s} W_{sj} + u_{2j} \tag{5}$$

$$\beta_{qj} = \gamma_{q0} + \sum_{s=1}^{S_q} \gamma_{qs} W_{sj} + u_{qj} \tag{6}$$

Equation 6 represented the condensation of Equations 3, 4, and 5. Equation 6 used vectors γ_{qs} as coefficients where $s=1,2,\dots,S$ represented level-2 teacher characteristics, and q indicated the respective level-1 coefficient. The parameter W_{sj} represented the value of teacher characteristic s in school j . This parameter, W_{sj} , predicted the coefficients β_{qj} obtained at level-1 in Equation 2. Variables u_{qj} represented the random errors. No level-2 variables were centered.

CHAPTER IV

RESULTS

This study examined the impact of teacher preparation and teacher qualifications on fifth grade student achievement in STEM content areas. Two hierarchical models, separately examined predictors' effects on student achievement and closing of achievement gaps in science and math. Ultimately, this study sought to examine the relationship between teacher qualifications and science achievement, utilizing the math education model as means for controlled comparison. Coefficients and significance levels of findings are displayed in Table IV.

Table IV

HLM Resultant Coefficients for Science and Math Predictor Variables

School Aggregate of Teacher Qualification	<u>Science</u>		<u>Math</u>	
	Coefficient	<i>p</i>	Coefficient	<i>p</i>
Intercept (β_{0j})				
Intercept (γ_{00})	45.18	<.001	146.01	<.001
Frequency of instruction (γ_{01})	1.40	.102	-6.54	.061
Workshop (γ_{02})	-0.14	.018	0.04	.583
Enjoy job (γ_{03})	2.63	.010	1.92	.228
Elementary courses (γ_{04})	0.03	.947	-2.00	.017
Content courses (γ_{05})	0.30	.507	-0.11	.897
Graduate degree (γ_{06})	-0.11	.949	0.16	.958
Content certification (γ_{07})	1.87	.267	-0.82	.779
Veteran teacher (γ_{08})	3.99	.091	7.15	.030
Gender (β_{1j})				
Intercept (γ_{10})	2.49	.572	-31.31	.023
Frequency of instruction (γ_{11})	0.52	.520	6.59	.033
Workshop (γ_{12})	0.01	.859	-0.08	.285
Enjoy job (γ_{13})	0.46	.597	1.11	.483
Elementary courses (γ_{14})	-0.54	.347	1.58	.078
Content courses (γ_{15})	-0.53	.171	0.31	.697
Graduate degree (γ_{16})	3.08	.055	4.10	.148
Content certification (γ_{17})	0.67	.652	-0.47	.866
Veteran teacher (γ_{18})	1.51	.439	-3.27	.321
SES (β_{2j})				
Intercept (γ_{20})	11.73	.003	8.81	.489
Frequency of instruction (γ_{21})	-0.16	.800	2.01	.486
Workshop (γ_{22})	0.13	<.001	0.00	.986
Enjoy job (γ_{23})	-1.77	.002	-0.92	.490
Elementary courses (γ_{24})	-0.03	.941	-0.31	.623
Content courses (γ_{25})	0.61	.069	-0.31	.581
Graduate degree (γ_{26})	-0.84	.432	1.61	.480
Content certification (γ_{27})	-0.22	.838	-2.53	.264
Veteran teacher (γ_{28})	-1.46	.343	-4.38	.086

Note. Significance $p < .1$ are in italics. Significance $p < .05$ are in boldface and italics.

Science Education

Findings attributed a large portion of the variance in science IRT scores ($\rho=.610$) to the school level. That is, aggregated teacher characteristics accounted for 61% of the total variance in test scores. This large attribution of variance to level-2 predictors supported the hypothesis that a relationship between level-2 variables and student achievement existed.

Two teacher characteristics proved to be significant predictors of the model intercept. Job enjoyment ($\gamma=2.63$, $p=.010$) corresponded with a greater intercept coefficient demonstrating that enjoyment increased average student achievement. Conversely, time spent at workshops ($\gamma=-0.14$, $p=.018$) corresponded with a decrease in average science achievement. No other variables significantly predicted the model intercept.

No teacher qualification predictors significantly affected the strength of the relationship between gender and science achievement. However, by increasing the significance level to $p<.1$, possession of a graduate degree increased the gender coefficient as a predictor of student achievement ($\gamma=3.08$, $p=.055$). Thus, these findings indicated that a graduate degree increased the gender gap in science

achievement such that males outperformed females at a greater rate.

Although teacher qualifications proved negligible in predicting changes in the gender achievement gap, the SES sub-model demonstrated that workshops and job enjoyment significantly impacted differences in achievement across the SES continuum. Figure 1 and Figure 2 show the effect of these predictors on the SES slope. Overall, the significant positive intercept coefficient ($\gamma=11.73$, $p=.003$) for the level-2 SES model demonstrated that an increase of 1 *SD* in relative SES correlated with a .79 *SD* increase in IRT scale score. The amount of time teachers' spent at workshops strengthened the relationship between SES and student achievement ($\gamma=0.13$, $p<.001$), increasing the achievement gap. Conversely, aggregated teachers' levels of job enjoyment ($\gamma=-1.77$, $p=.002$) weakened the relationship, decreasing the SES achievement gap.

With the exception of science workshops, no other content specific measure of teacher qualifications proved significant. Neither coursework in science pedagogy nor certification in science significantly impacted student achievement. However, it may be noteworthy that by expanding significance to $p<.1$, aggregated teachers'

coursework in science pedagogy significantly strengthened the relationship between SES and student achievement ($\gamma=0.61$, $p=.069$), accelerating the rate of increase in achievement as level of SES increased.

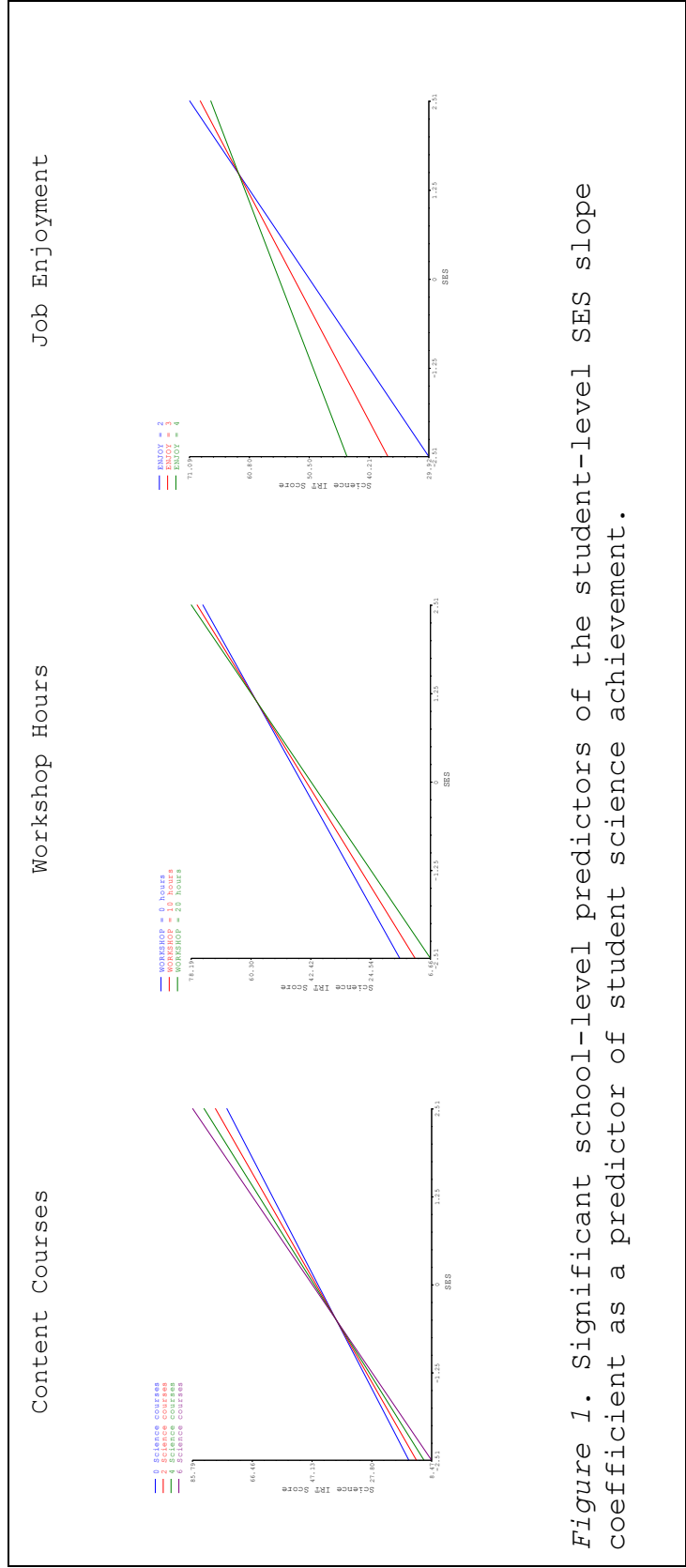


Figure 1. Significant school-level predictors of the student-level SES slope coefficient as a predictor of student science achievement.

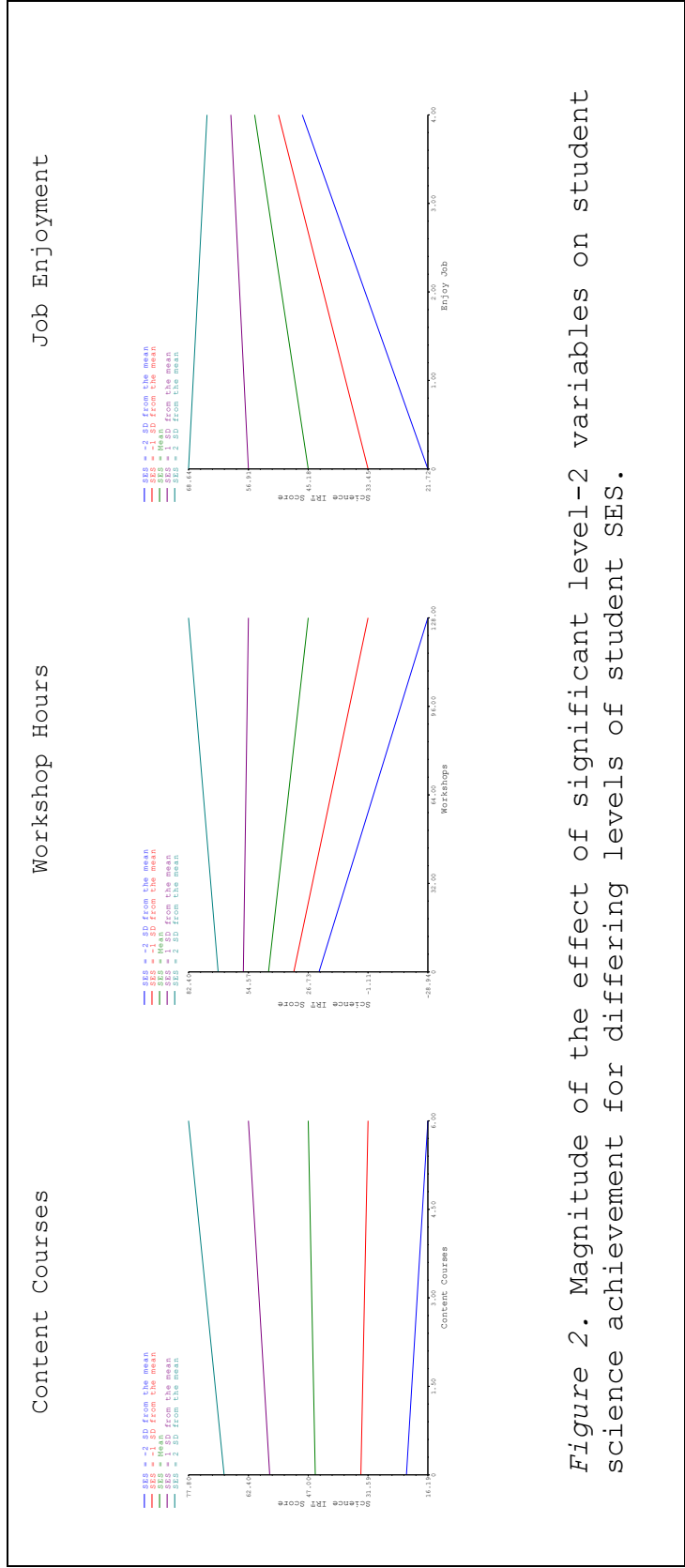


Figure 2. Magnitude of the effect of significant level-2 variables on student science achievement for differing levels of student SES.

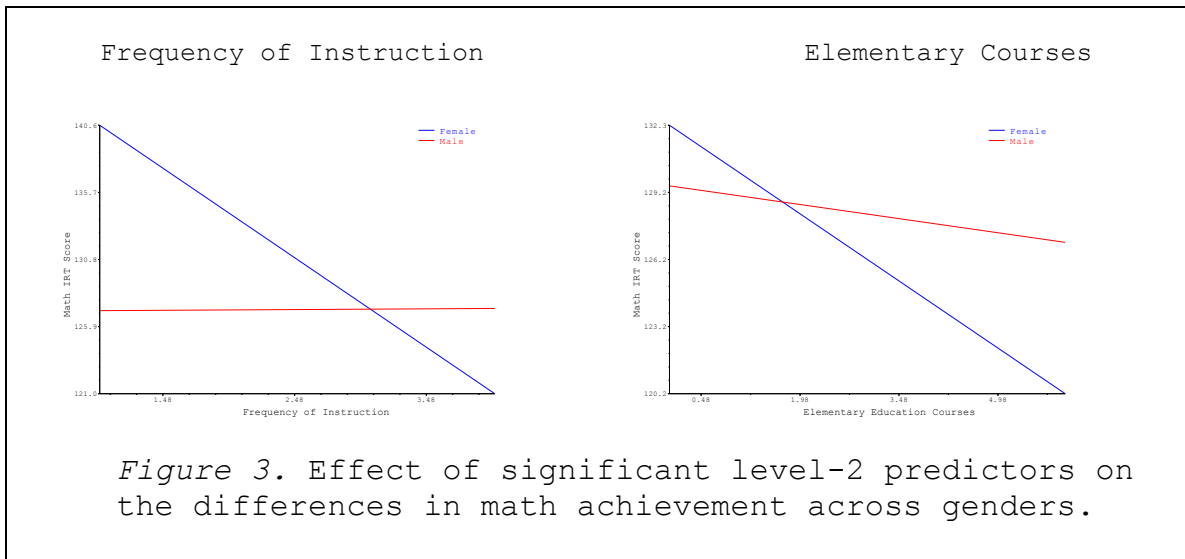
Math Education

Similar to findings for science achievement, the school level accounted for a large portion of the variance in math IRT scores ($\rho=.549$). Level-2 predictors accounted for 55% of the total variance.

Overall, the statistical model produced for math achievement yielded very different results than those found for science achievement. While time spent on workshops and job enjoyment proved significant predictors of the science achievement model intercept, neither of these variables proved significant in predicting the math model intercept. Courses in elementary education ($\gamma=-2.00$, $p=.017$) and veteran teacher status ($\gamma=7.15$, $p=.030$) significantly predicted the math model intercept. In addition, though less significant, frequency of instruction ($\gamma=-6.54$, $p=.061$) corresponded with decreased math achievement.

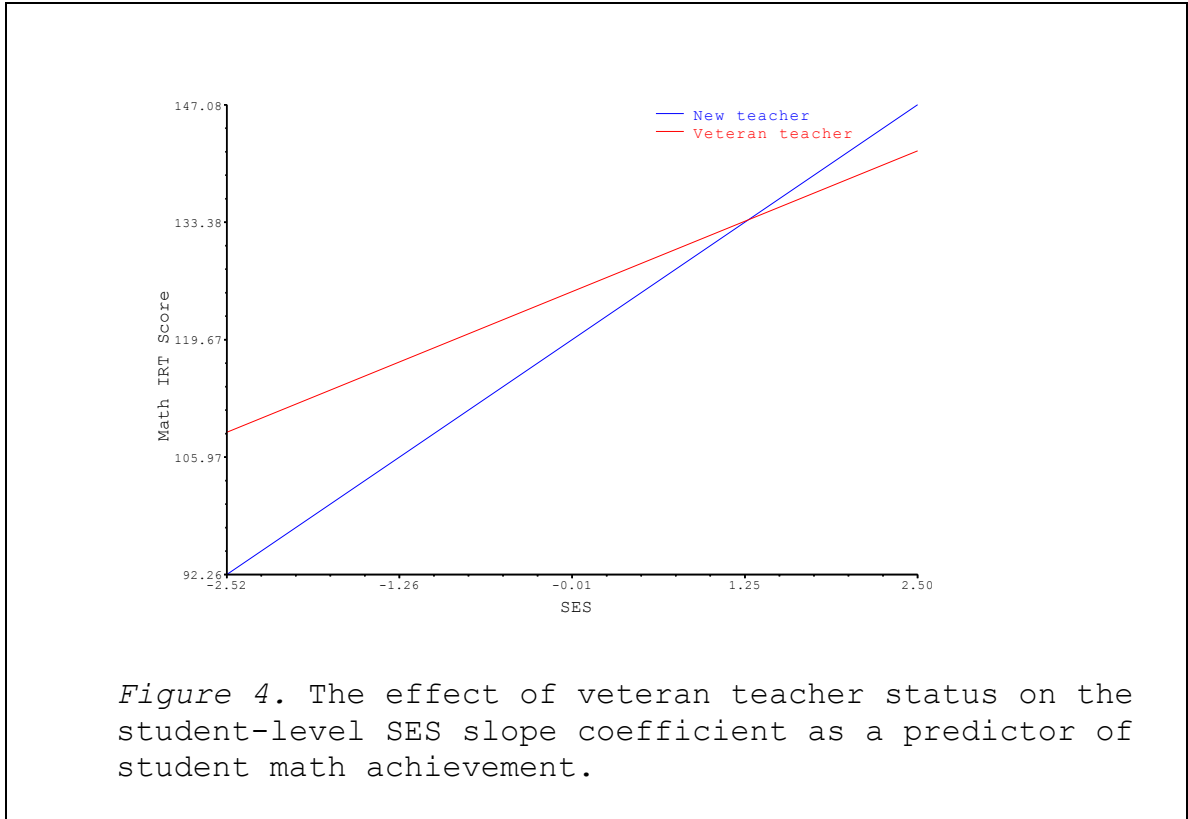
Findings demonstrated a large gender difference in math IRT score. The gender intercept coefficient ($\gamma=-31.31$, $p=.023$) indicated a significantly higher initial level of achievement for females. However, despite this initial gender difference, frequency of instruction ($\gamma=6.59$, $p=.033$) largely mitigated this difference in achievement level, see

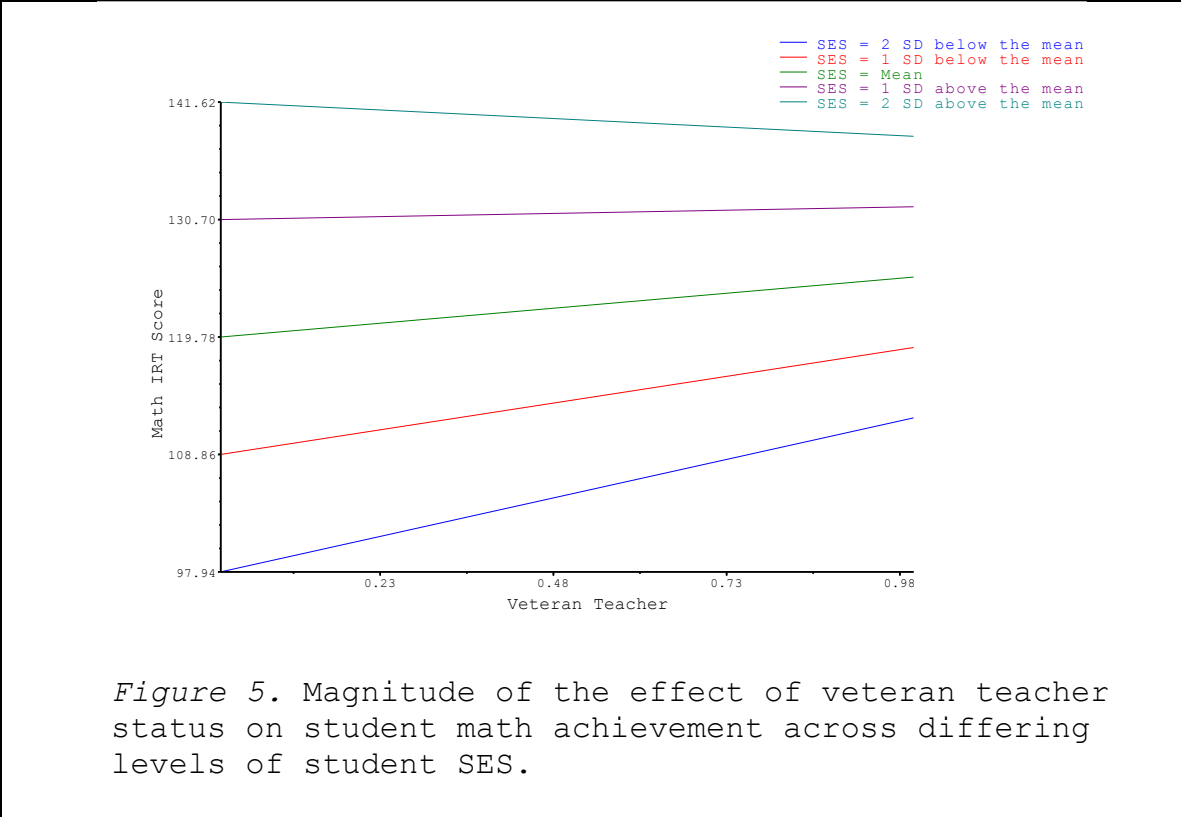
Figure 3. Number of courses in elementary education yielded a likewise, but less significant, relationship ($\gamma=1.58$, $p=.078$). Consequently, although the initial intercept showed females achieving well above males, the magnitude at which frequency of instruction and elementary education courses decreased the gender slope resulted in males outperforming females at the mean levels of instructional frequency and aggregated average number of elementary education courses.



Examining the SES achievement gap, only veteran teacher status ($\gamma=-4.38$, $p=.086$) only veteran teacher status significantly predicted the level-1 SES coefficient, and only after expanding the significance level to $p<.1$. No other SES coefficient predictors proved significant. As

shown in Figure 4 and Figure 5, experienced teachers decreased the SES achievement gap across level of SES.





Unlike the model for science achievement, time spent on workshops and level of enjoyment did *not* prove significant for any of the coefficients in the math model. Consistently math specific coursework and math certification failed to significantly predict variances in student academic achievement. In conclusion, no math content variables correlated with achievement.

Goodness of the Statistical Model

Findings for math achievement provided a means of assessing the goodness of the statistical models. Because

a large body of research explored the relationship between math teacher characteristics and student achievement, reliability of the statistical models was evidenced through producing results that concur with previous research on math education. Thus, the strength of findings on science achievement depended upon the reliability of findings on math achievement.

Findings on math achievement supported the reliability of the statistical modeling. Consistent with previous studies, five or more years of teaching experience significantly predicted increased student achievement (Chingos & Peterson, 2011; Kane et al., 2008). Moreover, understanding of general pedagogy, demonstrated by college coursework in elementary education, significantly impacted student achievement (Boyland & Moyer-Packenham, 2008). In addition, as expected, no discernible relationship existed between math content specific qualifications and student achievement (Boyland & Moyer-Packenham). Thus, findings for math achievement corresponded with findings reported in previous researcher.

However, one finding for math achievement failed to corroborate results of previous studies. The measure of time spent on math workshops failed to prove significant at

any level of the statistical model. A positive relationship between math workshops and student achievement was expected. However, failure to corroborate this expected relationship does not nullify the statistical modeling. In their synthesis of research on professional development, Scher and O'Reilly (2009) concluded that a generalized relationship between professional development and math achievement existed; however, they characterized this relationship as highly variable and greatly impacted by the type of professional development in which the teacher engages. Moreover, while Scher and O'Reilly concluded that a significant relationship existed, they also acknowledged that the magnitude of increased achievement may lack practical significance. In short, despite this unanticipated finding, the statistical models provided an accurate, reliable evaluation of teacher qualifications as predictors of student achievement.

CHAPTER V

DISCUSSION AND CONCLUSION

Discussion

The large effect that teachers have on student achievement is positive in that recruiting, hiring, and training quality teachers is a component of education that can be controlled externally by teacher education programs, school leaders, and policy makers. Findings showed schools and teachers accounted for a large portion of the variance in student achievement, sixty-one percent. This attribution of variance concurs with findings from previous studies (Kanter & Konstantopoulos, 2010; Shaw & Nagashima, 2009), and further iterates the importance of understanding

what constitutes an effective fifth grade science teacher. NCLB mandated every student be taught by a highly qualified teacher. Current findings substantiate this directive, in that quality teachers improved achievement. Consequently, knowing that teacher quality improved student outcomes, the central problem and the problem addressed in this study was what makes a teacher a high quality teacher and what criteria can be used to predict teacher quality?

Teacher characteristics. Research questions one and two sought to identify which teacher characteristics predicted fifth grade student science achievement. Findings indicated that job satisfaction and workshops significantly predicted overall mean student achievement, and teaching experience approached significance as a predictor of mean student achievement. Similarly, job satisfaction and workshops predicted changes in the SES achievement gap, and teachers' coursework in science pedagogy approached significance as a predictor of the SES achievement gap.

Job enjoyment. The most noteworthy finding in this study is the positive relationship between teachers' job enjoyment and students' science achievement. The magnitudes for the job enjoyment coefficients were greater

than the coefficient magnitudes for all other significant predictors. Previous research demonstrated that job satisfaction correlated with teachers' self-efficacy, content knowledge, years of experience, instructional practices, composition of students in the classroom, and school setting (Bolshakova et al, 2011; Opdenakker & Damme, 2006; Southerland et al., 2011). In short, job satisfaction represents a summation of teacher characteristics. Consequently, the large magnitudes of the job enjoyment coefficients corroborated that job enjoyment represents not a single teacher characteristic but rather the composite of many teacher characteristics.

Interpreting the current findings within the context of fifth grade, job enjoyment may be dependent upon the demands placed on a teacher when a teacher must take on the role of a generalist and teach multiple subjects. On the whole, generalist elementary teachers found teaching science to be less enjoyable than teaching other subjects (Wilkins, 2010), and elementary science teachers most enjoyed teaching lower elementary grade levels, expressing less interest in teaching upper elementary students (Westerlund et al., 2011). Conversely, middle school science teachers preferred teaching higher middle school

grade levels and expressed less interest in teaching upper elementary grade levels (Westerlund et al., 2011). When teachers demonstrated a lack in enthusiasm for teaching science content—in comparison to teaching other subjects—and when teachers expressed dissatisfaction with their current teaching assignments, teachers' unwittingly conveyed their lack of enthusiasm for teaching science to their students (Bolshakova et al., 2011). In turn this led to students expressing aversion towards science learning. This transference of disposition resulted in cyclical feedback wherein teachers conferred negativity to their students, and the resulting student negativity exacerbated the teacher's frustration. Teacher recruitment needs to address the need for teachers who are both interested in teaching science and interested in teaching at the upper elementary grade levels.

Enthusiasm and desire to teach science predicted the quality of instruction that students received (Bolshakova et al., 2011; Opdenakker & Damme, 2006). On the whole, teachers who enjoyed teaching science engaged students in more inquiry-based learning. Enthusiastic generalist teachers adapted instruction with the changes in subject being taught, adapting instruction to make it more student-

centered and inquiry-based when transitioning into teaching science (Bolshakova et al., 2011). Conversely, teachers with less enthusiasm for teaching science continued to teach via the instructional strategies they relied upon to teach other subjects.

Teachers' job enjoyment and enjoyment of teaching science impacted teachers' instructional strategies. Opdenakker and Damme (2006) reported that higher job satisfaction correlated with teachers implementing more student-centered instructional strategies. Students taught through inquiry demonstrated greater overall science learning than students who received more didactic instruction (Capps & Crawford, 2013; Geier et al., 2008; Mehalik et al., 2008; Morrison, 2013). Furthermore, beyond raising achievement for all students, inquiry-based instructional strategies diminished SES achievement gaps.

Current findings demonstrated a strong relationship between teachers' job enjoyment and the SES achievement gap. Typically didactic direct instruction subsumes most science instruction in low SES schools; however, less didactic inquiry-based instruction corresponded with increased student achievement in low SES schools, narrowing the SES achievement gap (Thadani, Cook, Griffis, Wise, &

Blakey, 2010). Concurring research reported similar relationships between inquiry-based instruction and race based achievement gaps and achievement differences between students in urban and suburban schools (Geier et al., 2008; Mehalik, Doppelt, & Schuun, 2008).

The implications of the relationship between instruction and teacher job enjoyment, and the subsequent relationship between instruction and achievement gaps extends beyond fifth grade. The need for inquiry-based instruction extends to all grade levels, including the lower elementary grades. Kanter and Kontantopoulos (2010) found that project-based science instruction increased minority student achievement in middle school, but project-based science corresponded with students expressing a general dislike towards science and decreased self-efficacy in their abilities to do science. The increased negative dispositions towards science resulted from lack of exposure to inquiry-based science earlier in the students' educations. Dispositions improved when students engaged in more inquiry and students became more familiar with the process of inquiry-based learning. Consequently, exposure to inquiry-based learning must occur early in the course of students' educations. To this end, early elementary

science teachers must also demonstrate competence in science instruction and enthusiasm for science.

Teachers' resiliency adds another dimension to the relationship between SES and teacher job satisfaction. A pattern of repetitious low student achievement pervades low SES urban schools, and teachers easily become demoralized when attempting to contend with chronic low achievement (Falch & Ronning, 2007). Moreover, Bolshakova et al. (2011) hypothesized:

One must wonder if the teachers rated with low sense of efficacy ... have experienced a decrease in efficacy over time as a response to the turbulence of urban schools including closing of schools, increased number of English Language Learners, large class size of over 36 students, and little encouragement to teach science as inquiry. (p. 992)

After years of teachers teaching in challenging schools, Bolshakova et al. observed more experienced urban school teachers expressed lower levels of efficacy and greater levels of frustration. Teachers most enjoy their jobs when they feel a sense of success and believe that they positively impact students. Because the challenges of teaching in a low SES school can, at times, be prostrating,

an interesting inverse relationship between teaching experience and job satisfaction emerges. While in general, at least earlier in teachers' careers, years of teaching experience correlates with increased teacher effectiveness, the inverse relationship between experience and job enjoyment observed among teachers in challenging low SES schools negates this relationship. Consequently those experienced teachers who persevere and continue to enjoy their jobs in spite of the challenges of teaching in a low SES setting, the more resilient teachers, are best capable of facilitating greater student achievement.

Given 80% of teachers in the sample population in this study were veteran teachers, the finding of a strong correlation between job enjoyment and diminished SES achievement gap supports the above teacher resilience hypothesis. Moreover, the inverse relationship between experience and job satisfaction explains why veteran teacher status predicted of overall student achievement but failed to significant predict changes in the SES achievement gap.

The finding that job enjoyment predicted student achievement raises some important questions. As policy initiatives delineating more ambitious student learning

outcomes, e.g. common core, are implemented, the impact of these initiatives on lower achieving, low SES schools must be considered. While such initiatives focus on student learning outcomes, the impact on teachers is not trivial. Teachers who already contend with chronic low achievement and students unable to attain current learning goals must now work towards meeting higher student achievement expectations. Moreover, the Race to the Top initiative enticed states to develop teacher evaluation systems that, in part, measure teacher quality via student achievement scores. While convoluted and indirect, these initiatives result in increased challenges for teachers who teach in adverse settings, in turn increasing the likelihood of lower levels of job satisfaction due to frustration stemming from overly ambitious policies.

Moreover, findings indicated an additional problem that policy makers must consider. This study attempted to identify teacher characteristics that can inform educational policy and provide insight into assessing HQT status. Job enjoyment is intangible, it is *not* paper-based, and it cannot be directly measured. However, this does not mean that job enjoyment is ineffectual. In fact, policy makers possess the direct ability to control many

contributors to teachers' job satisfaction. Job satisfaction is not a single teacher characteristic, but the summation of many components. Policy makers can provide science teachers with increased support from administrators, improved working conditions, increased autonomy, opportunities for job advancement, recognition of teachers' accomplishments, and adequate science equipment in the classroom (Anfara, 2013; Skaalvik & Skaalvik, 2011). However, this assertion clearly represents a shift in locus of control. It suggests that policy makers take on an active role in promoting teacher job satisfaction rather than passively require the submittal of documents to prove HQT status.

Nonetheless, there still persists a need to develop a mechanism to ensure every student is taught by a highly qualified teacher. Teachers' levels of job enjoyment cannot benchmark teacher quality. Because paper based measures of teacher quality such as measures of content knowledge and years of experience correlate with job satisfaction future research needs to explore if this correlation is the result of causality; are the aforementioned contributors to job satisfaction fundamental sources of job satisfaction or merely enhancers that

improve overall job satisfaction? Rather than construing job satisfaction as a sum of external factors, job satisfaction may be rooted in underlying personality traits or sets of epistemic beliefs. This distinction is important in that a mechanism to assess character traits may provide an appropriate tool to measure this facet teacher quality.

Regardless of policy implications, the finding that job enjoyment significantly contributed to teacher quality must not be underscored.

Time spent at workshops. Workshop hours corresponded with lower average student achievement. The relationship found indicated that achievement scores decreased by .14 points for every additional hour spent at science workshops. Thus, decreased scores lacked practical significance wherein the effect of workshops on achievement scores proved negligible around the mean number of hours spent at workshops ($M=6.76$). Only when teachers spend vast amounts of time at workshops, time away from their classrooms, did achievement declines become practically significant. Moreover, positive correlations (see Table II) between workshops and science coursework, between workshops and science certification, and between science

coursework and science certification signified that teachers who spent more time at workshops already possessed a rich understanding of science CK and PCK. Returns on increased teacher effectiveness from increased CK decrease as teachers build a deeper understanding of science content (Darling-Hammond, 1999).

A primary determinate of the effectiveness of workshops is the content teachers learn and the skills they develop while at the workshops. Some PD workshops focus on developing CK, some focus on developing PCK, and some focus on developing generalized pedagogic knowledge (Zwiep & Benken, 2013). This study posited that correlations between teacher characteristics and student achievement varied according to contextual factors and differences between individual teachers. Based on this hypothesis, teachers' professional needs do *not* conform to a uniformity in which all teachers need further development in the same skill sets (Southerland et al., 2011). Teachers graduate from their respective teacher education programs with a need to further develop many different instructional skills (Davis et al., 2006). While many of these skills develop as a result of experience, not all of these skills develop at the same rate. For PD to be meaningful, differentiation is

needed to ensure that teachers develop the skills that they personally need to improve upon (Southerland et al., 2011). This holds particularly true for fifth grade due to the great variance in teacher credentialing and preparation. Teachers prepared as elementary generalists and teachers prepared as science specialists differed in their dispositions towards attending PD (Torff & Byrnes, 2011). Consequently, the somewhat convoluted findings in this study were indicative of variation among teachers and variation in workshops. More time spent away from the classroom to attend workshops improves instruction only when teachers learn the skills that they personally need for improvement. For professional development, quality not quantity predicts teacher development. To this end, Davis et al. (2006), recommended future research explore the relationship between differences in teacher preparation programs and in-service teachers' PD needs.

Although a comprehensive investigation of how contextual factors shape teachers' PD needs exceeded the scope of this study, this study examined two student demographics in relation to professional development. Findings showed no relationship between PD and gender achievement gaps. However, time spent at workshops

corresponded with an increase in the SES achievement gap, accelerating the level of achievement for higher SES students. That is, teachers' time spent at workshops proved more effective in improving high SES students' achievement scores.

Interpretation of the relationship between PD and SES necessitates reiteration of the generalized differences between schools primarily serving high SES students and schools primarily serving low SES students. Teachers at schools serving low SES students, by and large, are comparatively less qualified and less experienced than teachers serving in more affluent schools (Lankford et al., 2002). In part, uneven distribution of experienced teachers results from both a high rate of teacher attrition in low SES schools and more experienced and more qualified teachers leaving urban schools to teach in suburban settings. To this end, newer teachers with fewer years of teaching experience characterize faculties at schools serving primarily low SES students. The sample used in this study concurred with this generalization, finding a positive correlation between SES and teachers identified as veteran teachers.

Novice teachers must confront a wide range of challenges when they first enter the classroom, and these challenges subsume most of novice teachers' focuses. Although early career teachers must continue to grow professionally and better develop many professional skills (Davis et al., 2006), attempting to develop new skills early in teachers' careers simply adds to the overwhelming transition to becoming a successful teacher (Southerland et al., 2011). Thus, for novice teachers, PD may be more of a hindrance, or even a source of frustration.

Nonetheless, more experienced teachers certainly benefited from PD via increasing science PCK and developing skills needed to implement project-based, inquiry-based lessons (Fields et al., 2013; Goodnough & Hung, 2009; Smith & Neale, 1989; Zwiép & Benken, 2013). The preponderance of research demonstrated that PD opportunities focused on developing CK and PCK facilitated teachers' implementation of project-based and inquiry-based instruction in the classroom, and these instructional strategies narrowed achievement gaps (Geier et al., 2008; Kanter & Konstantoppulos, 2010; Mehalik et al., 2008; Thadani et al., 2010). However, almost all studies that demonstrated the effectiveness of inquiry in narrowing achievement gaps

shared a common methodological aspect, they all provided teachers and schools with the materials and resources necessary to implement inquiry-based instruction. When teachers and schools lack facilities and resources, achievement stagnates in spite of teachers' increased knowledge. As a result, schools in more affluent settings demonstrated a stronger correlation between PD and student achievement. Moreover, deficient resources not only inhibit schools and teachers from realizing the benefits of PD, deficient resources are a source of teacher discontent (Anfara, 2013).

Again, the goal herein was identification of characteristics that predicted teachers' abilities to increase student achievement. Results demonstrated a relationship between teachers' time spent at workshops and their students' achievement. Moreover, findings implicated a correlation between teachers' PCK, instructional practices, and student achievement. However, I must caution that any policy mandating teachers engage in professional development must account for contextual factors. First, previous research demonstrated the effectiveness of PD increased with years of teaching experience. Any policy must reflect the differing needs of

novice teachers. Second, teachers need the opportunity to develop the skills that they personally need to improve. Third, in order for PD to improve instruction and learning, teachers need the resources necessary to implement inquiry-based instruction in their classrooms. Thus, as hypothesized, measures of teacher quality must account for contextual differences between schools.

Finally, I must stress that the correlation between PD and science achievement cannot be generalized to fifth grade reading and math. Science teachers increase in effectiveness through developing science content knowledge. This need for developing content knowledge does not extend to the subjects of math and reading (Zwiep & Benken, 2013).

Content specific measures of teacher quality. The third research question addressed content specific teacher qualifications as predictors of student achievement. While based on the results of this study the contention that science teachers must possess content knowledge may seem flawed given that most science specific teacher qualifications failed to prove significant, the vast majority teachers in the sample population taught for greater than five years and a significant amount of time elapsed since teachers completed their respective teacher

education programs. Because, most teachers in the sample were veteran teachers, time spent at science workshops should better predict content student achievement in comparison to other content specific teacher qualifications.

The workshops variables used in this study measured time spent at science workshops. The ECLS teacher survey explicitly asked teachers to report time spent at *science* workshops (NCES, 2005). Thus, while teachers did not report the specific skills that these workshops focused on developing, the specificity of the survey instrument along with previous research demonstrating that development of content knowledge served as the primary motivator for science teachers to seek PD opportunities (Fields et al., 2012; Zweip & Benken, 2013) confirms that workshops measured development of science specific skills.

Beyond workshops, the other two content specific teacher qualifications, certification in science and coursework in science pedagogy, failed to significantly predict student achievement. Findings indicated no relationship whatsoever between science certification and student achievement. However, college coursework in science pedagogy approached significance as a predictor of the

relationship between SES and student achievement ($p=.069$). Consistent with findings for time spent at workshops, coursework corresponded with an increase in the SES achievement gap. Thus, in spite of sample population of teachers being comprised of mostly experienced teachers, science coursework demonstrated a weak relationship with student achievement.

Failure to find any relationship between certification and student achievement results in implications for future research. This study failed to distinguish between grade level specifications of content certifications. That is no distinction was made between certifications in elementary level science, middle level science, and secondary level science. In elementary reading and math, previous research demonstrated no correlation between teachers' test scores on mandated elementary level teacher licensure tests and student achievement (Buddin and Zamarro, 2009). Conversely, secondary science certification correlated with fifth grade science achievement (Neild et al., 2009). Moreover, no research empirically demonstrated a positive relationship between middle level science certification and student achievement. To this end, future research needs to

examine the grade level specification component of science certifications.

In conclusion, the positive correlation between science workshops and student achievement along with the correlation between science coursework and student achievement supported the contention that effective fifth grade science teachers must possess science content knowledge. The finding that PD more strongly predicted student achievement than other content specific teacher qualifications concurred with Alake-Tuenter et al. (2013) who reported that many elementary science teachers developed science specific pedagogic knowledge after entering into the teaching profession. Consequently, it should be noted that teaching experience approached significance as a predictor of overall average student achievement. In short, regardless of when in teachers' careers that teachers learn science specific pedagogy, HQT fifth grade science teachers must possess an understanding of science and science pedagogy.

Conclusion

Research found that inquiry-based science instruction improved student learning outcomes. Knowledge of science PCK facilitated the delivery of inquiry-based instruction.

Job enjoyment predicted the likelihood of teachers implementing inquiry-based instruction. Moreover, science content knowledge predicted teachers' job enjoyment. The finding that teachers' job enjoyment best predicted student achievement demonstrated teachers' dispositions toward their work and their careers clearly impacted student achievement.

Fifth grade is unique. It straddles two points on the grade level continuum, straddling elementary education and middle-childhood education. Fifth grade represents a point in education where the importance of teachers understanding elementary pedagogy subsides and the need for teachers to possess science content knowledge begins to manifest. This point of transition where elementary level pedagogy and content pedagogy are both of somewhat lesser importance allows for the emergence of job satisfaction to supersede as the preeminent determining characteristic of teacher quality.

In part, job satisfaction can be described as the summation of teacher qualifications. The skills that paper based measures of teacher quality attempt to assess are all contributors to job satisfaction. But predictors of job satisfaction are not limited to teacher qualifications; job

satisfaction also encompasses the external contextual factors that characterize a teacher's job, the amount of support a teacher receives, the professionalism of the faculty, the student population, the equipment and instructional materials available, the physical space of the classroom, etc. (Anfara, 2013). Thus, while not a measurable teacher qualification, policy makers can work to enhance teacher job satisfaction in the same manner policy makers assert which pieces of paper must be submitted as proof teachers meet HQT criteria. To this end, teacher effectiveness is effectual.

Job satisfaction can be enhanced through positive initiatives, but the contrary is also true. However, in the end, job satisfaction, an enjoyment of teaching, a desire to teach science, an enthusiasm for science, a passion to be an educator, cannot be cultivated. It is an inherent characteristic that can only be enhanced or diminished. While it is true that every student deserves a qualified teacher, every student also deserves a passionate teacher.

The need for teachers to enjoy their work is not relegated to the subject of science. However, the necessity that fifth grade teachers possess sufficient

content knowledge is unique to teaching science. Research indicated that math and reading teachers do not require this background knowledge to be effective. Teaching science through inquiry is both a process and outcome of science learning, and, perhaps more importantly in the era of accountability policies, inquiry increases student achievement. Differences between science education and teaching in other content areas necessitates that science not be construed as one of the several subjects to be taught and learned. Science education must be acknowledged for what it is, science education, and educational policy makers must differentiate policies to meet differing needs.

Measures of teacher quality, pragmatic measures, must continue to assess fifth grade science teachers' science content knowledge and knowledge of science pedagogy. While professional development provides learning opportunities for in-service teachers, this study failed to indentify a universal metric that ensures all teachers satisfy the HQT mandate. In closing, the question must be raised: is there a universal single set of teacher qualifications that can measure the quality of all teachers, or all fifth grade teachers, or all fifth grade science teachers?

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