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The Effects of Teacher Education Level, Teaching Experience, And Teaching Behaviors On Student Science Achievement

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THE EFFECT OF TEACHER EDUCATION LEVEL, TEACHING EXPERIENCE, AND TEACHING BEHAVIORS ON STUDENT SCIENCE ACHIEVEMENT

by

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ABSTRACT

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Previous literature leaves us unanswered questions about whether teaching behaviors mediate the relationship between teacher education level and experience with student science achievement. This study examined this question with 655 students from sixth to eighth grade and their 12 science teachers. Student science achievements were measured at the beginning and end of 2006-2007 school year. Given the cluster sampling of students nested in classrooms, which are nested in teachers, a two-level multilevel model was employed to disentangle the effects from teacher-level and student-level factors. Several findings were discovered in this study. Science teachers possessing of advanced degrees in science or education significantly and positively influenced student science achievement. However, years of teaching experience in science did not directly influence student science achievement. A significant interaction was detected between teachers possessing an advanced degree in science or education and years of teaching science, which was inversely associated to student science achievement. Better teaching behaviors were also positively related to student achievement in science directly, as well as mediated the relationship between student science achievement and both teacher education and experience. Additionally, when examined separately, each teaching behavior variable (teacher engagement, classroom management, and teaching strategies) served as a significant intermediary between both teacher education and experience and student science achievement. The findings of this study are intended to provide insights into the importance of hiring and developing qualified teachers who are better able to help students achieve in science, as well as to direct the emphases of ongoing teacher inservice training.

(100 pages)

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INTRODUCTION

Science literacy for all citizens, a critical component to America's success in the future, is an important national goal (National Research Council, 1996; NRC). To promote student performance in science, it is important to determine which factors influence student science achievement in K-12 schools (Ye, 2000). Such an understanding will aid in the development of new interventions for influencing these factors, thus enhancing student achievement in science.

In an effort to improve student achievement, some educational research has focused on the development of highly qualified teachers (Greenwald, Hedges, & Lain, 1996; Hedge, Lain, & Greenwald, 1994). Researchers and policymakers have regarded improving teacher quality as a successful way to improve student achievement (Darling-Hammond, 2002; Greenberg, Rhodes, Ye, & Stancavage, 2004). For example, the "No Child Left Behind Act" requires that "all the teachers in core academic subjects should be highly qualified by the end of the 2005-2006 school year" (Greenberg et al., p. 1). Specifically, highly qualified teachers are required to (a) obtain full state certification, (b) have sufficient subject-matter knowledge and teaching skills, and (c) hold at least a bachelor's degree (Greenberg et al.).

Teacher education level and teacher experience, two main attributes of teacher quality, have gained attention and have been the focus of many investigations. However, results of existing meta-analytic reviews examining the relationship between student achievement and both teacher education level and experience are in conflict, with some suggesting a positive relationship and others suggesting no relationship (Goldhaber, 2004; Wenglinsky, 2002). In the area of science education specifically, only four studies investigating the relationship between these two teacher attributes and student achievement have been conducted. All four of these studies were longitudinal, focused on the 10th to 12th grades, and reached the same conclusions in that teacher experience had no effect on student science achievement. However, these same studies produced mixed results regarding the effect of the teacher holding an advanced degree on student science achievement. Therefore, further exploration of such relationships in science instruction is needed.

In addition, the degree to which the relationship between student science achievement and science teacher education level and experience is affected by classroom teacher behaviors has not been sufficiently investigated in previous research (Opdenakker & Damme, 2006). Many studies have demonstrated a link between the effect of teacher behaviors in the classroom on student achievement (for a review, see Fraser & Walberg, 2005). This link has also been found in the subject of science (Walberg, 1986; Wise & Okey, 1983). Among teacher behaviors that have been shown to lead to high student achievement are efficient classroom management skills, systematic teaching approaches, providing clear teaching goals, and using advance organizers (Fraser & Walberg, 2005; Skinner, Wellborn, & Connell 1990). As Wenglinsky (2002) has suggested, a teacher cannot be determined to be qualified by checking his or her education level, years of experience, or teaching certificate. Teachers influence students through their interactions with them, especially in the classroom. Thus, although important, teacher education level and experience only represent a portion of the ability to manage the classroom efficiently and to promote student achievement.

The existing literature, therefore, leaves two important questions unanswered: (a) To what extent does science teacher education level and experience influence student achievement in science? (b) Do science teacher behaviors mediate or moderate the effect of teacher education level and experience on student science achievement? To address these questions, this study will examine the joint effect of teacher behavior, experience, and education on student science achievement.

An examination of how teacher characteristics affect student achievement in science is important as results have the potential to provide insights into the importance of hiring and developing qualified teachers who are better able to help students achieve in science, as well as to direct the emphases of ongoing teacher inservice training (Wayne & Young, 2003). By improving our understanding in these areas, administrators, researchers, and policymakers will better understand which teacher characteristics have the greatest impact on student science achievement. This will also enable researchers and policymakers to design more effective intervention programs to influence teacher behavior.

LITERATURE REVIEW

The Need for Improvement of Student Achievement in Science

The 21st century is known as the age of knowledge, information, science, and technology (National Academy of Sciences, 1993). Future economic productivity will be tightly related to technological and scientific knowledge and skills (National Academy of Sciences). A critical component to America's success in this new millennium is to improve science competency and science literacy for all citizens, especially in facilitating science education for young students (NRC, 1996). Accordingly, the NRC established the National Science Education Standards (NRC), which provides "criteria to judge progress toward a national vision of learning and teaching science in a system that promotes excellence, and a banner around which reformers can rally" (p. 3). With the publication of this standard, K-12 school science learning, student science achievement, and science teaching in the classroom have attracted increased attention. More importantly, the implementation of these standards has been found to be effective in improving student achievement in science in K-12 schools and science teacher professional development (Johnson, Kahle, & Fargo, 2007; Kimble, Robert, & Yager, 2006). In 2002, President George W. Bush also secured passage of the "No Child Left Behind Act" (NCLB), in which improving student achievement in science has been identified as an explicit goal.

Factors Influencing Student Achievement

As the importance of achievement in science has been more widely and officially promoted, educational researchers have increased their attention on the factors that influence student achievement in science. Through study of these variables it is hoped that researchers and educators will better understand their effect on student achievement so that student achievement can be maximized as far as possible. Additionally, such an understanding has the potential to help researchers, educators, and policymakers in developing new interventions for influencing or changing these variables, thereby enhancing student achievement in science.

The factors that have been shown to influence student achievement can be categorized into three types: school-related factors, student-related factors, and teacher-related factors (Dossett & Munoz, 2003). Among these three, teacher-related factors, especially teacher quality, have generated a great deal of attention. The U.S. Department of Education has recognized that the most important factor contributing to poor student achievement may be unqualified teachers (Goldhaber, 2004). The NCLB Act states that "every child in America deserves a high-quality teacher" and "States will be accountable for ensuring that all children are taught by effective teachers" by the end of 2005-2006 school year (Goldhaber). An Education Week survey of registered voters (Education Week, 2002) determined that Americans believe improving teacher quality is the "number one way" to improve the quality of schools. The rationale behind this idea is that teacher quality is a modifiable factor. For instance, teachers may be required to demonstrate certain qualifications in order to be eligible for employment or external intervention and training programs could be required of current teachers to retain employment (Ye, 2000). Therefore, educational researchers have focused on improving teacher quality as a way to improve student performance.

Teacher experience and teacher education level have been viewed as two characteristics that are related to teacher quality. They may also be viewed as important criteria in selecting teachers, serving as proxy variables for skill level or expertise. Research on the impact of teaching experience and teacher education level on student achievement has a long history, beginning in the 1960s, of both elementary- and secondary-education teachers (Hanushek, 1997). Teacher education level refers to the highest educational degree obtained by a teacher. NCLB specifies that highly qualified teachers must have minimum of a bachelor's degree. However, because most of the teachers in the U.S. have a bachelor's degree, more recent studies have focused on whether teachers with a master's degrees or greater have a significantly greater impact on student achievement (Greenberg et al., 2004). Teacher experience is the number of years a teacher has taught. Teacher experience is a topic of potential concern to policymakers as experienced teachers have more opportunities to teach higher level or advanced classes, and thus have higher achieving students in their classrooms. Thus, it is possible that students with poor performance are more likely to have a double disadvantage because they are more likely to be taught by less experienced teachers (Greenberg et al.).

Influence of Teacher Education Level and Experience on Student Achievement

Despite the large amount of research on this topic completed to date, there is surprisingly no consistent empirical evidence supporting the link between teacher education level or experience and student achievement (Wayne & Young, 2003) as the existing studies have produced mixed findings (Goldhaber, 2004). Previous literature reviews on this topic have also yielded contradictory results (Xin, Xu, & Tatsuoka, 2004). In the following section, a systematic review of the five previous literature reviews conducted on this topic is presented.

A systematic literature search for previous literature reviews and individual studies related to teacher qualities and student achievement was conducted. Three electronic databases were searched extensively to identify articles of potential interest: (a) the ERIC via EBSCO host database, (b) PsycINFO via EBSCO Host database, and (c) Digital Dissertations. To broaden the search range, several key words: *review, teacher quality, teacher characteristics, student outcome, and student achievement*, were combined and used. In total, 155 results (109 from ERIC, 30 from PsycINFO, and 16 from Digital Dissertation databases) were obtained. After reading the abstracts, full text, and the reference lists of these studies, five systematic reviews were obtained. Four of them used meta-analytic methods and one narratively synthesized the conclusions.

These four meta-analytic reviews reached contradictory conclusions (see Appendix A) with regard to the relationship between teacher characteristics and student achievements and comprise the famous Hanushek versus Hedge debate, which is still ongoing (Xin et al., 2004). All four reviews investigated the relationship between the school inputs and student outputs from the perspective of economy; in other words, focused on the question whether more money should be spent in school in order to improve student achievements. Two reviews, conducted by Hanushek in 1989 and 1997, concluded that no strong evidence existed to suggest that teacher education and teacher experience had the expected positive effects on student achievement (Hanushek, 1989). The other two meta-analytic reviews conducted by Hedge and colleagues in 1994 and Greenwald, Hedge, and Lain in 1996 revealed that "resource variables that attempt to describe the quality of teachers (teacher education and teacher experience) show very strong relations with student achievement" (p. 384).

In both reviews conducted by Hanushek (1989, 1997), a vote-counting method was employed to synthesize the results. Vote-counting categorizes the results according to the sign (positive versus negative) and the significance (significant versus nonsignificant). Then, the category with the most entries is considered the best representation of the research findings in this area (Hedge et al., 1994). In order to avoid selection bias, he included all published studies that met two criteria: (a) those that provided reliable statistical information regarding the relationship between teacher inputs and student outcomes, and (b) those that included some student family background information as control variables. In Hanushek's first review (1989), he found that of the 113 studies investigating the relationship between teacher education level and student achievement, only eight studies (7%) showed statistically significant positive results. Similarly, of the 140 studies exploring the correlation between teacher experience and student achievement, only 40 studies (29%) showed statistically significant positive results. To minimize concerns that the study features or quality might bias the overall result, in his second review, a value-added method was employed by which different studies were given different weights according to their quality. Hanushek then reported that the vote counting method showed less statistically significant positive results. As a result, Hanushek concluded that there was no reason to believe that there is a systematic positive relationship between teacher education or teacher experience with student achievement. He further suggested that there was no need to examine effect sizes because of the small percentage of the statistically significant positive results across studies.

Hedge and colleagues (1994) reanalyzed the studies reviewed by Hanushek in 1989, and came to contradictory conclusions by using the inverse Fisher's chi-square method and combined effect size estimation methods. By testing the null hypothesis in both the positive and negative cases, they concluded that there was statistically reliable evidence suggesting a positive relationship between teacher experience and education level with student achievement, and there was no evidence of negative relationships between them. However, the median effects size for teacher experience was found to be 0.07, while the median effect size for teacher education was -0.02, which were very low. The discrepancy between the reported effect sizes and results of combined significance tests is due to the way in which the estimates were computed: the combined significance tests were based on all of the studies being reviewed; however, the calculation of median effect size were based on only the subset of studies that provided effect size estimates. Therefore, the conclusion of this review was to suggest positive effects of teacher education and experience on student achievement.

Greenwald and colleagues (1996) conducted a meta-analytic review on a more comprehensive collection of studies than Hedge and colleagues. However, they employed exactly the same two analysis methods used by Hedge and colleagues in 1994. After employing the combined significance test methodology, the general conclusion reached by this review was that teacher education and experience were systematically related to student achievement. However, the median effect sizes of these two relationships were .0003 and .046, respectively, which also were small.

The most recent review of the effect of teacher educational level on student gains was conducted by Wayne and Young (2003) by using a narrative synthesis of the individual studies. Different from the above four meta-analytic reviews, this narrative review only focused on a small number of studies. Twenty-one studies were selected according to four criteria: (a) studies that investigated the relationship between teacher characteristics and student standardized scores, (b) studies that focused on U.S. students, (c) studies that included prior student achievement, and (d) studies that accounted for student social economic status (SES). This literature review explicitly described each study, examined the study features that affected the results, and made joint interpretations on patterns of findings. The general conclusions made about the relationship between teacher education level and student achievement were: (a) in history and English, not enough empirical results were available to draw final conclusions; (b) in science, although some empirical findings were available, no final conclusion could be made and more research was necessary; and (c) in mathematics, as all determinant findings were positive, but they were all focused on high school students, with the conclusion that high school students learned more mathematics when their math teachers had an additional degree in mathematics.

Limitations of Previous Reviews

The methodologies used in the previous reviews have significant weaknesses. First, two methods used in these four meta-analysis review were *vote-counting* and the *combined significance test*. Vote-counting methods have been criticized as ignoring sample size and the magnitude of effect size, therefore, conclusions from this method can be misleading (Bangert-Drowns, 1985; Hedge et al., 1994). It has been suggested that the combined significance testing approach should only be used in conjunction with other types of meta-analytic methods, in order to produce more convincing results (Banger-Drowns).

Second, the combined effect size estimations from the two reviews were based on results from only a few studies that were able to provide useful analytical results. Thus, there is potential for biased or misleading conclusions. On the other hand, the mean effect sizes were calculated using beta coefficients. Beta cannot be viewed as a standardized effect size unless all the predictors in different regression models are exactly the same. Unfortunately, most of the studies included different predictors in their regression models. As a result, the betas obtained from different studies should not be viewed as being comparable and should be interpreted with caution.

Third, all the reviews employed the production-function approach to determine the relationship between the school inputs and student outputs from the perspective of economy, so as to explore the effects of educational expenditures on student achievement. As a result, they exclusively take teacher experience and education level as two kinds of school input variables. They also look for the general relationship between these variables and student achievement, rather than systematically investigating how the review results covary with different variables, which are:

1. Subject. There have been some suggestions within the relevant literature that such associations may exist in some academic subjects such as math, but will disappear

in other subjects such as reading (Goldhaber & Brewer, 1996). Wayne and Young (2003) also pointed out in their narrative review that the relationships between teacher education and student achievement vary across different subjects, such as math, reading, and science.

2. Teaching degree in subject. Goldhaber and Brewer (1996) suggested that the findings of the studies about the impact of teacher advanced degrees on students are inconclusive because they considered only the level of the degree rather than the subject of the degree. For example, it is possible that only science teachers who have Master's degrees in science will improve student science achievement substantially. On the other hand, science teachers with a master's degree in a subject other than science will not have great impact on student science achievement. In one study it has been shown that, when controlling for degree of subject, teachers with a math major positively contribute to student math achievement (Xin et al., 2004). In the U.S., 56% of high school students taking physical science are taught by out-of-field teachers (NRC, 2000). Therefore, it is necessary to investigate whether teachers with a higher degree in science or a relevant area, such as education, will be more effective in improving student science achievement than the teachers with a higher degree in a nonrelevant area.

3. Teaching experience in subject. None of the previous studies investigated the relationship between teaching experience in a subject, as measured by the actual number of years of teaching in that subject, with student achievement. It is possible that teachers who have more teaching experience in a certain subject will have greater impact on student achievement in that subject than those who do not. Therefore, it is important to

examine whether years of teaching experience in science or a relevant area will be significantly related to student science achievement.

4. Analysis clustering. Although the studies used student achievement on certain standardized tests as the dependent variable, they used different levels of clustering in the analyses. For instance, some studies used average student achievement in the school (school-level) as the outcome and some used average student achievement in the classroom (classroom-level) as the outcome. Other studies looked at the relationship between teacher education level and experience with individual student achievement (student- level). It is possible that the relationship existed at the classroom-level, but not at the student- or school-level. Therefore, it may not be appropriate to mix all these studies together in the same analysis to investigate the common trends among them.

Influence of Teacher Education Level and Experience on Student Achievement in Science

Over the past 20 years, only four studies have been conducted that investigated the relationship between teacher education level and years of teaching experience on student achievement in science (Goldhaber & Brewer, 1996, 2000; Monk, 1994; Ye, 2000). Three of the these four studies used data from the 1988 National Educational Longitudinal Study (NELS: 88) (Goldhaber & Brewer, 1996, 2000; Ye). The study conducted by Monk used achievement data from the Longitudinal Study of American Youth panel survey (LSAY). Both data sets are from a nationally representative survey of students in different states in the U.S. NELS:88 was conducted with approximately 24,000 8th -grade students in the spring of 1988, and LSAY was administered to 2,831

10^{th} -grade students in the fall of 1987. Follow-up surveys were also employed in both studies after 2 years.

In all four studies, student achievement was modeled as a function of teacher characteristics and student background information by using the conventional educational production-function methodology. In each, multiple regression analysis was used as the primary method to investigate the relationships between science teacher characteristics and student science achievement. Another similarity among these studies was that all of them investigated the relationship of these teacher characteristics on individual student standardized science achievement. Therefore, results across studies were comparable.

All four studies indicated that there was no relationship between teacher experience (measured by years of actual teaching at secondary level) and student science achievement. These findings implied that teachers with more years of teaching experience were no more effective than those with fewer years of teaching experience. However, all four of these studies did not measure teacher experience in terms of years in science teaching specifically, as well did not examine how this variable influenced student science achievement.

The four studies produced mixed results regarding the effects of teacher education (as measured by degree level) on student science achievement. Goldhaber and Brewer (1996, 2000) and Ye (2000) found that a teacher having a master's degree in science or education was not a statistically significant predictor of student achievement in science after controlling for other teacher demographic variables such as holding a teaching certificate. Goldhaber and Brewer reported that students taught by teachers with bachelor's degrees in science had significantly higher science achievement scores than teachers with a bachelor's degree in a nonscience subject. However, Ye did not find any significant results regarding the effectiveness of teachers with bachelor's degrees in science. In Monk's study (1994), the findings were still mixed, where a teaching degree in science influenced juniors, but had no effect on sophomores. Monk did not clarify whether these teachers' science degrees were bachelor's or master's degrees.

Influence of Teaching Behavior on Student Achievement

Research indicates that teacher effectiveness in the classroom is one of the most significant factors related to student achievement (Welsh, 2005). In 1996, the National Commission on Teaching and America's Future published a report that came to the following conclusion: "Teaching is the most important element of successful learning. Teaching quality will make the critical difference not only to the futures of individual children but to America's future as well." Almost all studies focusing on teacher effectiveness have identified teacher behaviors in the classroom as related to student outcomes. However, different researchers have different views with regard to how teacher behaviors should be conceptualized. Generally, researchers agree that classroom management skills, providing advance organizers, employing instruction strategies, demonstrating enthusiasm, and questioning are important teacher behaviors. Thus, the term *teaching behaviors* will be used in this study to refer to these characteristics collectively.

During the first half of the 20th century, researchers began to explain teaching and learning in terms of *teacher capacities*. These earliest studies focused on describing teaching behaviors, comparing different teaching methods, and observing student learning behaviors in the classroom. Some researchers concluded that different teaching approaches or teacher practices in the classroom lead to similar results in terms of student learning (Martin, 1979; Medley, 1979; Shavelson & Dempsey, 1976). In addition, these studies provided useful information about "what are good teaching behaviors" instead of "how teaching behaviors relate with student achievement" (Krichbaum, 1991). However, these studies have been criticized due to methodological problems. For instance, Good (1979) criticized the earlier efforts to examine teaching effectiveness for (a) lacking systematic observation of teacher behaviors, (b) insufficient measurement of teacher behaviors, and (c) inappropriate use of school as the unit of analysis.

Since the 1950s and 1960s, links have been made between the effects of teaching behavior on student achievement outcomes (Fraser, Walberg, Welch, & Hattie, 1987; Krichbaum, 1991; Martin, 1979). These studies were called process-product studies. The process variables refer to teaching behavior variables and the product variables are related to student achievement (Krichbaum). The process-product approach, also known as the teaching effectiveness approach, assumes that the type of approach teachers use, how teachers perform in classrooms, and how teachers interact with students will impact student learning and their achievement. Research of this kind is typically conducted in "existing classrooms which function normally during the period of observation" (Shulman, 1986, p. 10). Observers use rating scales to record teacher behavior, rather than judge or evaluate them. Prior research has used this technique to evaluate observed teaching behaviors such as classroom management (Walberg, 1986), instructional strategies (Quandahl, 2001; Slavin, 1994; Wise & Okey, 1983), questioning techniques (Redfield & Rousseau, 1980), and teacher engagement (O'Neill, 1988).

Several reviews of the literature have discussed the effect of teacher behaviors on different student outcomes (for a review, see Wang, Haertel, & Walberg, 1993). A critique of these reviews was conducted to better understand the types of teaching behaviors that are typically assumed to be indicative of teaching effectiveness, and how these behaviors are related to student outcomes. The searches included keywords related to teaching effectiveness and behaviors, such as teaching behaviors, teaching effectiveness, teaching strategies, and instruction. Searches of several electronic databases (e.g., ERIC, PsychLit, Digital Dissertations, and JSTOR) identified 18 literature reviews that were reviewed for inclusion in this critique. Half of the obtained literature reviews were meta-analytic reviews and half were narrative reviews (see Appendix B). These reviews are now discussed in turn.

O'Neill (1988) provided an extensive narrative literature review of teacher effectiveness research in which over 150 primary and secondary sources were represented. The purpose of this review was to investigate the factors related to teaching effectiveness. The factors were categorized into three clusters that represented stages of teacher interaction with students: preactive, interactive, and postactive stages of teacher instruction. The preactive stage refers to lesson planning, the interactive stage refers to classroom instruction, and the postactive stage refers to teacher response and follow-up activities. Among the 20 individual factors, those that described teaching behavior in the classroom were identified as: (a) teacher organization, (b) classroom management, (c) teacher clarity, (d) advance organizers, (e) instructional mode, (f) questioning level, (g) direct instruction, (h) time-on task, (i) variability, (j) teacher enthusiasm, (k) monitoring and pacing, (l) classroom climate, (m) teacher feedback, (n) teacher praise, and (o) teacher criticism.

The first comprehensive meta-analytic review of the effect of different teaching behaviors on student achievement was conducted by Wise and Okey (1983). This study included over 300 microfilmed dissertations covering the previous 30 years and over 2,000 ERIC abstracts and journal articles. The sample of studies selected in this review represented students from fifth grade through the early college years. This review identified 11 teaching behaviors, including questioning, wait-time, testing, focusing, manipulating (instruct students to operate, handle, or interact with physical objects), presenting approach, inquiry or discovery, audio-visual, grading, modifying, and teacher direction (different learning task explanation). A total of 400 effect size estimates, representing 160 studies, were produced. The overall standardized mean effect size on cognitive achievement was 0.34, demonstrating that, on the average, effective teaching techniques result in one third of a standard deviation achievement improvement over ineffective techniques. Among all the factors, teacher questioning and manipulative behaviors showed the most significant effects, with mean effect sizes of 0.56. The average effect sizes for the remaining behaviors ranged from 0.18 to 0.55.

Wang and colleagues (1993) conducted another comprehensive meta-analysis with the primary goal being to identify the relative effects of a wide range of teacher variables that influenced student learning outcome. They included evidence accumulated from 61 research experts, 91 meta-analyses, and 179 handbook chapters and narrative reviews. The data for this analysis represented over 11,000 bivariate relationships. In total, 228 variables were defined and grouped into 30 categories, which were represented by six theoretical constructs. One of the theoretical constructs was classroom practices, which included the subconstructs of classroom implementation support (implementation of the instruction materials or programs in classroom), classroom instruction, quantity of instruction, classroom assessment, classroom management, student and teacher social interaction, student and teacher academic interaction, and classroom climate. After transforming weighted mean correlations from different meta-analytic reviews into *z*-scores, it was found that the average *z*-score for the construct of classroom practices was 0.33, ranking as the second most important among all six theoretical constructs. Further, classroom management was found to be the most influential factor among all 30 categories ($z = 2.0$). In addition, quantity of instruction, student and teacher social and academic interaction, and classroom climate were also found to have a significant influence on student learning with *z*-scores equal to 0.37, 0.93, and 0.23, separately.

Combining all 18 reviews, a total of 15 teaching behaviors were defined and examined (see Appendix C). However, only 10 of them have been analyzed by meta-analysis and have standardized mean effect sizes reported. The remaining five behaviors have only been described and investigated in narrative reviews. The teaching behavior reviewed most often is classroom management, which was most highly associated with student achievement. Eleven out of 18 reviews suggested that the teaching behavior most related to student achievement was also classroom management. The mean effect size of questioning skills ranked second among all the 15 teaching effectiveness behaviors. Although using advance organizers showed a small effect size on student outcomes overall, it has been shown to be effective in improving student application abilities (Luiten, Ames, & Ackerson, 1980). The effect of teaching strategies has often been reviewed, but it has been shown to be less strongly associated with student achievement, its effect size reaching a magnitude of 0.28 (see Appendix C).

Classroom management has been defined as “all of the things that a teacher does to organize students, space, time, and materials so that instruction in content and student learning can take place” (Wong & Wong, 1998, cited by Chu, 2003, p. 4). Classroom management includes efficient handling of classroom routines, dealing with student behavior problems, and minimizing classroom interruptions (Anderson, Evertson, & Brophy, 1979; Emmer, Evertson, & Anderson, 1980; Evertson, Emmer, Sanford, & Clements, 1983). The mechanism by which classroom management is related to student achievement may be through (a) helping students cooperate and concentrate on learning tasks, (b) developing a positive classroom atmosphere, and (c) establishing a creative working environment. In addition, many of the process-product studies conducted to date have shown that classroom management is positively related to student achievement. For instance, Marzano, Marzano, and Pickering (2003) reported a standardized mean effect size of 0.52 from a sample of more than 100 experimental studies, suggesting a moderate positive link between classroom management and student achievement. Additionally, Walberg (1986) synthesized 15 reviews published from 1979 to 1982 and reported an effect size of 1.15, suggesting a strong link between classroom management and student achievement.

An additional teaching behavior related to effectiveness was questioning skills, which refers to using different “levels or positions of questions in instruction” (Wise &

Okey, 1983, p. 422). The importance of this teacher behavior has been identified in meta-analytic reviews by Schroeder, Scott, Tolson, Huang, and Lee (2007), Redfield and Rousseau (1980), and Wise and Okey. In these three reviews, the standardized mean effect sizes for the effects of questioning skills on student achievement were 0.74, 0.73 and 0.56, respectively, which could be considered large effect size estimates.

Lott (1983) explored another important teaching behavior in his meta-analytic review: the use of advance organizers. Thirty-nine studies spanning the period from 1957 through 1980 were examined. Results also indicated that the mean effect size for advance organizers on student knowledge was 0.09, while on student application ability measure was 0.77. The composite of these two relationships was 0.24. This finding indicates that using advance organizers, such as trying to connect new knowledge with student previous knowledge, improves students' abilities in application ability dramatically, but less effective in improving students' knowledge.

Three reviews addressed the relationship between teacher behaviors and student achievement in science in particular (Schroeder, et al., Walberg, 1984; Wise & Okey, 1983). Schroeder and colleagues synthesized 61 studies in a meta-analysis. Eight teaching strategy variables were classified in this study and six of them (manipulation, enhanced material, inquiry, enhanced content, instructional technology, collaborative learning) were closely related to particular teaching behaviors in science classrooms, such as how to teach students to do scientific experiments or activities. The largest effect size, 1.48, was for enhanced context strategies such as relating topics to previous experiences or learning and engaging students' interest in learning science. Identification of these six teaching strategies is important for understanding how teacher behaviors influence student achievement, especially in the subject of science. Wise and Okey found the overall mean effect size of all teaching behaviors on student achievement is 0.35 in general science, 0.55 in physical science, 0.25 biology, 0.22 in chemistry, 0.12 in earth science, and 0.52 in all other science areas. Walberg carried out a synthesis of teaching behaviors and student achievement in science through an investigation of 18 studies in science education. The results of this study indicated that the mean effect size of the overall quality of instruction including reinforcement, cues, and participation on student science achievement was 0.81. According to these three reviews, it can be can concluded that there is a strong relationship between teacher behavior and student science achievement.

Implications of Prior Research for Future Research

Unfortunately, our knowledge about the relationship between teacher education and experience with student achievement in science is limited by the relatively small number of studies conducted and the small number of available effect sizes available. More studies on these relationships in science education are needed. Additionally, previous research has not been consistent in whether student achievement is enhanced when the teacher has a degree in the content area. More research is needed to understand the incremental contribution of teacher education level to student science achievement.

Few of the aforementioned studies included multiple measures of student achievement. Multiple measures of student achievement would allow a better understanding of how student achievement varies with teacher-related variables. Additionally, student achievement at one time point can be used as a control variable in the relationship between teacher-related variables and student outcomes at another time point. Therefore, more longitudinal or quasilongitudinal studies should be conducted.

Additionally, none of the previous studies have appropriately modeled the clustered nature of the data. Given the cluster sampling inherent when students are nested in classrooms or by teachers, a multilevel model (i.e., hierarchical linear model, random-effects model, mixed-effects model) is needed to disentangle the components of the error term. Another significant benefit of using a multilevel model is that such techniques allow an examination of contextual factors (e.g., teacher, classroom, or school factors) on individual factors (e.g., student factors).

Finally, no previous research has investigated the interaction of teacher attributes, such as education and experience, and teacher behaviors on student achievement in science to understand whether such behaviors have a mediating or moderating role on student outcomes. The unclear conclusion concerning the relationships between teacher education level and experience with student achievement could possibly be attributed to the failure of these studies to capitalize on the importance of teaching behaviors in the classroom.

As suggested by Wenglinsky (2002), teacher education level and experience are only proxies of teacher knowledge and skills about how to teach effectively. In other words, such background teacher characteristics will influence their behaviors, which could then, in turn, affect student achievement. Therefore, it is possible that teacher education level and experience do not directly influence student achievement, occurring through the intermediating effects of teaching behaviors in the classroom.

Two studies in mathematics education have investigated the link between student achievement with teacher education and experience, while taking teacher classroom practices into account (Goldhaber & Brewer, 1996; Wenglinsky). Both studies revealed that while controlling for teaching behavior, teachers' degree in mathematics was significantly related to student math achievement. However, neither study modeled the complex interaction between teacher characteristics, teaching behaviors, and student achievement. Future studies should seek to fill this gap by including the interactions of teacher attributes with other science teaching behaviors.

Literature Review Summary

Two sections of literature review were included in this study. In the first section, the relationships between teacher education level and teacher experience with student achievement were discussed. An analysis of the previous reviews on this topic revealed that the relationships between teacher experience and education level with student achievement is still unclear, with some studies suggesting no relationship and others suggesting a small, positive relationship, especially in the subject of science education. Therefore, a final conclusion cannot yet be drawn as to whether science teachers' teaching experiences and education levels positively influence student science achievement. An important issue with regard to teacher "inputs" is what actually happens in the classroom (Goldhaber & Brewer, 1996; Lee, 2006). This includes a set of teaching behaviors, such as how the teacher conveys materials to students, how students receive this information, and the dynamic interaction between them (Goldhaber & Brewer). However, there has been little research into whether teacher behavior in the classroom is connected with teacher characteristics and whether this impacts student science learning (Wenglinsky, 2002). As a result, there is a great need to incorporate teacher behaviors into the analytical model. Additionally, as few studies have been specifically conducted in the subject of science, further studies in this area are warranted.

In the second section, the teacher behaviors most directly related to student achievement were identified from previous research. These variables are the most likely candidates to serve as mediating or moderating factors in the relationship between teacher characteristics and student science achievement. The previous reviews identified 15 teaching behavior characteristics that were predictive of student outcomes. These 15 characteristics were also categorized in three broad constructs: teacher engagement, classroom management, and teaching strategies.

A review of previous research indicates the need for more research to fill three important gaps in our current state of understanding: (a) to investigate whether the relationship between both teacher educational level and experience on student science achievement is direct or indirect, mediated by teaching behaviors; (b) to determine whether and which teaching behavior variables serve as mediators or moderators in the relationships between these two teacher attributes and student achievement in science; and (c) to employ more appropriate statistical models for the analysis of clustered or multileveled data.

OBJECTIVES

This study has two overall aims or objectives. First, to investigate the extent to which two attributes, teacher education and experience, influence middle school science achievement. Second, to explore whether a third variable or set of variables, teaching behaviors in the classroom, mediate or moderate the relationship between the two attributes and student performance in science. Therefore, four research questions will be addressed in this study: (a) whether teacher education level and years of teaching experience directly influenced student science achievement significantly; (b) whether teacher behaviors moderate the relationship between teacher attributes and student achievement in science; (c) whether teacher behaviors mediate the relationship between teacher attributes and student achievement in science; and (d) if a mediating relationship exists, whether the individual teaching behavior variables (teacher engagement, classroom management, and teaching strategies) serve as significant individual mediators.

METHOD

Procedure

This study utilized archival data collected during an evaluation of a professional development intervention study in the four middle schools (Grades 6 through 8) in a large urban school district in Utah between Fall 2005 and Spring 2008. The purpose of the original study was to investigate whether a whole-school, sustained, and collaborative professional development intervention program for middle-school science teachers was an effective way to improve student science achievement in this district. Therefore, middle-school science teachers from this district were included. In each year of the study, an evaluation team collected beginning and end of school year data on student science achievement, student demographic information, and teacher characteristics, including in-class teaching behaviors.

Only data from 2006 to 2007 school year from the original study were used in the present study (due to data restrictions from the owner of the data). Thus, data available for use in this study included: student and teacher demographic information, student science achievement, and teacher observations from the beginning of the school year and student science achievement from the end of the school year. Full Institutional Review Board approval from Utah State University was obtained for the completion of this study.

Participants

The sample in this study was comprised of 12 science teachers and 655 sixth-, seventh-, and eighth-grade students from four middle schools in a large urban school district in Utah. Basic demographic information for these schools from the 2003 – 2004 school year is presented in Table 1. Pseudonyms were used to protect the identities of individual schools, teachers and their students. See Table 2 for the number of teachers and students from each school.

Instruments

Four instruments were used to collect the data: (a) the Discovery Inquiry Test (DIT) in Science, which measured student science achievement; (b) a student demographic information questionnaire; (c) a teacher demographic information questionnaire; and (d) a teaching behaviors observation form, which evaluated teaching behaviors in the science classroom.

Discovery Inquiry Test (DIT) in Science was administrated to students at the beginning of Fall semester in 2006 and the end of Spring semester in 2007. The DIT in Science assessment was developed in 1994 by members of the Ohio Statewide Systemic Initiative academic leadership team, University science faculty members, and other Ohio science teachers. This test measured both content and process skills, including applying conceptual understanding of science, analyzing and interpreting data, and extrapolating from one situation to another situation (Kahle, Meece, & Scantlebury, 2000). The test consisted of 29 items, 11 focused on life science, 8 on physical science, 6 on both earth and space science, and 4 on the nature of science. The total number of items correct was used in the data analyses. The internal consistent reliability (Cronbach alpha) of the tests was .94, indicating a high intercorrelation among the items (Kahle et al.). This test has been validated by a national and international expert panel of science educators. Students were not allowed to use any notes or texts when taking the tests.

Table 1.

Demographic Information for Four School from the 2003-2004 School Year

Middle school	Students (*n*)	Science teachers (*n*)	Students above proficiency in science (%)	Latino student enrollment % (*n*)	Students receiving free lunch (%)
North	1051	6	54	32 (336)	56
South	661	4	39	40 (264)	68
West	724	4	34	26 (188)	69
East	595	3	15	64 (381)	66
District totals	3,031	17	38	39 (1,169)	64

Table 2

Demographic Information for the Sample

Middle school	Students (*n*)	Science teachers (*n*)	Grade
North	167	3	6 - 8
South	224	4	6 - 8
West	209	3	6 - 8
East	55	2	6 - 8
Total	655	12	

The student demographic survey was used to collect student demographic information at baseline. A substantial body of literature has indicated that male and female students differ in terms of their science achievement (Valentine, 1998). Therefore, student gender was included in this study to investigate whether it affected the relationship between teacher education level and teaching experience and their science achievement. The only other demographic information included in this study was student ethnicity, coded as White or non-White.

Teacher questionnaires were distributed to all the teachers at the beginning of the study. Variables in this survey included whether the teacher held an advanced degree (master's and above), the subject of their degree, years of teaching in K-12 classrooms, and years of teaching in K-12 science classes.

The Local Systematic Change Classroom Observation Protocol (LSCCOP) (Horizon Research, 1999) was used to evaluate the quality of science teaching behavior observed in the classroom. All 12 science teachers were observed by two raters during one randomly selected class period in September, October, and November of 2006. Both raters were PhD-level science education faculty members at a research university. The primary goal of the LSCCOP was to "measure the quality of an observed K-12 science or mathematics classroom lesson by examining the design, implementation, mathematics/science content, and culture of that lesson" (Horizon Research). All of the items on the LSCCOP were based on standards set by the National Science Education Standards for Mathematics and Science Instruction. Five subscales were included in the LSCCOP: (a) design (10 items), which measured the overall organization of the class; (b) implementation (8 items), which evaluated teachers' engagement in teaching; (c) content (9 items), which addressed questions related to the merit and application of the content; (d) classroom culture (6 items), which measured the overall classroom environment; and (e) overall rating (6 items), which pertained to the impact of instructions on students' understanding of science. Ratings for each item were provided on a 5-point Likert scale ranging from *to a great extent* (5) to *not at all* (1). Inter-rater reliability ranged from .80 to .86 across the three observation periods, indicating a high degree of consistency between raters.

In order to develop measures of teacher behavior consistent with the behaviors identified in the literature review as having an impact on student outcomes (e.g., teacher engagement, classroom management, teaching strategies), each item in the original LSCCOP was examined, evaluated, and re-categorized into three new subscales based on the wording of the question being related to the construct represented by each subscale. Three new subscales were: teacher engagement (how teachers interact with students) consisted of 12 items and had an internal consistency reliability of .95, classroom management (how teachers manage the classroom) consisted of 7 items and had an internal consistency reliability of .98, and teaching strategies (how teachers use teaching materials and teaching skills) consisted of 10 items and had an internal consistency reliability of .97. The high degree of internal consistency reliability of new subscales indicated the appropriateness of their use in the current study. The scores for three subscales were the average of their items, averaged over the three periods of observation. A measure of overall teacher behavior was also constructed, consisting of the average of the items from the original instrument over the three periods of observation.

Statistical Analyses

The process of analyzing data consisted of the following steps. First, descriptive statistics of central tendency and dispersion were computed on the beginning and end of year science test scores. Percentages were computed for categorical predictor variables. The intent was to further define the characteristics of the sample for purposes of generalizability and to reveal data patterns relevant to the second step of the analysis.

Second, multilevel modeling was conducted to assess the effects of teacher education, years of teaching experience, and teaching behaviors on student science achievement. Multilevel analysis is a methodology for the analysis of data with complex nested patterns of variability; for example, students nested in classroom/teacher, teacher/classroom nested in school. A multilevel model analysis approach would appropriately handle the complexity of the variations between different participants nested in various levels of the classrooms, the relationships between the outcome variables with the predictors at different levels, and the possible interactions between the predictors coming from different levels. Given the cluster sampling of students nested in teachers/classrooms, a two-level multilevel model (student level and teacher/classroom level) was needed to disentangle the contextual and participant factors in this study. The dependent variable was the student science end of year science scores. Independent variables at the individual or student level (level 1) included student beginning of year science scores, gender, and ethnicity (White/non-White). Predictors at the cluster or teacher/classroom level (level 2) included teachers' education level (master's degree or not), education in subject (yes or no), years of teaching, years of teaching in science, and overall teaching behavior. Subsequent analyses investigated the effect of individual teaching behaviors (teaching skills, teacher engagement, and classroom management) as mediators or moderators.

The first step in multilevel model analysis was to build up an unconditional model. This first null unconditional model characterized only random variation between groups and random variation within groups. Therefore, each student science achievement (end of year science scores) score was modeled as a function of the mean achievement of their classroom and random error at the student level, and each classroom's mean achievement as a function of the grand mean and random error at classroom-level, which could be represented as:

Student-level: $Y_{ij} = \beta_{0j} + r_{ij}$

Teacher-level: $\beta_{0j} = \gamma_{00}+U_{0j}$

Mixed model: $Y_{ij}= \gamma_{00}+U_{0j} + r_{ij}$

No predictors for either the student level or the classroom level were included in this null model. The purpose of this null model was to distinguish the estimations of the variances at two different levels and determine the justification of further multilevel analysis. Based on the unconditional model, a series of models with different random components were built to determine which random effect had the best fit for the data. In these models, the restricted maximum likelihood estimation method was used to estimate the parameters and to evaluate the overall model fit, because this method is better for estimating random components than the full maximum likelihood estimation method. In the next step, the relationships between predictors and student science achievement were investigated by employing all of the predictors and interactions at both levels into the model. The full maximum likelihood estimation method was used to estimate the parameters and model fit. All continuous variables were centered by their grand mean in order to clarify the interpretation of results. Diagnostic analyses were performed on the final model to explore whether there were problems with normality of the residuals and random effects.

The question of whether teaching behaviors moderated the relationship between teacher education level and years of experience and student achievement (see Figure 1)

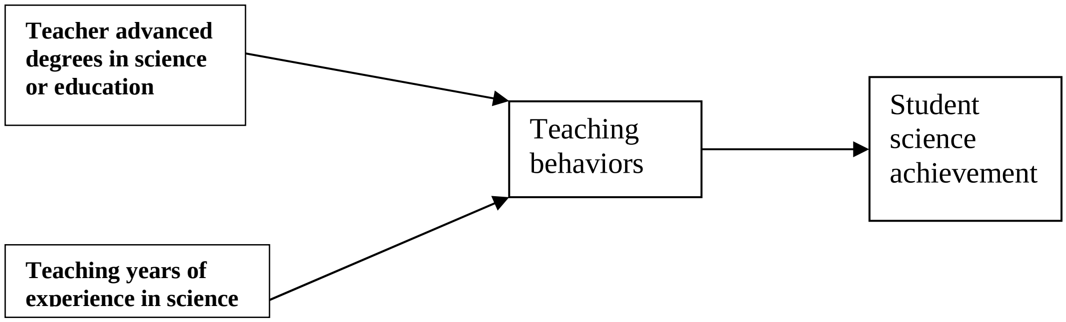

Figure 1: Teaching behaviors mediate the relationship between two teacher attributes and student science achievement.

was addressed by including a series of interaction terms between teacher attributes and teaching behaviors. The mediation effect of teaching behavior on the relationship between teacher characteristics and student science achievement was investigated through a three-step multilevel analysis. First, investigate the relationship between the two initial variables (teacher education and experience) and the outcome variable, student science test scores at end of year. Second, investigate the relationship between both initial variables and the mediator variable (teaching behaviors) with student achievement at end of year. Third, examine the relationship between the initial variables and the mediator variable. As mentioned before, the overall teaching behaviors in the classroom were actually composed of three specific behavior variables, (a) teacher engagement, (b) classroom management, and (c) teaching strategies. Therefore, in the last step, each of these variables were entered individually into the model to examine how specific teaching variables mediate the relationship between teacher attributes and student science achievements. Data analysis was conducted using the R software for statistical computing (R Development Core Team, 2007) and the lme4 package (Bates & Sarkar, 2007) for linear mixed-effects modeling.

RESULTS

The purpose of this study was to investigate the extent to which two teacher attributes, education level and years of teaching experience, influenced sixth-, seventh-, and eighth-grade students' achievement in science. In addition, this study explored whether a third variable, teaching behaviors in the classroom, can mediate or moderate the relationship between the first two attributes and student performance in science. First, descriptive statistics of student science achievement scores and other important predictor variables were computed. Second, multilevel model analyses of the effects of teacher education, years of teaching experience, and teaching behaviors on student science achievement were conducted. As described in the objectives, four specific research questions were addressed: (a) whether teacher education level and years of teaching experience directly influenced student science achievement significantly; (b) whether teacher behaviors moderated the relationship between teacher attributes and student achievement in science; (c) whether teacher behaviors mediated the relationship between teacher attributes and student achievement in science; and (d) exactly which teaching variables, teacher engagement, classroom management, and teaching strategies showed significant effects in the mediating relationship.

Descriptive Data

Descriptive statistics for the outcome variable and continuous predictor variables, at both the student and teacher level, were computed using raw scores and are presented in Tables 3 and 4. The mean of the outcome variable, student end of year science scores,

Table 3

Descriptive Statistics for Student Science Achievement Scores

Variable	*N*	*M*	*SD*
Student beginning of year science score	655	5.73	2.58
Student end year science score	655	8.32	3.49

Table 4

Descriptive Statistics for Teaching Behavior Scores

Variable	*N*	*M*	*SD*
Teaching behaviors observation total scores	12	3.40	0.87
Teacher's teaching engagement scores	12	3.20	0.91
Teacher's classroom management scores	12	3.40	0.83
Teacher's teaching strategies scores	12	3.20	1.03

for the entire sample (N = 655) students was 8.32 (SD = 3.49). Tables 5, 6, and 7 display the frequencies for categorical predictor variables.

Based on the descriptive statistics in Table 6, it was observed that the variable of whether the teacher had a master's degree and the variable of whether the teacher had a master's degree in science or education were exactly the same, thus these teachers did not obtain a master's degree in an area other than science or education. Therefore, in the analyses, only the variable indicating whether the teacher had a master's degree in science or education was included. Second, with respect to teaching experience, two variables, years of teaching, and years of teaching in science were identical for 9 out of 12 teachers, which indicated that these nine teachers had never taught other subjects. The teacher education level by teaching experience crosstabulation statistics is provided in Table 8.

Table 5

Frequencies for Student Demographic Information

Female		Minority		
%	*n*	%	*n*	*N*
44.90	293	52.80	341	645

Table 6

Frequencies for Teacher Advanced Degree

Whether teacher has advanced degree (Master's degree or above)		Whether teacher has advanced degree (Master's degree or above) in *Science* or *education*		
%	*n*	%	*n*	Total
55	5	55	5	9

Table 7

Frequencies for Years of Teaching and Years of Teaching in Science

	Years of teaching		Years of teaching in science	
Years of teaching	*n*	%	*n*	%
0-2 years	3	25.0	2	22.0
3-5 years	1	8.3	0	0.0
6-10 years	2	12.7	1	11.0
11-15 years	1	8.3	0	0.0
16-20 years	2	12.7	3	33.0
21-25 years	2	12.7	2	22.0
26 years or more	1	8.3	1	11.0
Total	12	100.0	9	100.0

Unfortunately, three teachers (two teachers from South middle school and one teacher from North middle school) did not provide information on educational attainment or teaching experience. If data are missing at the second level (teacher level), data from the first level (student level) will not be included in the analysis. Table 9 displays descriptive and inferential statistics for the retained sample and the eliminated sample

Table 8

Crosstab of Teacher Education Level by Teaching Experience

	Master in Science/Education		
Years of Teaching	No	Yes	Total
0-2 years	2	0	2
3-5 years	0	0	0
6-10 years	0	1	1
11-15 years	0	0	0
16-20 years	2	1	3
21-25 years	0	2	2
26 years or more	0	1	1
Total	4	5	9

that was included in the analyses in order to provide a comparison between them. As can be seen, differences between samples are minor.

Multilevel Model Analyses

Exploratory Analysis

Before beginning the multilevel analyses, exploratory analyses were performed on the outcome variable of student end of year science scores. The normality of the outcome variable was investigated by creating a normal quantile plot and a boxplot (see Figures 2 and 3). These figures did not indicate substantial problems with normality of end of year science scores and so this variable was modeled directly, without transformation. Figure 3 displays median achievement on the end of year science test stratified by teacher identification. It also indicated variation among teachers in terms of student science test performance at year end, indicating the necessity of investigating the random variance component for intercept in later models.

Table 9

Descriptive Statistics for Retained Sample and Eliminated (Due to Missing Data) Sample

Variable	Retained sample	Eliminated sample	Statistics
Student gender			$\chi2$ = 1.518
Male	292	67	p = .250
Female	249	44	
Student ethnicity			$\chi2$ = .709
White	256	49	p = .410
Non-White	276	63	
Student science scores at beginning of the year (Mean)	5.69	5.91	t = .809 p = .419
Student science scores at end of the year (Mean)	8.07	9.54	t = 4.100 p < .001
Teacher behaviors overall score	3.35	3.03	t = -.565 p = .584
Teacher engagement score	3.41	3.13	t = -.482 p = .640
Classroom management score	3.45	2.60	t = -1.436 p = .182
Teaching strategies score	3.42	3.23	t = -.394 p = .705
Years of Teaching			
0-2 years	2	1	$\chi2$ = 8.444
3-5 years	0	1	p = .207
6-10 years	1	0	
11-15 years	0	1	
16-20 years	3	0	
21-25 years	2	0	
26 years or more	1	0	

Five outliers were detected among the end of year science scores. In order to investigate any possible bias associated with these outliers, all analyses were conducted with and without the cases with outlying data included in the analyses. There were no appreciable differences between sets of analyses and, therefore, the cases with outlying data were included in the reported analyses.

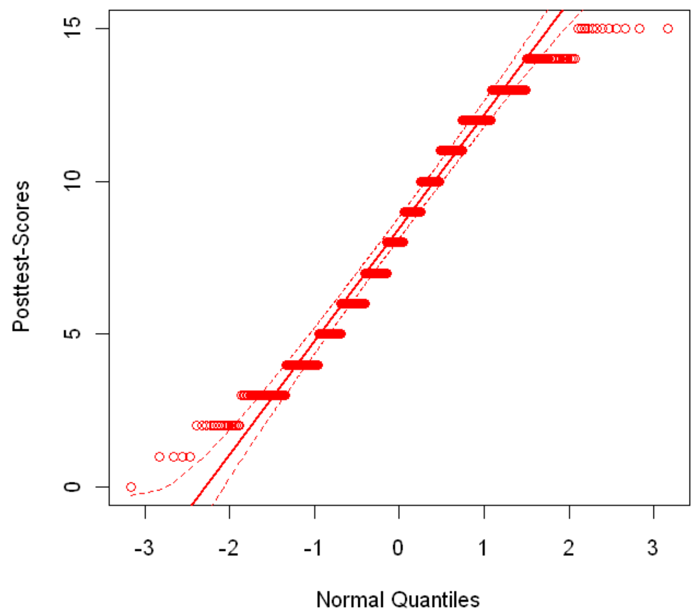

Figure 2. Normal quantile of student end of year science scores.

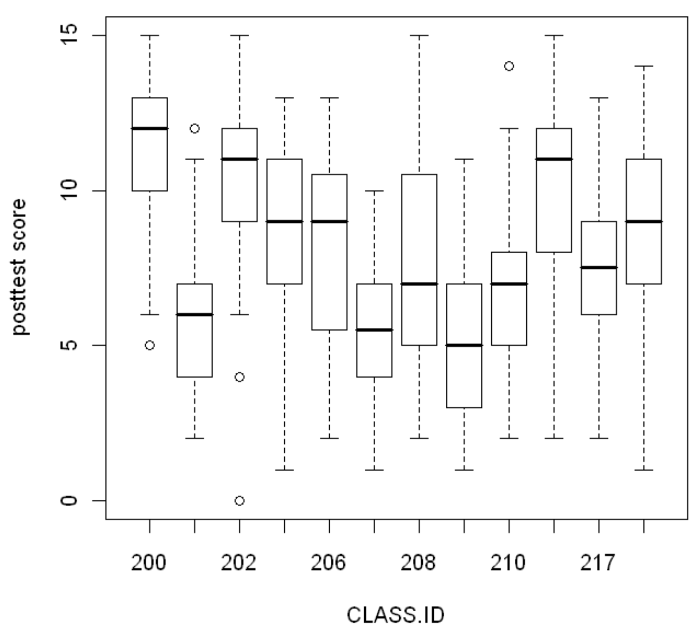

Figure 3. Boxplot of student end of year science scores.

Unconditional Model

Before including any predictors into the multilevel model, a preliminary unconditional model was performed to estimate the amount of variance in student end of year science scores that existed within and between classrooms. If the variance between classrooms was sufficient, then it would warrant further investigation using a multilevel analysis. The intraclass correlation coefficient (ICC), which is an indicator of the size of the clustering effect, was calculated to estimate how much between-classroom variances is represented in the total variance in student science scores using the following formula:

$$ICC = \tau^2 / (\sigma^2 + \tau^2)$$

τ^2 refers to the between-classroom variance, σ^2 refers to the within-classroom variance (residual variance), and the sum of σ^2 and τ^2 indicates the total variance.

In this null model, the between-group variance was 4.49 and the residual variance was 7.73. Therefore, the ICC was 36.7%, which indicated that the between-classroom variance accounted for 36.7% of the total variance in student science achievement. In other words, nearly 36.7% of the variance in student science scores occurred between classrooms. Thus, further analyses with multilevel techniques were justified.

This first analysis model was essentially an unbalanced one-way ANOVA with teacher treated as a random-effect variable. Additional stages of analysis produced estimates of linear equations that explained achievement in science as a function of the characteristics of student- (Level 1) and teacher-level characteristics (Level 2).

Random Effects Analysis

To investigate the random effects that best fit the data, a series of multilevel models with different random components were computed and compared, while holding constant all the other predictor variable effects. The restricted maximum likelihood estimation method was used to estimate the random-effect parameters and the overall model fit. All student-level predictors and teacher-level predictors were included in the model. Student-level predictors included students' beginning of year science scores, gender, and ethnicity. The teacher-level predictors included teaching behavior total scores, whether teachers had advanced degrees in science or education, and years of teaching science. No interaction effects were included in the models at this point.

In the first random-effects model, both a random intercept and a random slope were fitted, because this study was primarily interested in the effects of teacher characteristics (level 2 predictors) on student achievement. Random intercept assumed that the means of student science end of year scores varied across different teachers. Random slopes assumed that the relationship between student beginning of year and end of year science test scores varied across teachers. In the second model, only a random slope was assumed; in the third model, only a random intercept was assumed.

Comparisons between these three models were conducted to investigate which model had the best fit and was also the most parsimonious. For each of three models, a deviance statistic (-2*Log-Likelihood), which indicated model fit, was provided. When two models are nested, the difference of the two models' deviances can be used to perform a chi-square based likelihood ratio test (LRT) to investigate whether the more complex model fits significantly better than the simpler model (Hox, 2002). If two models are not nested, Akaike's Information Criterion (AIC) can be used to compare the models (Hox), with a smaller AIC indicating better fit. LRTs were conducted to perform nested model comparisons between Model 1 and Model 2 and between Model 1 and

Model 3 (Table 10). It was found that the model with only random intercept possessed a significantly better fit than the random intercept with random slope model or the random slope-only model. In conclusion, only the end of year student science test scores varied significantly across teachers. The final model was then used to address research questions 1 and 2.

Fixed Effects Analysis for Research Questions 1 and 2

After the random-effects portion of the model was finalized, the various fixed effects could be evaluated according to the hypotheses, including interaction effects. Maximum likelihood estimation was used to estimate the fixed parameters and model fit.

Interaction effects analysis. In a multilevel model, interactions can occur within a level or across levels. Therefore, interactions within the student level, within the teacher level, and between the student and teacher level were included, primarily to investigate the moderating effect of teaching behaviors on the relationship between teacher characteristics of degree and experience on student outcomes. Two-way interactions within the student level included the interactions among gender, ethnicity, and beginning of year student science scores. Interactions within the teacher level included all of the two-way interactions between the three teacher variables of interest: (a) overall teaching behavior scores, (b) whether the teacher had an advanced degree in science or education, and (c) years of teaching science. Two-way interactions across levels included those between student beginning of year science scores, gender, and ethnicity at the student level and the three teacher characteristics at level 2. Thus, there were three student-level interaction effects, nine cross-level interaction effects, and three teacher-level interactions tested in the model (all of them were two-way interactions).

Table 10

The Comparison of Random Effect Components of Model 1, 2, and 3

	Model 1 Random intercept and random slope	Model 2 Random slope only	Model 3 Random intercept only
-2*Likelihood	2500	2534	2504
AIC	2521	2550	2520
$\chi 2$ for Model.1 and Model.2	$\chi 2 = 25.38$, *df* = 2, $p < 0.0001$		
$\chi 2$ for Model.1 and Model.3	$\chi 2 = 4.68$, *df* = 2, $p = 0.09$		

Each interaction effect was entered into the model one at a time, while holding all other variables constant, including the random intercept and all the other predictors at both levels. The interaction term between whether the teacher held a Master's in science or education and the teacher's years of teaching in science was found to be statistically significant, $t = -3.12$, $p < .001$. The other significant interaction term was between ethnicity and years of teaching, $t = 2.46$, $p < .001$. Therefore, these two interaction terms were included in the final model. The nonsignificance of the interaction between teaching behaviors and teaching degree or years of teaching experience indicated that teaching behavior did not moderate the relationship with science achievement.

Fixed effects of individual predictors. The evaluation of the main effect of the fixed effect predictors was the last step in the modeling process. With the random intercept and the two interaction effects included in the model, the effect of individual predictors from both levels on student science achievement at end of year were investigated using a maximum likelihood estimator. Predictors were employed into the model sequentially, first including only student-level variables, then adding the predictors from the teacher level. This sequential approach was used to disentangle the effects of student-level predictors from those of teacher-level predictors. Student beginning of year science scores were found to be the only significant predictor at the student level. For the teacher-level predictors, teaching behaviors and whether the teacher had a Master's degree in science or education significantly influenced student science end of year scores. Years of teaching science and student ethnicity did not show significant effects on student science end of year scores at the 0.05 level. However, because there was a significant interaction between teachers possessing an advanced degree in science or education and years of teaching in science as well, a significant interaction between ethnicity and years of teaching in science, years of teaching science, and student ethnicity were included in the final model as a main effect.

Summary of the Multilevel Analysis

The results of the final multilevel model are summarized in Table 11. Student beginning of year science scores (b = 0.38, p < .001), teaching behavior (b = 0.97, p < .001) and teachers' advanced degrees in science or education (b = 7.54, p < .001) were significant predictors of student end of year science scores. Two interaction effects influenced student science scores significantly: years of teaching science and teacher advanced degrees in science or education (b = -1.19, p < .001), student ethnicity and years of teaching science (b = 0.30, p < .001). Therefore, it could be concluded that years of teaching science influenced the relationship between teachers' advanced degrees in science or education with student science achievement, or teacher's advanced degrees in science or education influenced the relationship between years of teaching science and student science achievement. In addition, student ethnicity influenced the relationship between years of teaching science and student achievement. The interpretations of each

Table 11

Final Model with Random Component and Fixed Predictors

Fixed effect	Coefficient	Standard error	*t* value	*p* value
Model for student mean end of year science scores β_0				
Intercept γ_{00}	5.93	0.82	7.21	<.0001
Student beginning of year science scores γ_{01}	0.38	0.04	8.15	<.0001
Teacher behaviors γ_{02}	0.97	0.47	2.03	<.001
Teacher Master's degree in science or education γ_{03}	7.54	2.17	3.47	<.0001
Years of teaching science γ_{04}	0.18	0.21	0.86	>.05
Student ethnicity γ_{05}	-0.26	0.60	-0.43	>.05
Interaction between student ethnicity and years of teaching science γ_{06}	0.30	0.12	2.46	<.001
Interaction between teacher Master's degree in science or education and years of teaching science γ_{07}	-1.19	0.38	-3.12	<.0001
Random effect	Variance component	Standard deviation		
Random intercept U_{00j}	0.54	0.73		
Level-1				
r_{ij}	6.33	2.52		

parameter estimate are presented in Table 12. The significance of the random components indicates that mean student science achievement at the end of the year varied significantly across teachers. The final model could be represented in the following set of equations:

<u>Level-1 Model</u>

$Y_{ij} = \beta_{0j} + r_{ij}$

<u>Level-2 Model</u>

Table 12

Interpretation of the Parameter Estimates of Final Model

Variables	Parameter estimates	Interpretation
Intercept	5.93	Mean student end of year science scores when beginning of year science scores is the average, teacher does not have advanced degree and years of teaching experience, but have mean teaching behavior scores.
Beginning of year science scores	0.38	Linear change of student end of year science scores by beginning of year science scores. One unit change in beginning of year science score will lead to 0.38 unit change in student end of year science scores
Interaction between advanced degree and years of teaching science	-1.19	For the group whose teacher do not have advanced degree in science or science education, the regression coefficient between teaching years and student science achievement was 0.18; For the group whose teacher has advanced degree in science or science education, the regression coefficient between teaching years and student science achievement was 0.18-1.18= -1
Teaching behavior	0.97	Linear change of student end of year science scores by teaching behaviors. One unit change in teaching behavior will lead to 0.97 unit change in student end of year science scores, *if all the other predictors were at "0" or mean.*
Master's degree in science or science education	7.54	Mean difference of student end of year science scores between those whose teacher has advanced degree in science or education and the others whose teacher does not have. Mean scores of the students whose teacher has advanced degree is 5.93+7.54 = 13.47*, if other predictors were at "0" or mean***.**
Years of teaching science	0.18	Linear change of student end of year science scores by teaching years. One unit change in teaching years will lead to 0.14 unit change in student end of year science scores, *if all the other predictors were at "0" or mean.* Given this variable is categorical, the mean difference between each category is almost 5 years, therefore, we can say that every three teaching years increase will lead to .14 increase in student science achievement.
Student ethnicity	-.26	Mean difference of student end of year science scores between White student and non-White student. Mean scores of the White student is 5.93-.26 = 5.67, while mean scores of the non-White student is 5.93, *if all the other predictors were at "0" or mean.*
Interaction b/w student ethnicity and years of teaching science	0.30	For the White students, the regression coefficient between teaching years and student science achievement was 0.18 +0.3 = 0.48; For non-White students, the regression coefficient between teaching years and student science achievement was 0.18.

$\beta_{0j} = \gamma_{00} + \gamma_{01}$*(science score at beginning of the year)$_j$ + γ_{02}*(teaching behaviors)$_j$ + γ_{03}*(teacher's Master's degree in science or education + γ_{04} *(years of teaching science)$_j$ + γ_{05}*(ethnicity) + γ_{06}*(ethnicity)$_j$ *(years of teaching in science)$_j$ + γ_{07}*(Master's degree in science or education)$_j$*(years of teaching in science)$_j$ + U_{00j}

Combined Mixed Model

$Y_{ij} = \gamma_{00} + \gamma_{01}$*(science score at beginning of the year)$_j$ + γ_{02}*(teaching behaviors)$_j$ + γ_{03}*(teacher's Master's degree in science or education) + γ_{04} *(years of teaching science)$_j$ + γ_{05}*(ethnicity) + γ_{06}*(ethnicity)$_j$ *(years of teaching in science)$_j$ + γ_{07}*(Master's degree in science or education)$_j$*(years of teaching in science)$_j$ + U_{00j} + r_{ij}

Comparison Between Different Models

To answer the question concerning how well different predictors from two levels explained the variance in the outcome variable–student end of year science scores–comparison between null models, the student-level predictor-only model, and the final model was performed (see Table 13). In the student-level predictor-only model, the single significant predictor, student beginning of year science scores, was retained. The explained proportion of variance in student science end of year scores was calculated using the following equation: (σ^2_e (null model) – σ^2_e (model with student-level predictors))/ σ^2_e (null model), which was (7.73-6.39)/7.73 = 17.3%. This indicated that the beginning of year science scores accounted for 17.3% of the variance in end of year student science scores. Comparing the student-level-only model and the final model, the proportion of variance explained in σ_e^2 was calculated by (σ_e^2 (Model 2) – σ_e^2 (final

Table 13

Comparison Between Null Model, Model with First-Level Predictors, and Final Model

Model	Null model	Model with first-level predictors	Final model
Fixed Predictors			
—Student Level			
Intercept		7.32	5.93
Student beginning of year science scores		0.39	0.38
Student ethnicity		1.13	-0.26
Fixed Predictors			
—Teacher Level			
Teaching behaviors			0.97
Teacher advanced degree in science or education			7.54
Years of teaching science			0.18
Interaction between teacher advanced degree and years of teaching science			-1.18
Interaction between student ethnicity and years of teaching science			0.30
Random part			
σ_{u00}^2	4.49	4.67	0.54
σ_e^2	7.73	6.39	6.33
Deviance	2676	2526	2504

model))/ σ_e^2 (Model 2), which was almost 0%. This indicated that teachers' teaching behaviors and teachers' advanced degrees in science did not contribute much to the variation in the outcome. In total, compared with the null model, the final model explained almost 18% more of the total variance in the outcome, which could be calculated by (7.73-6.33)/7.73.

Given that the data are clustered and between-group variance (variance between teachers) stand for 36.7% of the total variance, teacher-level predictors were included in the analysis to account for the variances among teachers. To answer the question concerning how well different teacher-level predictors explained the variance among teachers, comparison between the student-level predictor-only model and the final model was performed (see Table 13). The explained variance between teachers was calculated by (σ_{u00}^2 (in Model 2) – σ_{u00}^2 (in the final model))/ σ_{u00}^2 (in Model 2), which was 88.4%. Therefore, we could conclude that the variances among teachers were partially due to differing teaching behaviors, whether teachers had advanced degrees in science or education, and teachers' years of teaching science.

As the LRT indicated that the final model with both student- and teacher-level predictors was significantly different from the student-level-only predictor variable model and the null model without any predictors, ($\chi^2 = 182.85$, $df = 7$, $p < .0001$). Therefore, it could be concluded that student beginning of year science score, teacher education level, years of teaching, and teaching behaviors made significant contributions to the explanation of the variances in student science achievement, when compared with the previous two models.

Diagnostics of the Final Model

The last step in building the statistical model was to examine whether any important assumptions had been violated. These assumptions included normality of the residuals and normality of the random effects. Figure 4 indicates that the standardized residuals were nearly normally distributed when plotted against a theoretical normal distribution. This plot also indicates only one obvious outlier (the standard deviation of this residual was below -3). Altogether, the assumption of normality of residuals was not violated. Figure 5 shows the normal quantile plot of the random intercept versus a

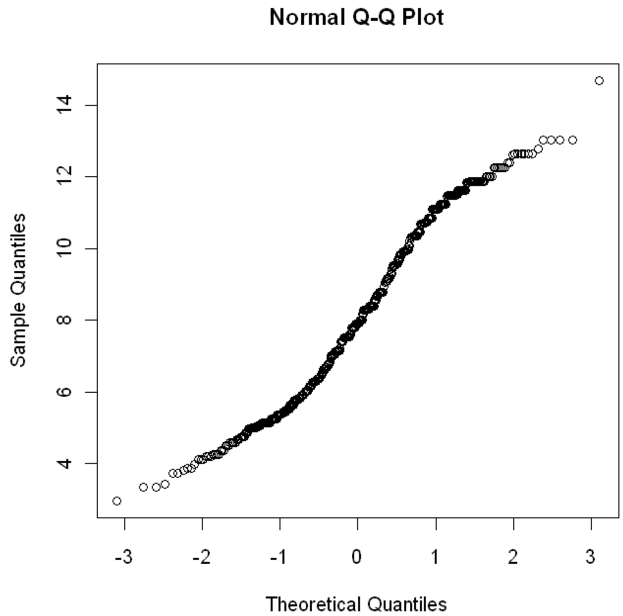

Figure 4. Normal quantile of standardized residuals.

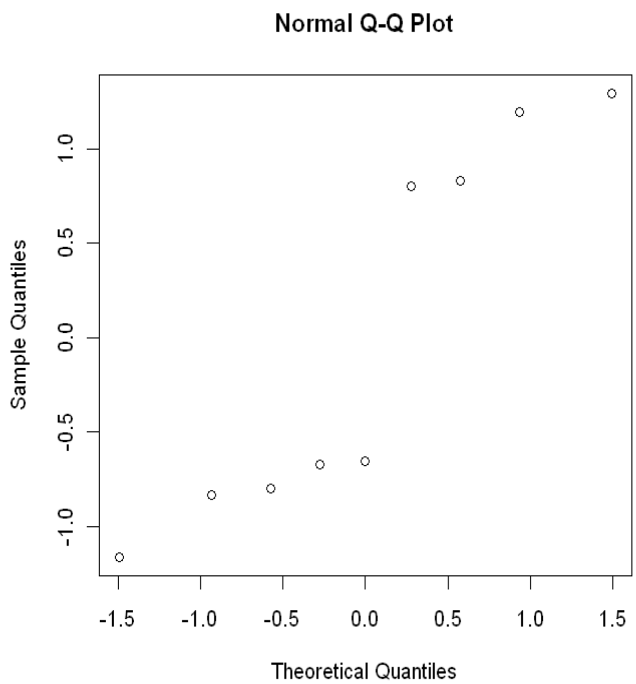

Figure 5. Normal quantile of random intercept.

normal distribution. As only 9 teachers (clusters) were included in the final analysis, the random effects do not follow a normal distribution, and instead indicate differences in student performance between teachers of mostly White and mostly non-White students.

Summary of Research Question 1

Research Question 1 was related to whether a relationship existed between teachers' education level and years of experience and student science achievement. To address this question, a multilevel model was tested with predictors at the student and teacher level. The final multilevel model indicated that teacher's advanced degrees in science or education was a statistically significant predictor of student science achievement. Years of teaching science did not show any significant influence on student achievement in science. However, a significant interaction between teacher education level and years of experience indicated that the relationship between teacher education level and student achievement was conditional on the number of years of experience in teaching science. The significant negative coefficient associated with the interaction term was -1.18, which indicated that the slope between student end of year science scores and teacher experience is 1.18 points less for teachers with an advanced degree than for those with a lower level degree. Figure 6 illustrates the interaction effect, suggesting that when comparing students whose teachers had advanced degrees in science to those whose teachers did not, the former students' mean end of year scores would be higher than those of the latter students. However, the relationship between years of teaching science and student end of year scores was negative, with every one year increase in experience leading to worse student achievement, if the teacher held an advanced degree. Additionally, a significant interaction effect between years of teaching and student

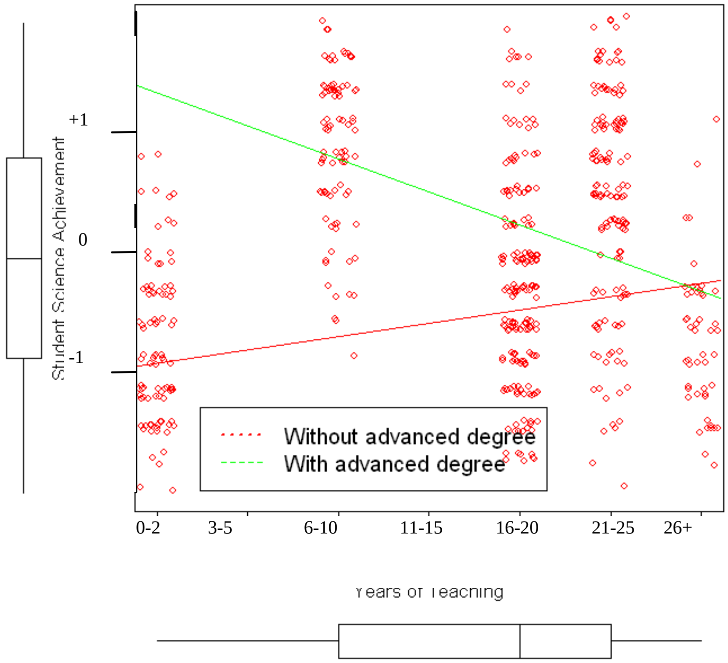

Figure 6. Predicted relationship between years of teaching experience in science and student science achievement (*Z* score) as a function of whether the teacher possessed an advanced degree.

ethnicity was observed in this study. This finding indicated that as teachers' years of teaching science increased, White students increased their science achievement more rapidly than non-White students (see Figure 7).

Summary of Research Question 2

Research Question 2 was related to whether teaching behaviors moderated the relationship between teacher education level and teaching experience and student science achievement. Two-way interactions included in the multilevel model between teaching behaviors and the two teacher characteristics indicated that neither interaction effect had a significant impact on student achievement in science. Therefore, it may be concluded

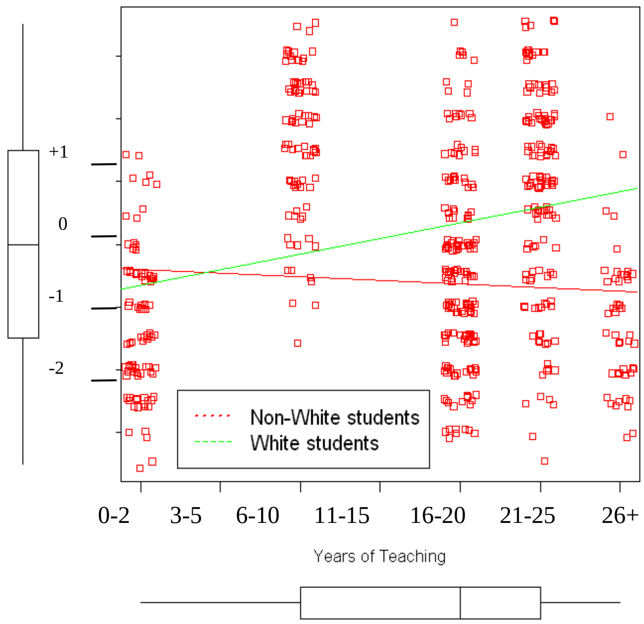

Figure 7. Predicted relationship between years of teaching experience in science and student science achievement (*Z* score) as a function of student ethnicity.

that no evidence was found in this study to indicate that teaching behaviors moderated the relationship between the two teacher characteristics and student achievement in science..

Analyses for Research Question 3

The next step was to determine whether teaching behaviors mediate the relationship between teacher attributes and student outcomes. In this meditational relationship, the initial variables were teachers' advanced degrees in science or education and years of teaching science. The mediator variable was overall teaching behavior score, and the outcome variable was student science achievement at end of year. The initial variables and the mediator variable were teacher-level variables, while the outcome variable was a student-level variable. Therefore, the mediation effect was cross-level. Student science outcomes at beginning of year were still included as a level-1 covariate.

In order to test the meditational relationships, three steps were followed. The first step was to investigate the relationship between the two initial variables (teacher education and experience) and the outcome variable, student science test scores at end of year. This was the same analysis as conducted to address research question 1. The second step differed from the first by including both initial variables and the mediator variable at level-2 to predict student achievement at end of year. This was also similar to previously constructed models. The third step was to examine the relationship between the initial variables and the mediator variable. In this step, estimates of the coefficients were obtained through simple Ordinary Least Squares (OLS) regression estimation, because all of the variables were on the same level (i.e., teacher). The overall coefficients of the mediated effect are shown in Table 14. The path model depicting the meditational relationships among variables is presented in Figure 8. A summary of the steps for fitting the multilevel regression analysis are presented below in equation format:

Step 1: <u>Level-1 Model</u>

$Y_{ij} = \beta_{0j} + \beta_{1j}$*(beginning of year science scores) $_{ij} + r_{ij}$

<u>Level-2 Model</u>

$\beta_{0j} = \gamma_{00} + \gamma_{01}$ *(teacher's advanced degree in science or education) $_j$ +

γ_{02}*(years of teaching in science) $_j + U_{0j}$

$\beta_{1j} = \gamma_{10} + U_{1j}$

Step 2: <u>Level-1 Model</u>

$Y_{ij} = \beta_{0j} + \beta_{1j}$*(beginning of year science scores) $_{ij} + r_{ij}$

<u>Level-2 Model</u>

$\beta_{0j} = \gamma_{00} + \gamma_{01}$*(teacher's advanced degree in science or education) $_j$ +

Table 14

Mediational Relationship Between Two Teacher Attributes, Teaching Behaviors, and Student Science Achievement

Initial variable	Mediator variable	Outcome variable	β (path between initial variables and mediator variable) Step 3	γ_{04} (path between mediator and outcome) Step 2	Mediated effects $\beta^* \gamma_{04}$
Teacher's advanced degree in science or education	Teaching behaviors	Student end of year science score	$\beta_{1j} = 1.46$ $t = 24.74$***	$\gamma_{03} = 2.8$ $t = 6.5$ **	$\beta_{1j}\,\gamma_{03} = 4.09$***
Years of teaching science			$\beta_{2j} = -0.17$ $t = -11.45$***		$\beta_{2j}\,\gamma_{03} = -0.48$***

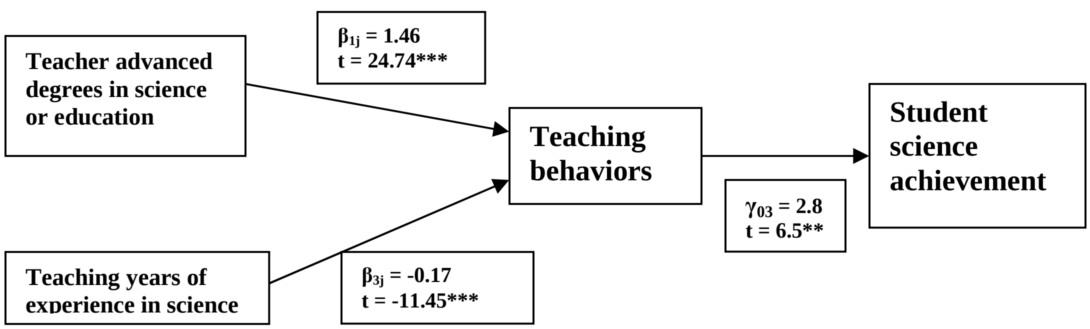

Figure 8. Mediational relationship between two teacher attributes, teaching behaviors, and student science achievement

γ_{02} *(years of teaching in science) +γ_{03} *(teaching behaviors) + U_{0j}

$\beta_{1j} = \gamma_{10} + U_{1j}$

Step 3:

$M_{(\text{teaching behaviors})\,j} = \beta_{0j} + \beta_{1j}$*(teacher's advanced degree) $_j$ +

β_{2j}* (years of teaching in science) $_j + r_j$

Summary of Research Question 3

A three-step analysis of mediation effects yielded three results: (a) as before, advanced degrees in science or education and years of teaching science were significantly associated with end of year student science achievement; (b) teaching behaviors were significantly associated with end of year student science achievement; and (c) advanced degrees in science or education and years of teaching science were significantly associated with teaching behaviors in general. Based on these three findings, it could be concluded that an advanced degree in science or education and years of teaching science influenced student achievement in science through affecting teaching behaviors as an intermediary variable. While possessing an advanced degree in science or education had a positive relationship with teaching behaviors, years of teaching experience had a negative relationship.

Analysis of Research Question 4

The last research question was related to the issue of whether specific teaching behaviors (teacher engagement, classroom management, and teaching strategies) mediated the relationship between teacher attributes and student science achievement, instead of a more global measure of teacher behavior. In this step, teacher engagement, classroom management, and teaching strategies were tested one at a time through the three-step mediation analysis method described above. The results were summarized in Table 15 and the mediation effects were displayed separately as path models in Figures 9, 10, and 11.

Table 15

Mediational Relationship Between Two Teacher Attributes, Three Specific Teaching Behaviors, and Student Science Achievement

Initial variable	Mediator variable	Outcome variable	β (path between initial variable and mediator variable)	γ (path between mediator and outcome)	Mediated effects B* γ
Teacher's advanced degree in science or education	Teacher engagement	Student end of year science scores	$\beta_{1j} = 1.37$ $t = 22.35$***	$\gamma = 3.0$ $t = 6.85$**	$\beta_{1j}\ \gamma = 4.1$***
Teacher's years of experience in science			$\beta_{2j} = -0.16$ $t = -9.92$***		$\beta_{2j}\ \gamma = -0.48$**
Teacher's advanced degree in science or education	Classroom management	Student end of year science scores	$\beta_{1j} = 1.33$ $t = 20.16$**	$\gamma = 2.45$ $t = 5.37$**	$\beta_{1j}\ \gamma = 3.26$ **
Teacher's years of teaching science			$\beta_{2j} = -0.17$ $t = -10.07$**		$\beta_{2j}\ \gamma = 0.42$***
Teacher's advanced degree in science or education	Teaching strategies	Student end of year science scores	$\beta_{1j} = 1.46$ $t = 34.60$ **	$\gamma = 3.44$ $t = 4.18$**	$\beta_{1j}\ \gamma = 5.02$***
Teacher's years of teaching science			$\beta_{2j} = -0.11$ $t = -10.43$**		$\beta_{2j}\ \gamma = -0.38$**

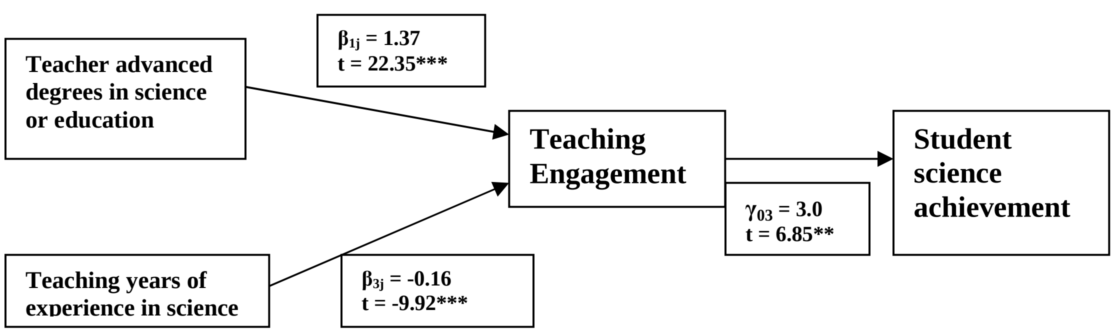

Figure 9. Mediation relationship between two teacher attributes, teaching engagement, and student science achievement.

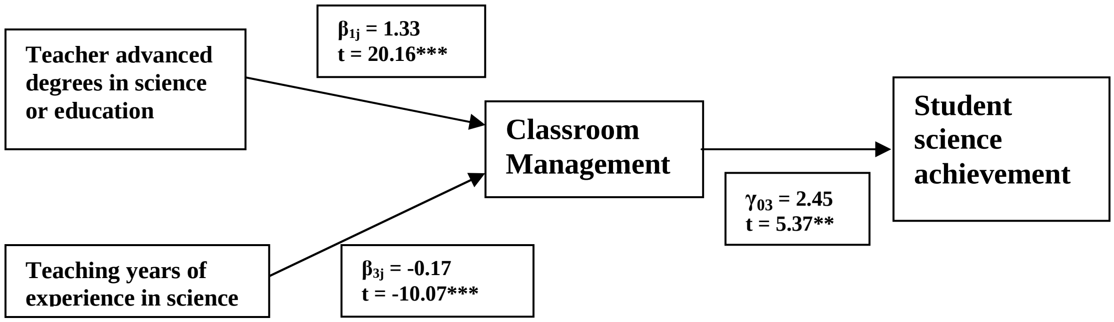

Figure 10. Mediation relationship between two teacher attributes, classroom management, and student science achievement.

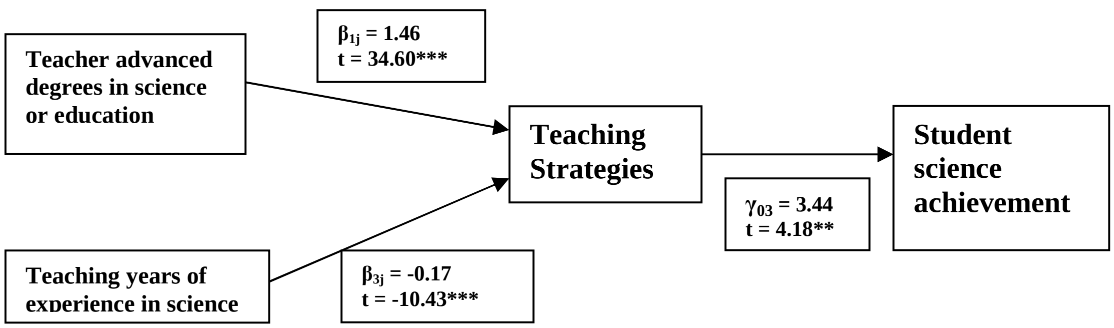

Figure 11. Mediation relationship between two teacher attributes, teaching strategies, and student science achievement.

Summary of Research Question 4

All three specific teaching behavior variables were significant mediating variables. Therefore, it could be concluded that teacher engagement, classroom management, and teaching strategies were found to show significant mediational effects on the relationship between the two teaching characteristic variables and student science achievement at end of year.

DISCUSSION

A central focus of science education research is to gain a better understanding of how various factors influence student achievement. For instance, school-related factors (e.g., school dropout rate), student-related factors (e.g., social economic status), and teacher-related factors (e.g., teaching behaviors) are all known to influence student achievement in science. However, teacher-related factors have gained a great deal of attention as they are important considerations in teacher employment and teacher training policies. Results of educational research (American Association for the Advancement of Science, 1993; NRC, 1996; Reiser, Kraicik, Moje & Marx, 2001) suggest that the teacher is an essential element in structuring and guiding students' understanding of science.

The purpose of this exploratory study was to gain a better understanding of how teacher education, teacher experience, and teaching behaviors influence student achievement in science. Two broad research questions guided this inquiry: (a) whether a relationship existed between both teacher educational level and experience with student science achievement; and (b) whether teacher behaviors mediated or moderated the relationships between both teacher educational level and experience and student achievement in science. As suggested by some researchers, teacher education level and experience may not directly influence student science achievement, but may do so indirectly (Wenglinsky, 2002). In other words, it may be possible that these two teacher attributes (i.e., education and experience) influence one or more other important variables, which then influences student science achievement, thus suggesting a mediating role for other teacher- or student-related factors. The roles of mediating factors, such as teacher behaviors, have not been examined in previous research investigations. Alternatively, teacher education and experience may influence student science achievement when they are conditioned on other variables, suggesting a moderating effect. An exploration of the mediating or moderating role of teacher behaviors in the relationship between both teacher education and experience and student achievement was the contribution of this study to our existing knowledge in this area.

The approach to data analysis was twofold. In the first part, basic descriptive statistical analyses were conducted to investigate individual variables and to provide general information for further analysis. In the second part, multilevel statistical models were employed to investigate the relationships among the teacher- and student-related factors with student science achievement as the ultimate outcome. In this second set of analyses, the mediating and moderating role of teacher behaviors was investigated. The following conclusions were drawn from the results of these analyses:

1. In terms of direct effects, an advanced degree in science or education significantly and positively influenced student science achievement. In addition, better teaching behaviors were also positively related to student achievement in science. However, years of teaching experience in science did not directly influence student science achievement.

2. In terms of moderating effects, a significant interaction was detected between teachers possessing an advanced degree in science or education and years of teaching science, which was inversely associated to student science achievement (more discussion to follow). However, teaching behaviors did not moderate the relationship between teacher education and experience with student achievement in science.

3. In terms of mediating relationships, teaching behaviors mediated the relationship between student science achievement and both teacher education and experience. Teachers with advanced degrees in science or education were more likely to exhibit positive teaching behaviors, which in turn was associated with better student performance in science. However, greater teaching experience in science was negatively associated with positive teaching behaviors, in that more teaching experience in science ultimately lead to worse student achievement in science. Additionally, when examined separately, each teaching behavior variable (teacher engagement, classroom management, and teaching strategies) served as a significant intermediary between both teacher education and experience and student science achievement.

Relationship Between Teaching Behaviors and Student Achievement in Science

The often observed (Schroeder et al., 2007; Walberg, 1984; Wise & Okey, 1983), strong relationship between in-class teacher behavior and student achievement in science was replicated in the present study. In comparison with teacher education and experience, teacher behaviors related to classroom management, teacher engagement, and teaching strategies possessed the stronger relationships to student achievement in science. Thus, this result was not surprising as teaching behavior is frequently shown to have a significant effect on student achievement, as described in the literature review (e.g., Marzano et al., 2003; Walberg, 1986). The implications of this finding for teacher quality and optimum student outcomes are that pre- or inservice education programs should especially focus on in-class teaching behaviors and skills.

An important contribution of this study to the body of previous research literature in this area was the inclusion of teaching behaviors as a mediator when investigating the relationship between teacher education level and experience with student science achievement. Previous research, however, has only focused on the direct relationship between each of these two teacher attributes (in isolation) and student achievement in science. In the present study, it was found that the quality of teaching behavior observed in the science classroom was influenced by teachers' educational and experiential backgrounds. The critical importance of understanding this mediation effect is underscored by the fact that teaching behavior was the core reason for better student performance in science.

The observation of a significant mediation effect of teaching behaviors in the relationship between holding an advanced degree in science or education and student science achievement was consistent with the study hypotheses. Specifically, higher-level or superior teaching behaviors significantly mediated the relationship between possessing an advanced degree in science or education and student science achievement. Possible explanations for this finding are that teachers with advanced degrees in science or education not only possess more subject knowledge, but have also likely developed more advanced teaching skills and strategies, enabling them to demonstrate more effective teaching behaviors in the classroom. In turn, because of their better classroom management and instructional strategies, teachers are more likely to help their students succeed in learning science-related concepts.

Although a mediation effect for teaching behaviors in the relationship between teaching experience in science and student science achievement was observed in this study, the nature of the meditational effect was contrary to what was expected. Specifically, greater experience in teaching science was negatively related to higher-quality teaching behaviors, which was then associated with student science achievement. Thus, it would be unjustified to conclude, at least from the results of the present study in the area of science education, that previous teaching experience would automatically imply high-level teaching behaviors in the classroom. Further, students might not reap educational benefits solely on the basis of one teacher having more experience than another. However, such a finding is contrary to our common sense understanding about the relationship between teaching experience and both teaching behaviors and student achievement. A possible cause of this negative effect of experience is that older teachers might not always continue to improve their performances. It is also likely that older teachers might get tired, burned out, and lose self-motivation in their jobs (Schwab, 1983). Therefore, they could not give of themselves as they were able to earlier in their careers. More research should be conducted to explore the effect of teacher experience on teaching behavior and student outcomes to understand exactly why there is either a negative effect, as shown in the present study, or no effect, as shown in previous research (Goldhaber & Brewer, 1996, 2000; Ye, 2000).

The Interaction Effect Between Years of Teaching in Science and Teacher Advanced Degree in Science on Student Science Achievement

An important finding discovered by this study was the negative interaction between teachers possessing an advanced degree in science or education and years of teaching experience. Such finding has never been observed in previous research. With this negative interaction effect, the direct relationships between the two variables carrying this interaction and student science achievement indicated different meaning than in a model without the interaction effect. Figure 5 indicated that, depending on whether or not a teacher possessed an advanced degree in science or education, the relationship between years of teaching experience in science and student science achievement differed dramatically. Very well-prepared beginning teachers who possess advanced degree can be highly effective. Thus, students whose teachers had advanced degrees in science or education demonstrated better performance on a science knowledge assessment test, if their teacher had relatively little experience. However, these students performed increasingly worse as the number of years that their teacher had been teaching increased. On the other hand, for the students whose teacher did not have an advanced degree, the relationship between teacher experience and student science knowledge was only slightly positive, really indicating no meaningful effect. The overall conclusion in terms of this interaction effect was that teachers with advanced degree might not remain effective through their whole career.

Three experts in science teaching were contacted in an attempt to find an explanation for this finding. They were all experienced science teachers with advanced degrees. One explanation, according to these individuals, was that such a counterintuitive trend may be due to levels of self-motivation and teaching attitudes possessed by these teachers. For instance, when a science teacher with an advanced degree begins their work in a middle school, they tend to be optimistic about teaching and are highly self-motivated. They may actively implement their recently developed teaching strategies in their classrooms, try to incorporate all the knowledge they acquired during graduate school, and are ready to give of themselves to their students. Therefore, although beginning teachers' teaching experiences were little, their advanced degrees, their high motivation, and positive attitudes compensate their teaching skills in the classroom. This approach likely has an immediate impact in terms of enhancing student performance. However, as time goes on and as difficulties are encountered from various sources (students, school/administration, other teachers), their motivation is reduced, attitudes are soured, and feel burned out as time goes, resulting in less productive effort on behalf of the student, thus leading to a decrease in student performance. Another explanation is that teachers with advanced degrees are more likely to have opportunities to get promoted and take on administrative responsibilities, especially if they work for a long time in the schools. Therefore, they may need to spend more time on those organizational duties and put less time and effort into their teaching. However, we might be cautious about the generalizability of this conclusion since it was based on the cross-sectional teacher-level data rather than the longitudinal data.

Relationship Between Years of Teaching in Science and Student Science Achievement

This study extended the previous knowledge in this area through examining the relationship between teacher years of teaching specifically in science and student science achievement. All previous studies (Goldhaber & Brewer, 1996, 2000, Monk, 1994; Ye, 2000) have not differentiated among teacher specialties, instead focusing on teacher experience in general and the effect it may or may not have on student achievement. However, inclusion of information on subject-specific teaching experience is critical in developing an understanding of potential differences between teachers who have experience in a given subject and those do not.

Three important discoveries related to years of teaching experience in science were made in this study. First, there was little evidence to suggest that years of teaching science, as an individual factor (direct relationship), contributed to student achievement in science. Therefore, one could conclude that teachers with a greater number of years of science teaching experience were no more effective than those with a lesser number of years experience in influencing student science achievement. Second, student ethnicity influencing the relationship between years of teaching science and student science achievement was another finding made by this study. With this positive interaction, as displayed in Figure 6, White students seemed to improve their science achievement a little bit faster than non-White students, as their teachers' teaching experience increased. The third finding was the negative interaction effect between years of teaching in science and teacher advanced degree in subject, as we discussed in the previous section.

In sum, the results of this study do not provide strong enough evidence to indicate that years of teaching in science strongly influences student science achievement as much as other factors, such as teaching behaviors. Increased years of teaching experience in science might not lead to better student science achievement outcomes. However, such a finding could be useful from a policymaking perspective as well as in considerations of teacher employment and training. For instance, increased years of teaching experience do not automatically translate into better qualified job candidates for teaching positions. Also, despite their individual amounts of experience, all teachers can develop effective teaching skills that can have benefits for their students in terms of learning outcomes.

Relationship Between Teacher Advanced Degree in Subject and Student Science Achievement

Findings in the present study related to the relationship between having an advanced degree and increased student science achievement replicated the results of previous research. As for the effect of teacher's advanced degree in science or education, two important findings were made in this study. First, a teacher's advanced degree in science/education, as an individual variable (direct relationship), was associated with higher student achievement in science. Although this relationship makes intuitive sense, that more highly educated teachers are indeed more successful teachers in terms of student outcomes, such a finding is contradictory to that of previous research (Goldhaber & Brewer, 1996, 2000; Ye, 2000), where a teacher's advanced degree was not shown to influence student achievement, no matter what the subject was, in science, science education, or another area. A possible explanation that has been offered to account for a lack of relationship between science achievement and higher teacher education levels as found in previous research is that science teachers with advanced degrees might not be able to effectively teach at a level that would most benefit students, especially students in the middle-school years, who are at a lower level in terms of their understanding and appreciation for science. In other words, as science teachers pursue advanced degrees in the university setting, they are trained, in terms of their knowledge in science, at the adult level and may have difficulties making the transition to teaching middle-school students the same concepts that they learned at a much higher level. As a result, students may feel frustrated, lose interest in learning, and then show poorer performances on knowledge assessments. Thus, the mixed findings to date leave us with an unclear picture of the exact role that having an advanced degrees has on student achievement in science. The second major finding related to teacher education was the previously mentioned negative interaction between years of teaching experience in science and holding an advanced degree

The U.S. schools districts' teacher compensation system rewards teachers for holding advanced degrees (Wayne & Young, 2003). The results of the present study would suggest that this practice is justified, but especially for new teachers whose students demonstrated the highest performance. More research or intervention work is needed to help teachers with advanced degrees remain effective throughout their careers.

There are several limitations to the present study that should be mentioned. First, the generalizability of study results is limited by the fact that the study was restricted to a sample of sixth-, seventh-, and eighth-grade science classes in one school district in the western U.S. Half the teachers in the sample participated an undergoing professional development program. More than 50% of the students in the sample were minorities. Therefore, the extent to which findings apply to other grades, subjects, teachers, or locations remains to be seen. In addition, as was mentioned before, the cross-sectional data might limit the generalization of some findings. Second, school-related factors, such as school type, average school social economic status, school enrollment, school average pupil-teacher ratio, were not investigated in this study. These variables likely play an important role in the relationship between teacher factors and student outcomes and should be investigated in future research. Third, only teaching behavior was included as mediating variables in this study. It is possible that other teacher-related characteristics, such as teacher attitude and self-efficacy, could also serve to mediate the relationship between both teacher education level and experience on student achievement in science. Fourth, due to missing data on teacher education level and years of teaching in science, data for three teachers and their students were not included in the analyses. This resulted in a smaller than expected sample size at level 2, likely reducing power for level-2 covariates and cross-level interactions.

Despite these limitations, the results of this study extend those of previous research in several important areas. First, effective teaching behaviors mediate the relationship between teacher education and experience with student outcomes, indicating that teacher behaviors carry the most weight in terms of impacting those ultimate outcomes. Second, teacher experience played a smaller role in terms of resulting in high student achievement. Third, an advanced degree in science or education impacts student outcomes, but only as a function of how long the teacher has been in their career. More research needs to be done to find ways to help teachers with advanced training maintain their level of effectiveness with students over the course of their career, not just in the early stages.

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Appendix A

Table A1

Previous Reviews of the Influences of Teacher Experience and Education Level On Student Achievement.

Author	Year	Articles included	Conclusion	Review method
Hanushek	1989	38 articles & books	Teachers’ education and experience do not have positive impacts on students’ achievement.	Vote count
Hedge et al.	1994	38 articles & books (the same as those used by Hanushek in 1989)	There is systematic positive relations between teachers’ quality (education level and experience) and students’ outcomes	Combined significant tests and effects estimation methods
Greenwald et al.	1996	60 studies	The quality of teachers showed strong relations with student achievements.	Combined significant tests and effects estimation methods
Hanushek	1997	90 studies	There is no obvious evidence indicating that teacher education level and experience will have significant impacts on students’ achievements.	Vote count value-added model
Wayne & Young	2003	21 studies	The relationship between teacher education degree and student achievement varies by different subjects.	Narrative synthesizing the individual studies

Appendix B

Table B1

Reviews of Teaching Effectiveness

Author	Year	Teaching behaviors In classroom	Mean ES	# of studies or reviews	Time range	Sample	Conclusions
Medley	1979	1.Classroom management 2.Use of pupil time 3.Method of instruction	N/A	N/A	N/A	Primary grades	Teachers differ on these three categories of behaviors
Martin	1979	1.Teacher interpersonal functioning 2.Teacher and student interaction 3.Classroom management 4.Teacher enthusiasm 5.Praise 6.Feedback 7.Cognitive organization	N/A	More than 10	N/A	N/A	Teacher behaviors make a difference on student learning.
Luiten, Ames, & Anderson	1980	Effects of advance organizers on learning	.23	135 studies	N/A	N/A	Using of advance organizer is very helpful to learning
Wilkinson	1980	Effects of praise on achievement	.16	14	N/A	N/A	Praise only slightly influence students achievement
Redfiled & Rousseau	1980	Effects of higher and lower cognitive questions	.73	20 studies	N/A	N/A	Higher level questioning is effective in learning

(Table continues)

Author	Year	Teaching behaviors In classroom	Mean ES	# of studies or reviews	Time range	Sample	Conclusions
Wise & Okey	1983	1.Questioning	.56	160 studies	past 30 years	5th grade through the early college years.	The effective teaching techniques on the average results in one third of a standard deviation achievement improvement over ineffective techniques.
		2.Wait-time	.53				
		3.Testing	.37				
		4.Focusing	.48				
		5.Manipulating	.56				
		6.Presenting approach	.24				
		7.Inquiry or discovery	.41				
		8.Audio-visual	.16				
		9.Teacher direction	.18				
		10.All above combined	.34				
Lott	1983	1.Inductive versus deductive 2.Use of advance organizer	0.06 0.24	39 studies	1957-1980		Advance organizer is effective
Walberg	1986	1.Classroom management	1.15	15 reviews	N/A	N/A	Strong implication about the influences of teachers management of classroom
		2.Engagement	.88	10 reviews			
		3.Reinforcement	.94	13 reviews			
O'Neill	1988	1.Teacher organization 2.Teacher enthusiasm 3.Classroom climate 4.Classroom management 5.Teacher clarity 6.Advance organizer 7.Instructional mode 8.Questioning level 9.Direct instruction 10.Time-on-task 11.Variablity 12.Monitoring and pace 13.Teacher feedback	N/A	150 studies	1971-1988	N/A	These research factors are well defined and well documented, which showed important influence on student learning.

(Table continues)

Author	Year	Teaching behaviors In classroom	Mean ES	# of studies or reviews	Time range	Sample	Conclusions
Krichbaum	1991	1.Questioning skills 2.Teacher Feedback 3.Structuring of content 4.Direct vs. Indirect 5.Classroom management 6.Teacher organization 7.Emotional Climate 8.Academic focus 9.Interpersonal relationship 10. Scaffold 11.Teacher clarity	N/A	More than 50 studies	1966-1988	N/A	Through reviews a lot of process-product researches, it was found that many teacher behaviors contribute to student learning
Slavin	1994	1. Quality of instruction 2. Appropriate levels of instruction 3. Incentive 4. Time	N/A	More than 50 studies	1971-1992	N/A	These four elements are proved to be multiplicatively related with student achievement.
Quandahl	2001	1.Specified praise 2.Confirming feedback 3.Variety of instructional activities or teaching strategies, 4.Organizational skills 5.Clear and Focused instruction 6.Closely monitor of student progress 7.Interaction with students 8.Scaffold 9.High cognitive level questions	N/A	More than 10 studies	1979-2000	N/A	These characteristics were found to relate with student achievement

(Table continues)

Author	Year	Teaching behaviors In classroom	Mean ES	# of studies or reviews	Time range	Sample	Conclusions
Chu	2003	1.Classroom management 2.Teacher enthusiasm 3.Instruction skills (questioning, variability, and direct instruction)	N/A	11 studies	1976-1998	N/A	These characteristics were found to be good indicators of teaching effectiveness
Marzano	2003	classroom management techniques	.521	more than 100 separate reports,	N/A	N/A	Effective classroom management techniques can improve student achievement
Welsh	2005	1.Systematic teaching 2.Teacher and student interaction 3.Teacher knowledge 4.Teacher competence 5.Teaching time 6.Instructional strategy 7.Questioning skills 8.Pace of instruction 9.Teaching organization 10.Classroom management and classroom climate 11.Monitoring 12.Teaching variety 13.Advance organizer	N/A	More than 50 studies	1974-1997	All grade level	Teacher effectiveness had the greatest influence on student academic progress compared to an array of other possible factors, including previous achievement, class size, poverty, and race.
Walberg	1984	Reinforcement in Science	.81	18 studies	1969-1979	6^{th} to 12^{th} grade	Reinforcement is very important in science

(Table continues)

Author	Year	Teaching behaviors In classroom	Mean ES	# of studies or reviews	Time range	Sample	Conclusions
Wang, Haertel, & Walberg	(1993)	1.Classroom implementation support	-.43	91 meta-analyses, and 179 handbook chapters and narrative reviews, the data for this analysis represent over 11,000 relationships.	1963-1993	All education level	Classroom management was found out to be the most influential factor to student learning
		2.Classroom instruction	.21				
		3.Quantity of instruction	.37				
		4.Classroom assessment	.04				
		5.Classroom management	2				
		6.Student and teacher social interaction	.13				
		7.Student and teacher academic interaction	.93				
		8.Classroom climate	.23				
Schroeder, Scott, Tolson, Huang, & Lee	2007	Questioning Strategies	.74	61 studies	1980-2004	K-12 science education	The largest effect size, 1.48, was for enhanced context strategies such as relating topics to previous experiences or learning and engaging students' interest.
		Manipulation Strategies	.57				
		Enhanced Material Strategies	.29				
		Assessment Strategies	.51				
		Inquiry Strategies	.65				
		Enhanced Content Strategies	1.48				
		Instructional Technology Strategies	.48				
		Collaborative Learning Strategies	.95				

Appendix C

Table C1

Effect Sizes of Teacher Behaviors In Classroom

#	Teacher behaviors in classroom	Mean *ES*	*T* score	# of reviews
1.	Classroom management	.74	70	11
2.	Time	n/a	53.7	5
3.	Teacher and student interaction	n/a	59.3	5
4.	Teacher enthusiasm	n/a	n/a	3
5.	Advance organizer	.235	n/a	6
6.	Questioning	.68	n/a	7
7.	Feedback (Praise and Criticism)	.16	n/a	6
8.	Classroom climate	n/a	45.9	4
9.	Monitor	n/a	n/a	3
10.	Clarity	n/a	n/a	2
11.	Pacing	.53	n/a	2
12.	Variability	n/a	n/a	4
13.	Clear focused instruction	.48	n/a	3
14.	Teaching strategies	.28	47.2	9
15.	Teacher organization	n/a	n/a	4