Recruiting Effective Math Teachers,
Evidence from New York City

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I. Introduction

For well over a decade school districts across the U.S. have struggled to recruit and retain effective mathematics teachers. This problem appears to be more acute in schools serving high poverty student populations (Hanushek et al., 2004). Historically, this has meant that many middle and high school mathematics teachers are teaching out of field (Ingersoll, 2003). NCLB attempted to address this issue by requiring that all children in core academic subjects be taught by a highly qualified teachers (HQT) beginning in 2005-06. To be highly qualified a teacher must, among other things, have state certification and demonstrated knowledge in the subject area. States were afforded substantial discretion in how they met the HQT requirements. Nonetheless, there is evidence that not all teachers meet the HQT standard and that children in high poverty schools are much more likely to be taught mathematics by a teacher who does not meet this requirement (Peske and Haycock, 2006).

In response to the shortage of qualified math teachers, school districts have employed a variety of strategies. Some of these strategies, including paying a one-time signing bonus or a subject-area bonus, largely target the distribution of teachers between districts while leaving the overall pool of candidates relatively unchanged. Other strategies, such as alternative-route certification programs, expand the pool of potential math teachers. For example, the New York City Teaching Fellows Program provided nearly 12,000 new teachers to New York City schools from 2003 to 2008. However, many alternate routes, including the Teaching Fellows, have not been able to attract large numbers of teacher candidates with undergraduate degrees in mathematics or science. For example, fewer than 10 percent of the math certified teachers who entered teaching in New York City in 2007-08 through the New York City Teaching Fellows program had an undergraduate major in mathematics. More recently, several teacher residency programs that focus on math, such as Math for America, have been directing substantial effort to the recruitment and preparation of highly qualified math candidates. While these programs have attracted individuals with undergraduate degrees in Mathematics from very strong undergraduate institutions, to date we know little about the effectiveness of the teachers from these programs compared to those from alternative certification or tradition teacher preparation programs.

In response to the need for qualified math teachers and the difficulty of directly recruiting individuals who have already completed the math content required for qualification, some districts, including Baltimore, Philadelphia, Washington D.C., and New York City, have developed alternative certification programs with a math immersion component to recruit otherwise well-qualified candidates, who do not have undergraduate majors in math. Such programs provide candidates with intensive math preparation to meet state certification requirements while, at the same time maintaining the early-entry approach common in alternative pathways; in these programs, individuals who have not completed a teacher preparation program can become a qualified teacher with only five to seven weeks of coursework and practice teaching. This approach is becoming increasingly widespread but to date there is little evidence of the effectiveness of teachers that enter through this immersion route.

The New York City Teaching Fellows program was among the first to employ a math immersion component in the recruitment of math teachers. Prior to 2003, in the absence of sufficient numbers of teachers who met the math major requirement, New York City employed many uncertified (temporary license) teachers to teach math. These uncertified teachers disproportionately taught low-performing students who frequently were from non-white and low-income families.[1] As of September 2003, the New York State Board of Regents required all districts to hire certified teachers. To address this shortage in mathematics and in other subjects, the New York City Department of Education created the alternative certification pathway, the New York City Teaching Fellows (NYCTF). NYCTF was successful in recruiting new teachers to NYC schools. For example, for the 2007-08 school year, there were 11 applicants to the Fellows program for every vacancy filled by a Fellow. However, recruiting math teachers is often difficult. New York State requires that math teachers receive 30 semester hours of undergraduate mathematics coursework, typically equivalent to a mathematics major, which is not so different from the requirements in many other states. Few college graduates meet this requirement and even fewer of those who do choose to enter teaching. Thus, even with the creation of the alternative certification route, New York City finds it difficult to recruit sufficient numbers of teachers with substantial math coursework or a math undergraduate major.

In response to the continued shortage of qualified math teachers, the district developed the Math Immersion component of the New York City Teaching Fellows. Math Immersion began as a small pilot in 2002-03, just as NYCTF was beginning, and, depending on the year, supplies nearly 50 percent of all new middle and high school math teachers in New York City. Math Immersion seeks to increase the supply of math teachers by reducing entrance requirements and providing opportunities for teaching candidates interested in mathematics to complete the mathematics required to be qualified, without returning to college for an additional degree. By design, the Math Immersion program recruits individuals who did not major in mathematics but who demonstrate evidence of math proficiency by having a math related undergraduate major (e.g., economics or science) or who have math related work experiences.

In this study, we examine the following research questions:

- How does the background and preparation of Math Immersion teachers compare to math teachers entering through other pathways?
- How do the achievement gains of the students taught by Math Immersion teachers compare to those of students taught by math teachers entering through other pathways?
- How does the retention of Math Immersion candidates compare to math teachers entering through other pathways?

II. Background

Theoretical Framework: Content knowledge for teaching

Underlying all teacher preparation policies and programs are implicit and explicit assumptions about what teachers need to know and how they can best acquire that knowledge. For example, policies requiring a mathematics major for entry into secondary mathematic teaching place explicit value on the importance of content knowledge for teaching and make the assumption that such knowledge is best gained through academic preparation in the subject matter. Policies that require passing a test of mathematical knowledge, rather than possession of a college major, also value content knowledge, but do not make the same assumption that knowledge is necessarily linked to specific academic coursework. Similarly, teacher education programs differ in how they include content knowledge for teaching in preparation programs. Some programs require a major or substantial coursework prior to entry, to ensure sound content knowledge, while other programs weave content coursework into the preparation (Author, 2008). In the former case, content knowledge is seen as a pre-requisite background for learning how to teach content, while in the latter case, teacher educators may believe that learning subject matter content in the context of learning to teach may provide more usable knowledge for teaching.

In his seminal article, Shulman (1987) lays out a taxonomy of knowledge for teaching, including knowledge of subject matter. Under knowledge of subject matter, Shulman discusses the importance of deep content knowledge for teachers and proposes the centrality of pedagogical content knowledge, knowledge of subject matter that is uniquely tied to the demands of teaching. His framework suggests that teachers need both formal knowledge of the content they teach, gained through study, as well this more pedagogical understanding of content, gained through both preparation and experience. Research on the relationship between subject matter knowledge in mathematics and teaching, while still equivocal, would seem to support this contention (c.f. Monk, 1994 ; Wilson, Floden, & Ferrini-Mundy, 2001;

National Research Council, 2010). David Monk's work suggests that for secondary mathematics teachers, courses in methods of teaching mathematics may be as important as additional mathematics classes in preparing them to teach. Recent work by Heather Hill, Deborah Ball, and colleagues (c.f. Hill, Schilling & Ball, 2004) elaborates the concept of mathematical knowledge for teaching. Such knowledge focuses on the mathematical aspects of teaching practice and the mathematical knowledge that is required in classroom practice. Examples might include the ability to diagnose students' mathematical errors and their relationship to the mathematics they are learning. Studies using a test of mathematical knowledge for teaching developed by Hill and Ball have found that teachers' performance of such items is related to their students' gains in mathematics (Hill, Rowan, & Ball, 2005).

What is less clear is how teachers develop such mathematical knowledge for teaching. Content-area methods classes during teacher preparation represent one avenue for developing this knowledge (c.f. Clift & Brady, 2005; Author, 2005). Based on this premise, many teacher preparation programs require courses in methods of teaching mathematics as a core part of the curriculum. Programs that see such mathematical knowledge for teaching as central to teaching effectiveness might require more such courses, while programs that see content knowledge as critical may require more mathematics courses. Alternatively, programs may believe that generic teaching ability is more important and require to take classes in more general aspects of teaching, including classroom management, child development, or approaches to teaching culturally and linguistically diverse students.

The curriculum of teacher education, whether alternative or traditional, is always making bets on the knowledge teachers need most as they enter the classroom, and the variation in curricular offerings across programs and pathways reflects these different bets (Author, 2008). The study of Math Immersion programs provides an opportunity to see how institutions organize their programs to provide the mathematics they believe secondary teachers need for teaching.

Linking Teacher Preparation and Student Learning

Linking teacher preparation and pathways into teaching to student learning is a complex process. Student outcomes are influenced directly by the teacher workforce but also by other school inputs and external factors such as student background and environment. Because of these complexities, linking teacher preparation to student achievement is difficult to model empirically. On top of this, the teacher workforce and each teacher's decisions of where to teach and how to teach is influenced by many institutional factors such as state and district policies, by teacher preparation pathways, and even by student performance. Teacher preparation, alone, is difficult to describe and measure, as it comprises many elements from subject-matter, to pedagogy, to child and youth development and classroom management. In addition, quality of implementation likely is at least as important as content coverage in preparation.

With the increasing availability of rich data on students, teachers and schools in recent years, researchers have begun to develop a range of empirical models to examine the relationship between how teachers are prepared and the outcomes of their students. Most of these models either compare the learning gains of students taught by teachers in the same school or compare the learning gains of the same students taught by different teachers in different years. Recent rigorous research using these approaches to assess the effectiveness of alternative routes to teaching shows that individuals entering teaching through highly selective early-entry routes are either as effective in teaching math as teachers entering through traditional preparation programs or become so within the first few years of their careers, (Decker et al. 2004; Authors 2006; Kane et al. 2007; Harris and Sass, 2008; and Constantine et al. 2009).

However, there is wide variation in the selection and preparation requirements of both traditional and alternative preparation programs, and comparing broad categories of pathways into teaching does little to uncover the effects of program or pathway characteristics. In some instances the difference between an alternative route and a traditional route can be more a matter of timing of requirements than a substantive difference in requirements (Authors, 2009). In other cases there are dramatic differences in the requirements that teachers must fulfill to become certified through alternative and traditional preparation programs, (Feistritzer, 2008; Author, 2008). Nearly all of the research examining the relative effectiveness of various forms of teacher preparation has been limited to exploring relative differences in the gains of student achievement for teachers from different programs (e.g. Authors, 2006; Harris and Sass, 2008; Decker, Mayer, & Glazerman, 2004; Raymond, Fletcher, & Lucque, 2001; Xu, Hannaway and Taylor, 2007) without attempting to understand the many components of teacher preparation. There are a few exceptions to this focus on program effects. Constantine et al., 2009 provide a detailed description of differences in programs in their analysis. Author, 2009 assess the effects of preparation program characteristics for elementary school teachers on student learning and Harris and Sass, 2007, examine the extent to which a teacher's specific preparation coursework is associated with achievement gains in her students.

Thus, several studies have examined the effectiveness of teachers from alternative pathways and some have included middle school math outcomes. In addition, a few studies have examined the relationship between preparation features and classroom achievement gains. On the other hand, to our knowledge, no prior research has systematically examined the specific preparation and effectiveness of math teachers, in particular, nor has it examined the effectiveness of routes into math teaching based on a math-immersion model.

Recruiting Math Teachers. New York City hires between 6,000 and 9,000 new teachers every year. In many years prior to the 2003-04 school year, uncertified teachers (temporary license teachers) constituted as much as fifty percent of all new hires. The New York State Board of Regents required that effective as of 2003-04 virtually all teachers must be certified. The Regents also created the opportunity for districts to hire alternatively certified teachers. In response, the New York City Department of Education working with the New Teacher Project created the New York City Teaching Fellows program (NYCTF) and soon thereafter the Math Immersion component of NYCTF (NYCTF-MI). These changes dramatically altered the composition of entering teachers to New York City Public Schools. Figure 1 shows that uncertified teachers were largely replaced by NYCTF and NCTF-MI teachers, although there has also been meaningful increases in the number of College Recommended (traditional teacher preparation) teachers in recent years.

Figure 1 reflects the hiring of all teachers in New York City; however,, for this analysis, we are particularly interested in math teachers. The change in pathways for math teachers was even greater than the changes overall. Prior to 2003, NYCDOE relied heavily on uncertified teachers, because sufficient numbers of College Recommended math teachers were unavailable. In addition, from 2003-04 through 2007-08 New York City expanded the total number of math teachers by 18 percent due to increasing enrollments and reductions in class size.[2] As a result, New York City needed to recruit between 600 and 800 new math teachers per year during this period. When other sources of supply were unavailable, New York City turned to the Math Immersion program to meet demand. For each year starting in 2005-06 until 2009-10 that meant that approximately 20 percent of Math Immersion Fellows did not meet internal selection standards for the NYCTF. The problem is more acute in the recruitment of math teachers than other teachers as only about 12 percent of non-Math Immersion Fellows in that period failed to meet internal standards.[3] Below we explore whether the need to go beyond selection standards affected student

[Figure 1 about here]

performance. Figure 2 shows the number of new teachers who are certified in math.[4] In recent years Math Immersion has supplied nearly half of all new math teachers, far more than any other pathway into math teaching. College Recommended programs have shown strong growth in recent years, but as of 2008 still only supplied about 30 percent of new math teachers.

[Figure 2 about here]

New York City has come to rely heavily on Math Immersion for its new math teachers, accentuating the importance of a better understanding the effectiveness of these teachers and this approach to pre-service preparation. Dramatic changes in other pathways would be needed to fill the demand for middle and high school math teachers if the Math Immersion program were eliminated. In this analysis we compare Math Immersion to other current pathways as a means to understand their effect on student achievement and teacher retention.

III. Data and Methods

The data for this analysis come from three distinct sources: extensive administrative data, information about teacher preparation programs obtained from document reviews and interviews with administrators in teacher preparation programs, and from a survey of teachers.[5] We describe each of these datasets in turn below.

Administrative data: We employ administrative data on students, teachers and schools drawn from a variety of databases from the New York City Department of Education, the New York State Education Department and the College Board. Student achievement exams are given in grades 3 through 8. All the exams are aligned to the New York State learning standards and each set of tests is scaled to reflect item difficulty and are equated across grades and over time.[6] Tests are given to all registered students with limited accommodations and exclusions. Thus, for nearly all students, the tests provide a consistent assessment of achievement for a student from grade three through grade eight. Since the Math Immersion program was initiated in the 2003-04, we include data for all teachers who teach students with mathematics achievement outcomes from 2003-04 through 2007-08. The dependent variables in our models come from annual student achievement exams given in grades four through eight to almost all New York City students. The student data, provided by the New York City Department of Education (NYCDOE), consists of measures of gender, ethnicity, language spoken at home, free-lunch status, special-education status, number of absences, and number of suspensions for each student who was active in any of grades three through eight that year.

For most years, the data include scores for approximately 65,000 to 80,000 students in each grade. Using these data, we construct a set of records with a student's current exam score and his or her lagged exam score. For this purpose, a student is considered to have value added information in cases where we had a mathematics score for the current year and a score for the same subject in the immediately preceding year for the immediately preceding grade. All student achievement scores have been normalized by grade and year to have a zero mean and a unit standard deviation.

To enrich our data on teachers, we match New York City teachers to data from New York State Education Department (NYSED) databases, using a crosswalk file provided by NYCDOE that links their teacher file reference numbers to unique identifiers employed by NYSED. We draw variables for NYC teachers from New York State data files as follows:

- Teacher Experience: For teacher experience, we use transaction-level data from the NYCDOE Division of Human Resources to identify when individuals joined the NYCDOE payroll system in a teaching position. When this information is missing or when the value is less than the value in the NYSED personnel master files, we use the NYSED data.
- Teacher Demographics: We draw gender, ethnicity, and age from a combined analysis of all available data files, to choose most-common values for individuals.
- Test performance: We draw information regarding the teacher certification exam scores of individual teachers and whether they passed on their first attempts from the NYS Teacher Certification Exam History File (EHF).
- Pathway: Initial pathway into teaching comes from an analysis of teacher certification data plus separate data files for individuals who participated in Teach for America or the New York City Teaching Fellows Program.
- College Recommended: We obtain indicators for whether an individual had completed a College-Recommended teacher preparation program and, if so, the level of degree obtained (bachelor's or master's) from NYSED's program-completers data files.

Program Data: The information on preparation programs comes from a data collection effort in the spring and summer of 2004 designed to characterize the preparation received by individuals entering teaching in 2004-05 but also applicable to surrounding cohorts. We focus specifically on the 18 institutions that prepare about two-thirds of the College Recommended teachers hired in NYC schools in recent years. Within these institutions, we concentrated on the pre-service preparation at 25 college-Recommended math certification programs, as well as the preparation provided by two large alternative route programs: the New York City Teaching Fellows and Teach for America.

We rely on a number of data sources to document information about programs: state documents, institutional bulletins and program descriptions, NCATE documents when available, and institutional websites to find information about requirements and course descriptions. In documenting information about courses, whenever possible we use the information that is closest to what is actually taught. For example, we asked programs for the names of instructors who taught math methods for the cohorts completing programs in 2004, and use this list rather than the list of faculty included in the state documents. In addition, we interviewed program directors and directors of field experiences about the curriculum, structure, and field experiences in their programs. We also documented the curricular requirements in each program, focusing specifically on the number of required courses in math methods and in math content, as well as required courses related to learning, assessment, diverse learners, and classroom management. To further document the preparation received in mathematics, we collected syllabi from both math content and math methods courses whenever possible. In our analyses of preparation to teach mathematics, we looked at the overall emphasis on the teaching of mathematics, as represented by the percentage of the curriculum that focused on math, as opposed to an emphasis on less subject-specific preparation. In addition to analyzing course requirements and credit hours, we analyzed syllabi for all mathematics and mathematics methods courses. We developed a coding scheme to look at how closely the mathematics taught in content courses was linked to school mathematics and the ways in which classes asked students to learn about students' understanding of mathematics. We also looked at the mathematical topics included in these courses. These analyses allowed us to investigate the mathematical richness of the required classes, as well as the opportunities to investigate the pedagogical issues related to the teaching of mathematics.[7]

Because participants in these various pathways complete their coursework at different times, it is important to remember that students in the College Recommended programs will have completed all of these requirements prior to teaching full-time as a teacher of record; in both TFA and the NYC Teaching Fellows, participants complete 6-8 weeks of initial coursework prior to becoming full-time teachers, completing the rest of the requirements during their first 2-3 years of teaching.

Surveys: In the spring of 2005 we conducted a survey of all first-year New York City teachers in which we asked detailed questions about their preparation experiences, the mentoring they received in their first year, and their teaching practices and goals; separate section for math teachers focused specifically on aspects of their math teaching and preparation to teach mathematics. Our overall response rate is 71.5 percent. Respondents were asked to consider the preparation they received prior to entering the classroom—what is typically referred to as pre-service teacher education. For teachers who entered through TFA or NYC Teaching Fellows, this referred to the 6-8 weeks of preparation, generally offered in the summer. We received completed surveys from 603 math teachers including 210 Teaching Fellow Math Immersion teachers (NYCTF-MI), 130 Teaching Fellows (NYCTF), 22 Teach For America teachers (TFA), 129 College Recommended teachers (CR), and 112 teachers from "other" preparation routes ("other path").

We employ factor analysis of survey items to measure the extent to which programs emphasize various aspects of preparation. These factors and the survey questions on which they are based are summarized in Appendix A.[8] For this purpose, we identify factors for opportunities to learn about teaching math, their subject matter preparation in math, their preparation in specific teaching strategies, their preparation for special education students, the quality of their field experience, and the overall opinion of the quality of their teacher preparation program.

Methods. In describing teacher preparation programs, we employ data from our analysis of program documents and interviews with program administrators that is summarized in tabular form. We employ the factors constructed from the survey questions in regression analysis to examine whether teachers prepared in certain pathways and programs identify similarities in their preparation that differentiates it from that of other pathways. These regressions also include controls for the school context in which teachers work and their personal characteristics.

As described above, a number of factors potentially complicate the identification of aspects of teacher preparation that may influence the achievement of students taught by these teachers. First, teaching candidates select their teaching pathway, preparation institution and program. This selection is important because of the need to account for it in our assessment of program effects. Also by identifying the features of pathways that attract individuals with the greatest potential, programs can recruit more effective teachers. Second, different pathways into teaching can lead teachers into schools and classrooms with different characteristics. For example, even at the pathway level there exist systematic differences in the observable characteristics of the students they teach (see Table 1). On average the students of Math Immersion teachers appear to be meaningfully more challenging to teach than the students of College Recommended teachers. The students of Math Immersion teachers have math achievement scores that average nearly 30 percent of a standard deviation lower than those of students of College Recommended teachers. They are also more likely to be eligible for free lunch and are more likely to be absent. By the same measures, the Math Immersion teachers have students who appear less challenging than other New York City Teaching Fellows teachers or Teach for America teachers. Because these differences likely influence student outcomes, our empirical models must be able to control for them if we are to identify the effects of preparation as distinct from placement.

[Table 1 about here]

There are two parts to our multivariate analysis of the effects of math preparation. In the first, we explore the effect of pathways by estimating the mean differences in value-added to student achievement in math of teachers from different preparation pathways. We net out the effects of student, classroom and school influences from the effects of preparation pathway. The model for estimating pathway effects is based on the following equation:

$$A_{ijst} = \beta_0 + \beta_1 A_{ijs(t-1)} + X_{it}\beta_2 + C_{ijst}\beta_3 + T_{jst}\beta_4 + \Pi_j + \nu_s + \varepsilon_{ijst} \quad (1)$$

Here, the achievement (*A*) of student *i* in year *t* with teacher *j* in school *s* is a function of his or her prior achievement, time-varying and fixed student characteristics (*X*), characteristics of the classroom (*C*), characteristics of the teacher (*T*), indicator variables (fixed effect) for the preparation pathway, e.g., College Recommended, the teacher completed (Π), a fixed-effect for the school (ν), and a random error term (ε). Student characteristics include race and ethnicity, gender, eligibility for free or reduced-price lunch, whether or not the student switched schools, whether English is spoken at home, status as an English language learner, the number of school absences in the previous year, and the number of suspensions in the previous year. Classroom variables include the averages of all the student characteristics, class size, grade, and the mean and standard deviation of student test scores in the prior year. All pathway effects are estimated relative to Math Immersion.

Because the field is not settled on the appropriate specification for estimating student achievement gains, we estimate a variety of alternative specifications. As noted above, the students of Math Immersion teachers have attributes frequently correlated with students with lower achievement gains than students typically taught by College Recommended teachers. To level the comparisons between Math Immersion and College Recommended teachers, our value-added estimates control for these observable attributes. In particular we include student and classroom-level variables for: prior achievement, absences, suspensions, and poverty status. We also include a school fixed effect, which has the effect of only comparing teachers from different pathways if they taught in the same school. For example, estimates of the effectiveness of Math Immersion teachers are formed by comparing Math Immersion teachers to teachers from other pathways who teach in the same school, thus controlling for many important influences, e.g., the impact of a principal or of differences in student characteristics across schools. Taken together, these controls have the effect of largely controlling for the differences in students that exist across pathways. To explore the robustness of results, we estimate alternative specifications. For example, instead of estimating current achievement as a function of prior achievement, we employ achievement gains. For each of these models we substitute student fixed effects for school fixed effects. Including student fixed effects causes differences in the effects of preparation pathways to be estimated based only on the differences in a given student's performance with teachers from different pathways, most typically in different grades. Finally, we limit the sample to only individuals who began teaching in New York City in 2004-08, rather than all teachers in 2004-08. All models cluster errors at the teacher level.

Whether or not to include teacher characteristics depends upon the question at hand. If we want to know whether teachers from Math Immersion are more effective than teachers from another pathway then there is no reason to include fixed teacher characteristics, such as SAT or certification exam scores. In fact, the benefit of one pathway may come from its ability to recruit and select high quality candidates. However, if we want to separate the selection from the preparation aspects of programs, then it is important to control for teachers' initial characteristics. These controls are particularly important for the parts of our analysis that look at the effects of program characteristics on preparation, as opposed to programs overall. The teacher characteristics that we include are age, gender, race and ethnicity, whether they passed their general knowledge certification exam on the first attempt, SAT scores and a series of indicator variables summarizing the ranking of their under graduate college.

In addition to exploring the average effects of pathways, we are interested in a series of related questions. How do the effects of pathways differ based on teaching experience—that is do the students of novice teachers in Math Immersion experience different achievement gains from the students of novice teachers in other pathways and how do these patterns change as teachers become more experienced? To examine this question we interact pathways with teaching experience for each of the first four years of experience.

IV. RESULTS

In this section we address each of the three research questions in turn.

Question 1) How does the background and preparation of Math Immersion teachers compare to math teachers entering through other pathways?

Attributes of Mathematics Teachers. There are meaningful differences between the attributes of Math Immersion teachers and teachers who enter through pathways other than NYCTF, particularly the College Recommended pathway. As shown in Table 2, Math Immersion teachers, both those teaching in high school and middle school, are a more diverse group of teachers than their College Recommended peers—they are substantially more likely to be male, Black and Hispanic. They also tend to perform better on most measures of academic ability, including the math and verbal SAT exams, the Liberal Arts and Sciences Test (LAST), New York's general knowledge certification exam, and the math/science sub-score of the LAST, although they perform slightly worse on the Content Specialty Test in Mathematics

(CST Math) and the secondary pedagogy exam (ATS Secondary). Not surprisingly Math Immersion teachers are fairly similar to other NYCTF teachers but perform less well on all measures of academic ability than TFA mathematics certified teachers.

[Table 2 about here]

Many of the Math Immersion teachers who become mathematics certified either have a mathematics related undergraduate major (49 percent) or mathematics related work experience (19 percent).[9] Although it appears that a substantial percentage of Math Immersion teachers do not have mathematics related majors or work experiences, we do not have information on college course work which is another way candidates may have met the Math Immersion eligibility criteria. On most measures, Math Immersion teachers who do not have mathematics related backgrounds have qualifications that are at least as strong, and sometimes stronger, than those with mathematics related backgrounds.

NYCTF mathematics teachers and the subcomponent of Math Immersion teachers are prepared at several different institutions. Table 3 shows that four campuses[10] are responsible for the vast majority of these teachers. In an analysis of the attributes of mathematics certified teachers prepared at these campuses, many of the demographic characteristics of teachers are very similar, though Campus C's teachers tend to be somewhat older and are more likely to be male, while Campus A's teachers are more likely to be Black. There is remarkable consistency across many of the measures of ability, with the exception that Campus C's relatively small Math Immersion program has teachers who outperform several other campuses on the pedagogy exam. On the SAT mathematics and verbal tests, Math Immersion teachers at Campus Z perform better, while those at Campus A appear to perform worse than the other campuses.

[Table 3 about here]

Among the College Recommended programs, a similarly small number of campuses account for most of the mathematics certified teachers. Three institutions R, S, and T account for 40 percent of all the mathematics certified teachers produced by College Recommended programs hired by New York City schools over the five years 2004-08. Each year, most programs produce only a handful of mathematics certified teachers who are hired in New York City.

Differences in Preparation Between Math Immersion and College Recommended Pathways. Our reviews of program requirements across 25 College Recommended and 5 Math Immersion programs suggest that there is relatively little variation between pathways but substantial variation within each pathway with regard to required coursework. Table 4 shows the average number of courses and course credits required across several key components of pathways; we have where we have separated the requirements of graduate and undergraduate College Recommended programs. As these results show, the average Math Immersion program requires roughly as many or more courses and credit hours in most components of the programs, including mathematics content and mathematics methods, as either the average graduate or undergraduate College Recommended program. There are two exceptions. The undergraduate College Recommended programs require more credits in classroom management and learning than do Math Immersion programs (1.75 credit hours v. 0.6 credit hours for classroom management and 4.5 v. 2.4 credit hours for learning). Both undergraduate College Recommended programs and Math Immersion program required more credits in math content than did the graduate CR programs; this difference reflects the fact that New York State requires a mathematics major or its equivalent for entry into most graduate certification programs.

[Table 4 about here]

These findings are often, but not always, supported by our survey of teachers regarding their perceptions of the preparation they received in their programs. Table 5 presents the results of regression analyses where factors created from teachers' responses to survey questions regarding their perceptions of the opportunities they had to engage in various preparation activities during pre-service education are regressed on preparation pathways and school context factors. In this analysis, all pathways are relative to the Math Immersion pathway. As shown, teachers from College Recommended programs cite significantly greater general opportunities to learn about the teaching of math, preparation in specific teaching strategies, greater quality of field experiences and more opportunities to learn to work with special education students. There is no difference in perceptions of opportunities to learn mathematics content between College Recommended teachers and Math Immersion teachers. It is also the case that Teach for America teachers report more opportunities to learn specific strategies and better field experiences but less opportunity for mathematics subject matter preparation, as was the case with regular Teaching Fellows. Regular Teaching Fellows also report fewer opportunities to learn how to teach mathematics but more opportunities in learning about specific strategies. Again, it is important to remember that the survey asked specifically about opportunities to learn prior to entering the classroom as a full-time teacher; teachers in both TFA and NYC Teaching Fellows, including Math Immersion, were still taking courses to fulfill program requirements as first-year teachers at the time they completed this survey.

[Table 5 about here]

Although we find only modest differences in the average program requirements between Math Immersion and College Recommended programs, we do observe greater differences among programs within each pathway.

Variation Within Preparation Pathways. While Math Immersion was designed as a single program, the preparation experiences of NYCTF-MI teachers can be quite different depending on which institution they attend. College Recommended programs also establish differing program requirements within the broader requirements established by New York State. To understand the preparation in each program, we accessed program documents and accreditation materials as well interviewed program directors and field coordinators.

A Math Immersion Teaching Fellow could be prepared in mathematics and general pedagogy in very different ways, depending upon the campus at which he or she was prepared. As Table 6 suggests, the programs vary in terms of their course requirements.[11] There are three telling aspects of this analysis. First, there are remarkable differences across campuses in their mathematics content and mathematics methods requirements, ranging from one 3-credit course in mathematics content required by at Campus Z to 5 or more courses required by Campuses A, B and C. The range in requirements for mathematics methods was smaller. In sum, Math Immersion Fellows could receive different emphasis on mathematics content or mathematics methods depending on the campus they attend. Second, there is a range of requirements in general pedagogy[12] across these programs. As seen in Table 6, only two of the five campuses required courses on assessment, and, despite the continued emphasis upon and discussions about the role technology should play in teacher education programs, only one campus required coursework in technology. Finally, of the five campuses that prepared Math Immersion Fellows, four programs required at least one course in learning or child development.[13] However, again, as with the preparation in other areas reported thus far, the requirements in learning range substantially. Variation across the other components of preparation programs was not meaningful.

[Table 6 about here]

In sum, the most striking variation across programs lies with whether programs put greater emphasis on mathematics content and methods, or more emphasis on more general preparation for teaching that was not specific to teaching mathematics topics, courses or issues. For instance, two of the Math Immersion fellows programs are structured around heavier requirements in general courses on pedagogy and learners and learning (Campus Z and Campus D), and require fewer courses in mathematics and mathematics methods. Campus Z has particularly weak requirements in mathematics content. Campus Z program requires 3 credits in mathematics content, and 6 credits in methods; these requirements represent 9 of the total of 39 credits, or 23 percent of the total required. On the other hand, at Campus C, mathematics methods and mathematics content credits represent 30 of the required 47 credits, for 63 percent of the total requirements. Campus A and Campus C stand out for their curricular emphasis on mathematics content and mathematics methods in their course requirements.

We also examined program documents and interviewed program administrators of College Recommended programs in mathematics who supply the majority of mathematics teachers from College Recommended programs for New York City public schools (See Table 7). The programs we reviewed included a total of 25 programs at 16 campuses, 14 of these programs were graduate programs, 11 were undergraduate programs. Of the 16 institutions, 10 are private and 6 are public. It is worth noting that all of the institutions that offered NYCTF Math Immersion programs also offered College Recommended programs in mathematics.

[Table 7 about here]

We find a substantial range in requirements in mathematics content across these programs. For graduate programs in the teaching of mathematics, requirements ranged from *no* courses required in mathematics content, to *five* courses in mathematics content (See Table 7). In part, these lower requirements in mathematics content in graduate programs may be due to the fact that most of the graduate programs required mathematics preparation prior to entry; in many of these programs, incoming applicants were required to have been mathematics majors, although there is substantial variation among undergraduate programs in mathematics content, too. In terms of mathematics methods courses, we find a similar range with regard to requirements; almost half of the programs required just one mathematics methods course and four programs required either three or four courses. In sum, the range of requirements in mathematics methods appears to be somewhat similar to the range seen in the Math Immersion programs.

The variation in requirements for preparation in learning and in classroom management in College Recommended programs also is similar to that in Math Immersion. As summarized in by the standard deviations of required courses and credit hours for Math Immersion and College Recommended programs (Tables 6 and 7), the variation of within pathway course requirements substantially exceeds the variation between pathways. This is perhaps not surprising in that New York's alternative preparation pathways are best characterized as allowing for differences in the timing of meeting New York State certification requirements rather than allowing for different requirements.

In light of our program analyses revealing that one program, Campus Z, stands out as having the fewest requirements in mathematics-related preparation, we examine the results of the survey comparing the responses of students from campus Z to students from the other Math Immersion campuses. To explore differences among Math Immersion programs across our measures of teacher preparation, we estimate models including indicator variables for each campus within the Math Immersion pathway where the comparison group is teachers prepared at Program Z. Because a teacher's perspective on her preparation may be influenced by the context in which she is teaching at the time she completes the questionnaire, we estimate models that include school context factors as controls. This has the effect of only comparing teachers from different pathways who teach in the same school.[14]

As compared to teachers from Campus Z, we find that Math Immersion teachers from other campuses score higher across survey factors measuring preparation program attributes.[15] Though the coefficients are only sometimes statistically significant, they are consistently positive. When we group together all other campuses and compare them to Campus Z, teachers from all other campuses report having significantly more opportunities to learn to teach mathematics and more preparation to use specific teaching practices; however there are no differences in their perceptions of opportunities to learn mathematics content. These results are consistent with many, but not all, of the findings from our program review. Additionally, teachers from other campuses report higher quality field experiences.

Based on our review of the structure and content in Math Immersion and College Recommended preparation programs in mathematics and based on teacher reports of their preparation, there appears to be substantial variation within and across pathways. We now explore whether different pathways influence gains in student achievement outcomes.

Question 2) How do the achievement gains of the students taught by Math Immersion teachers compare to those of students taught by math teachers entering through other pathways?

Are teachers entering teaching in New York City through the Math Immersion program more or less effective in producing student gains on achievement tests than mathematics teachers from other pathways? Based on their preparation and their background, there are reasons to believe that NYCTF-MI teachers may have different effects on students than do other teachers. By definition, Math Immersion teachers do not have an undergraduate major in their subject area, which is commonly required for teachers entering through the College Recommended pathway. However, Math Immersion teachers also tend to have stronger academic credentials than teachers from other pathways with the exception of those entering through Teach for America. To explore the relative effectiveness of Math Immersion teachers in improving student achievement outcomes, we estimate several value-added models for students taking standardized mathematics achievement exams in grades 6-8.

We should note that to more fully examine mathematics achievement, we would like to have value added measures for high school mathematics, but such data do not currently in exist in New York City, or most other districts. This does raise a potentially important methodological issue of the placement of mathematics teachers between middle school and high school. There is anecdotal evidence that many mathematics teachers prefer to teach in high school and that many preparation programs steer their strongest students toward teaching positions in high schools, where content knowledge may be even more important. To assess whether there is any evidence of this and more importantly if such placements differentially affect some pathways or programs (a sample selection issue), we examine the qualifications of high school and middle school mathematics certified teachers by pathway (Table 2) and by program (not reported here[16]). In both instances, there is systematic evidence that, on average, more qualified mathematics teachers are found in high schools; however, this phenomenon appears to occur across pathways and programs and thus does not raise concerns regarding our estimates.

Our value-added estimates of mathematics achievement gains in grades 6 through 8 are consistent with theory and what is found in most other research employing administrative data (see Table 8). All of the student attributes affect achievement. For example, prior achievement (Lag Score and Lag Score Squared) is an important predictor of current achievement, Asian students outperform whites (the reference group), while Black and Hispanic students have lower achievement gains than whites. Our normalization of achievements to zero mean and unit standard deviation implies that coefficients are measured in standard deviation units. Thus, for example, Black students are estimated to have achievement gains that are 0.06 standard deviations less than whites. Students who have changed schools perform substantially more poorly than those who are not mobile, as do students with more absences and suspensions, other things being equal. The attributes of class peers also influences student achievement in the expected ways (see Class Average Measures). As has been found in several previous studies (see

Rockoff, 2004; Rivkin et al, 2005; Author, 2008), increasing experience as a teacher improves student mathematics achievement for the first four or five years, with additional experience having no meaningful effect on achievement. This effect includes both changes in an individual teacher's ability to improve achievement and the changing composition of the workforce. If teachers who are less effective are disproportionately more likely to leave middle school mathematics classrooms then at least some of the gains to experience may reflect this attrition.

[Table 8 about here]

Pathway Effects. The focus of this research is the effect of the pathway through which a teacher enters teaching, and in particular the relative effect of teachers who enter through Math Immersion, the omitted pathway in the estimates found in Table 8. These estimates suggest that on average, students of Math Immersion teachers in grades 6-8 have smaller gains in mathematics achievement than students of teachers from the College Recommended, Teaching Fellows, and TFA pathways. Coefficients reflect effect sizes. In gauging effect size magnitudes, it is useful to compare coefficient estimates to the effect of student gains produced by the first year of teaching experience, which most observers regard as important to student achievement. In this context, the effect of having a Teach for America teacher relative to a Math Immersion teacher is roughly the same as the first year of teaching experience (an effect size of 0.05). The additional achievement of students of College Recommended (0.016) and regular Teaching Fellows (0.021) relative to Math Immersion teachers is estimated to be between 32 and 40 percent as large as the first year of teaching experience; although not statistically significant in these estimates, they are significant at the 10 percent level in models with school fixed effects.[17]

Although there are significant differences between the mean effects of some of the pathways, there is also substantial overlap of the distribution of teacher value added. Figure 3 shows the distribution of the teacher fixed effects by pathway.[18] The distribution of TFA teachers is generally shifted to the right, but they also have a meaningful number of relatively more effective teachers as indicated by the bump in the distribution between effect sizes of 0.4 and 0.6. Although the distributions diverge in some interesting ways, it is clear that most of the teachers from one pathway are indistinguishable from teachers who entered through other pathways.

[Figure 3 about here]

To explore the robustness of these findings, Table 9 compares these estimates across a variety of model specifications. We examine the consequences: of employing student fixed effects rather than school fixed effects, of including teacher controls (age, gender, race and ethnicity, whether they passed their general knowledge certification exam on the first attempt, SAT scores and a series of indicator variables summarizing the ranking of their under graduate college), and of employing achievement gains rather than levels as the dependent variable. In general, the effect of gains rather than levels results in only minor changes in the estimated effects of pathways (columns 1 and 3 versus 2, and 4). Similarly employing student fixed effects rather than school fixed effects as controls changes the estimated coefficients in small ways, though the regular Teaching Fellows and College Recommended pathways are now statistically significantly different from Math Immersion at the 5 percent level or better (e.g., column 1 v. 5).

[Table 9 about here]

<u>Does Selection Matter?</u> Including teacher controls substantially reduces the magnitude of the pathway coefficient estimates (Table 9, columns 3, 4, 7 and 8). In general we believe that teacher preparation programs perform two functions—selection and preparation, and should be judged on the combined effect. However, we also find it interesting to attempt to disentangle these components by including teacher controls that can be viewed as proxies for variables programs use in determining admissions. Admittedly these are not strong controls for the characteristics that likely differentiate teachers when they apply to programs. However, the effect of including the teacher controls that we can observe has the effect of reducing the TFA pathway effect by more than 70 percent (0.055 to 0.018) in the model estimated in levels with school fixed effects. This is consistent with the notion that TFA is very good at recruiting and identifying teachers who are ultimately effective in producing achievement gains. This also suggests that our proxies for teacher qualifications are important in improving student achievement.[19] In addition, we estimate the same models presented in Table 9 but limiting the sample to only teachers who began their careers in 2003-04 or later. These results are very similar to those presented in Table 9; however they indicate that College Recommended teachers outperform Math Immersion teachers (effect size =0.035).[20] To understand this result better, we explore the relationship between experience and pathway in more detail.

<u>Are there Differential Gains from Experience?</u> As mentioned earlier, the timing of teacher preparation is much different for teachers entering through alternative certification pathways such as Math Immersion than for teachers entering through College Recommended programs in New York. Due to these timing differences, it is useful to explore how the effects of pathways may differ systematically with the early years of teaching experience. We might expect that teachers entering through alternative certification pathways might be less effective in their first year or two of teaching but that the gap would close as they both gained more experience and completed their preparation requirements.[21] Table 10 summarizes the difference at each level of experience between each pathway and Math Immersion and whether that difference is statistically significant. Students of Math Immersion teachers typically have smaller mathematics achievement gains at every level of experience than those of College Recommended and Teaching Fellows teachers. However, these differences are typically not statistically significant at the 10 percent level. Math Immersion teachers are estimated to be less effective than TFA teachers at each level of experience. These effects are statistically significant only in the first and second years, which likely reflects the small sample sizes in both groups, as the point estimates remain relatively large.

[Table 10 about here]

Are Some Programs More Effective? Our earlier analysis of the structure and content of the preparation that Math Immersion Teachers revealed substantive variation across the five programs that prepared the vast majority of Math Immersion Teachers. Further we found some differences in the teaching candidates who participated in each of these programs. To explore whether these differences resulted in differential student achievement gains, we estimated models that included all pathways but also identified the specific institutions through which Math Immersion teachers were prepared (see Table 11). Here teachers enrolling at Campus Z are the comparison group. These results suggest that Campuses B, C and E appear to outperform Campus Z in most model specifications and Campus D does so less consistently. When Campus Z is eliminated from the estimation of pathway effects there are no differences between College Recommended, Teaching Fellows and Math Immersion teachers. Taken together, these results suggest that the specific implementation of Math Immersion in different programs can importantly affect teacher preparation and resulting student achievement.

[Table 11 about here]

In trying to understand the relatively less effective performance of teachers from Campus Z, we refer back to our analysis of program requirements and of the survey results. As described above, Campus Z had the fewest requirements in mathematics and mathematics methods of all the Math Immersion campuses, while Campus C had the greatest followed closely by A and B. These results are suggestive, but given the few programs training Math Immersion teachers and the numerous ways in which they may differ, we cannot hope to make causal statements of the effects of program design on outcomes. These results do suggest that more research should focus on the relationship between the quantity and quality of mathematics content and pedagogy preparation and a teacher's ability to improve mathematics achievement.

Question 3) How does the retention of Math Immersion candidates compare to math teachers entering through other pathways?

The students of individuals who enter teaching through the Math Immersion program appear to have mathematics achievement gains that are somewhat lower than those of College Recommended and substantially lower than TFA teachers.. Most policy makers appropriately place great weight on student outcomes as means of evaluating alternative policies and programs. Increasingly, teacher attrition has become an important issue, as there is concern that individuals who enter teaching through alternative certification routes, such as Math Immersion, are less likely to remain in teaching. Teacher attrition is potentially troubling for several reasons. First, there is very strong evidence that the effectiveness of teachers improves during their first four or five years (see Rockoff, 2004; Rivkin et al, 2005; Author, 2008) and as a result losing teachers who have gained experience directly influences student achievement, other things being equal. There are indirect effects as well. High turnover rates make it difficult for school leaders and teachers to work together effectively, thus compromising the learning environment. Finally, the costs associated with recruiting and mentoring new teachers represents a substantial investment that could easily be employed in other ways (see, for example, Barnes et al. 2007).

We employ personnel files from the New York City Department of Education to explore teacher attrition. These files identify each time a teacher changes status, e.g., retire, transfers schools, take a leave of absence, etc. Using these data we define a teacher in any given year as someone employed as a teacher as of October 15th of that academic year.[22] Teachers are defined as remaining in the same school if their personnel records indicate they began the next academic year teaching in the same school; they are defined as having transferred to another school in NYC at the beginning of the next academic year they are a teacher in a different school; and they are defined as leaving teaching in New York City public schools if personnel records show they have retired, exited or were on leave and not returning for more than one year.[23]

Descriptive statistics characterizing the attrition rates for math-certified teachers by pathway in grades 6 through 12 are shown in Table 12. Math Immersion teachers had relatively low first year attrition but in years 2 through 4, Math Immersion teachers, like teachers from other alternative certification pathways experienced a higher likelihood of transferring and leaving the New York City public school system. By the end of what would have been their fourth year, more than 40 percent of Math Immersion teachers have left teaching in New York City and fewer than a third remain in their original school. This is higher attrition than College Recommended teachers, 31 percent of whom have left New York City teaching while about half remain in their original school. Math Immersion teachers persist in teaching at somewhat greater levels than other New York City Teaching Fellows, and at much greater levels than Teach for America teachers. By the conclusion of the fourth year, nearly 80 percent of TFA teachers have left teaching in New York City public schools, while fewer than 10 percent remain in their original schools.

[Table 12 about here]

How would the academic gains of students differ as a result of school officials systematically filling job openings by hiring teachers entering through one pathway versus another? The answer, in part, depends upon the relative effectiveness of teachers at each level of experience across pathway as discussed above. However, it is also necessary to account for differences in retention rates across pathways. This follows from the meaningful gains in teacher value-added associated with increased experience over the first few year of teaching. If one pathway consistently has higher turnover, even if its teachers do well relative to those in other pathways with *the same experience*, the pathway may not be providing the most effective teachers, on average.

How does the average value-added of teachers vary across pathways once differences in teacher retention rates are taken into account? We address this question using the following simulation. Suppose that school officials hired an arbitrary number of new teachers (e.g., 1000) from each of the pathways. For subsequent years, the teachers hired from each pathway are allowed to age through the experience distribution, applying the pathway dependent retention rates implied in Table 12. Teachers who leave are replaced by teachers with no prior experience from the same pathway. These new hires in turn age through the system. Pathway value added is computed as the pathway by experience value added (Table

10 without teacher controls) adjusted to accounted for teacher retention (Table 12). In this way, it is possible to simulate how the experience distribution of teachers from each pathway would evolve over time and differ across pathways, thus allowing us to estimate how such differences affect the average value-added of the teachers from each pathway. These results are shown in the top panel of Table 13. The most striking result is that the clear advantage that TFA teachers had at every level of experience (see the value added estimates in the bottom panel of Table 13) dissipates as the very high attrition of TFA teachers following their second and third years of experience causes many more TFA teachers to be replaced by novices. Because of its lower attrition, the College Recommended pathway develops a small advantage relative to the Math Immersion and is roughly equivalent to the regular Teaching Fellows and TFA pathways.

[Table 13 about here]

V. Conclusion

Math Immersion was born of necessity to assist in filling the vacancies when uncertified teachers were barred from teaching and insufficient numbers of College Recommended or alternatively certified teachers who met the existing mathematics certification requirements were available to teach in New York City. Four years since its inception, the Math Immersion preparation pathway has supplied 50 percent of all new certified mathematics teachers to New York City public schools. Given this growth, it is important to examine the design of the program and its effects on student achievement.

In general, we find that Math Immersion teachers have stronger academic qualifications, e.g., SAT scores and licensure exam scores, than their College Recommended peers, although they have weaker qualifications than Teach for America teachers. In addition, Math Immersion teachers are found in some of the most challenging classrooms in New York City. In this respect, the program has succeeded in attracting teachers with stronger academic backgrounds to teach in high needs schools.

However, despite stronger general academic qualifications, Math Immersion teachers are responsible for somewhat smaller gains in mathematics achievement for middle school mathematics students than are College Recommended teachers, although in many cases these differences are not statistically significant. Math Immersion teachers have substantially smaller gains than Teach for America teachers. These results are robust to a variety of alternative specifications. However, Math Immersion teachers are more likely to leave teaching in New York City than are their College Recommended peers, but substantially less likely to do so than Teach for America teachers. In simulating the impact of attrition on the effectiveness of different pathways, the College Recommended pathway develops a small advantage relative to Math Immersion but is roughly equivalent to Teach for America and regular Teaching Fellows.

Based on the value-added and attrition results, one might be tempted to conclude that New York City should be hiring more TFA and College Recommended teachers and looking to dismantle the Math Immersion program. However, such a conclusion ignores the fact that for many years prior to the creation of Math Immersion, New York City hired a very large number of uncertified teachers; many of these teachers taught middle and high school mathematics classes precisely because there were insufficient numbers of College Recommended teachers certified in mathematics who were willing to staff these low-performing schools. While the number of math teachers prepared through College Recommended programs has increased in recent years, these programs are still not preparing sufficient math teachers to fill the demand. Additionally, due to reduced demand for teachers beginning in 2008-09, the Math Immersion program has been able to raise the standards by which it accepts applicants. It will be interesting to assess whether this change affects the average effectiveness of new cohorts.

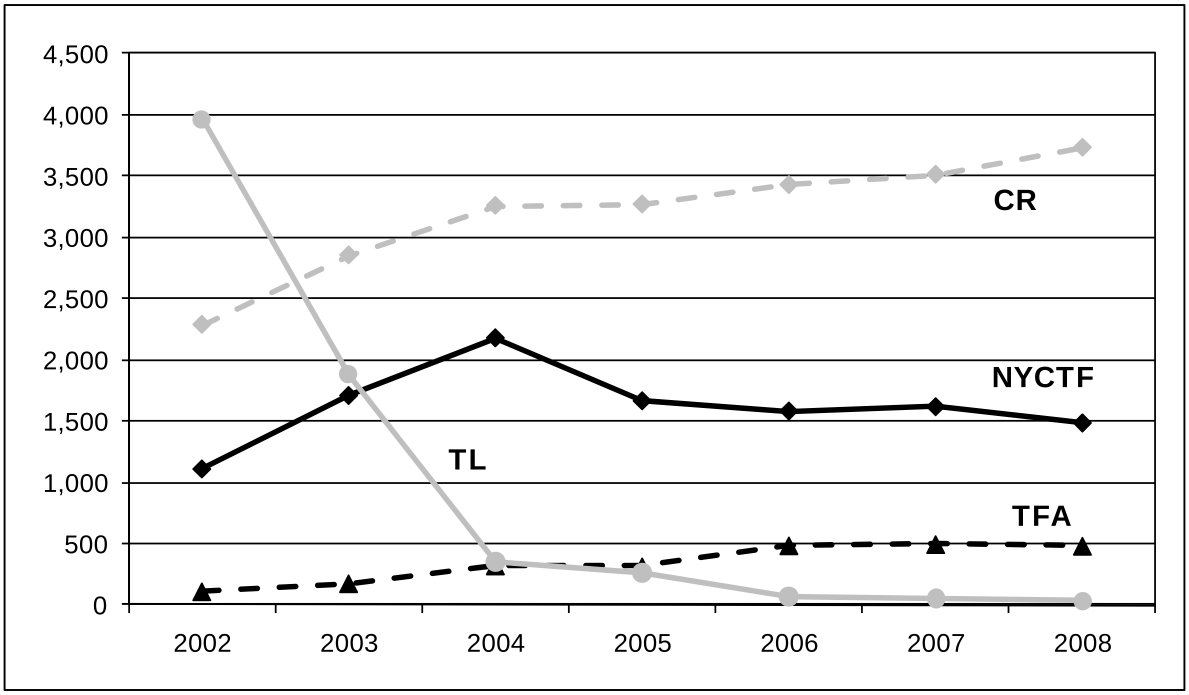
Recruiting and preparing high quality teachers to meet the demand of K-12 schools is a massive undertaking, and many high needs schools have found it very difficult to recruit and retain effective teachers. While there is a great deal to learn regarding the effective recruitment and preparation of teachers, there is already ample evidence that each pathway produces teachers who range in effectiveness, with some very effective teachers and some teachers who are less so. Similarly, within pathways programs vary in their effectiveness. This suggests that the policy discussion about teacher preparation should be focused on the features of programs and pathways that contribute most powerfully to successful teachers and not whether one pathway outperforms another. Given variation within pathways, policymakers are well advised to invest in the development of programs that draw on the most promising features of the more successful existing programs.

As we have argued earlier, programs can influence their outcomes through both the recruitment and selection of promising candidates and strong preparation. The analysis in this paper suggests that on average TFA teachers produce student achievement gains in middle school mathematics that exceed those of teachers from other pathways with comparable experience. TFA has invested heavily in the recruitment and selection of its Corps members and our findings suggest this effort accounts for a substantial portion of the difference achievement differences between TFA and Math Immersion or College Recommended teachers. However, this advantage is largely eliminated once the much higher attrition of TFA teachers is taken into account. Additionally, TFA recruits far fewer teachers into New York City schools than do either the Teaching Fellows or College Recommended pathways. Although programs may have differing goals, investing resources to develop a more qualified pool of teacher candidates can produce more effective teachers for low-performing schools.

Selection, however, is only one part of the equation. We also suspect, although we have only limited evidence to support the hypothesis, that a teacher's preparation in mathematics content and pedagogy may influence the mathematics achievement of his/her middle school students. We found evidence regarding the positive influence of mathematics content and the nature of field experiences when we examined the attributes of teacher preparation programs in childhood education (Author, 2009). The somewhat weaker performance of Math Immersion teachers relative to College Recommended teachers in light of the stronger academic skills of Math Immersion teachers also may suggest that preparation can improve teacher effectiveness; and the TFA advantage in middle school mathematics may in part signal the importance of strong mathematics content knowledge as well. In addition, the more circumstantial evidence on the impact of a program with limited content preparation, indicated by the weak effects of program Z, also suggests that programs invest in math-specific preparation, in both content and pedagogy.

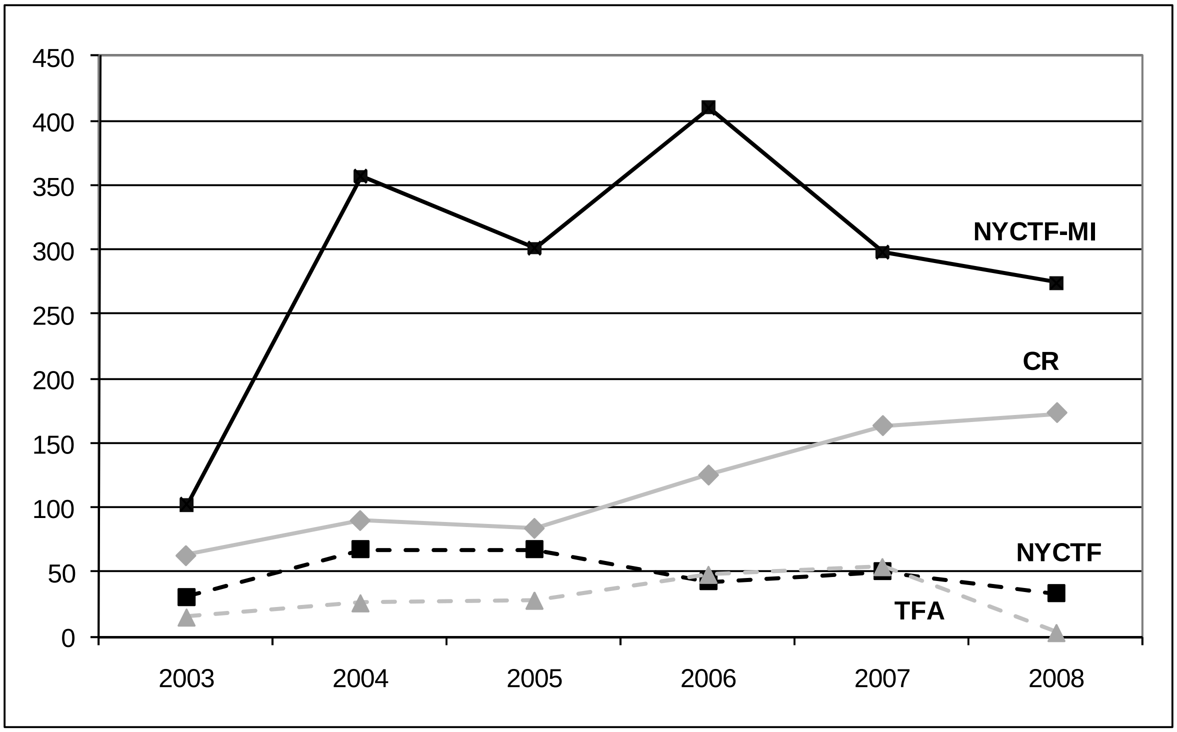
One of the implications of this line of reasoning is to design and evaluate programs that combine the recruitment of academically strong candidates with high quality preparation in mathematics content, mathematics pedagogy, and field experiences that provide them with opportunities to observe effective teachers and practice their teaching skills in closely supervised classrooms of high needs students. The variability of teachers within each pathway points both to the importance of better understanding effective recruitment *and* preparation and to the importance of monitoring and supporting teachers once in the classroom. Improving the quality of mathematics teaching in our schools will require more systematic and rigorous evaluation of the selection and preparation components of teacher education and attention to the impact of retention on the effectiveness of different pathways.

Figure 1: Number of Teachers Entering New York City Public Schools by Pathway, 2002-2008*



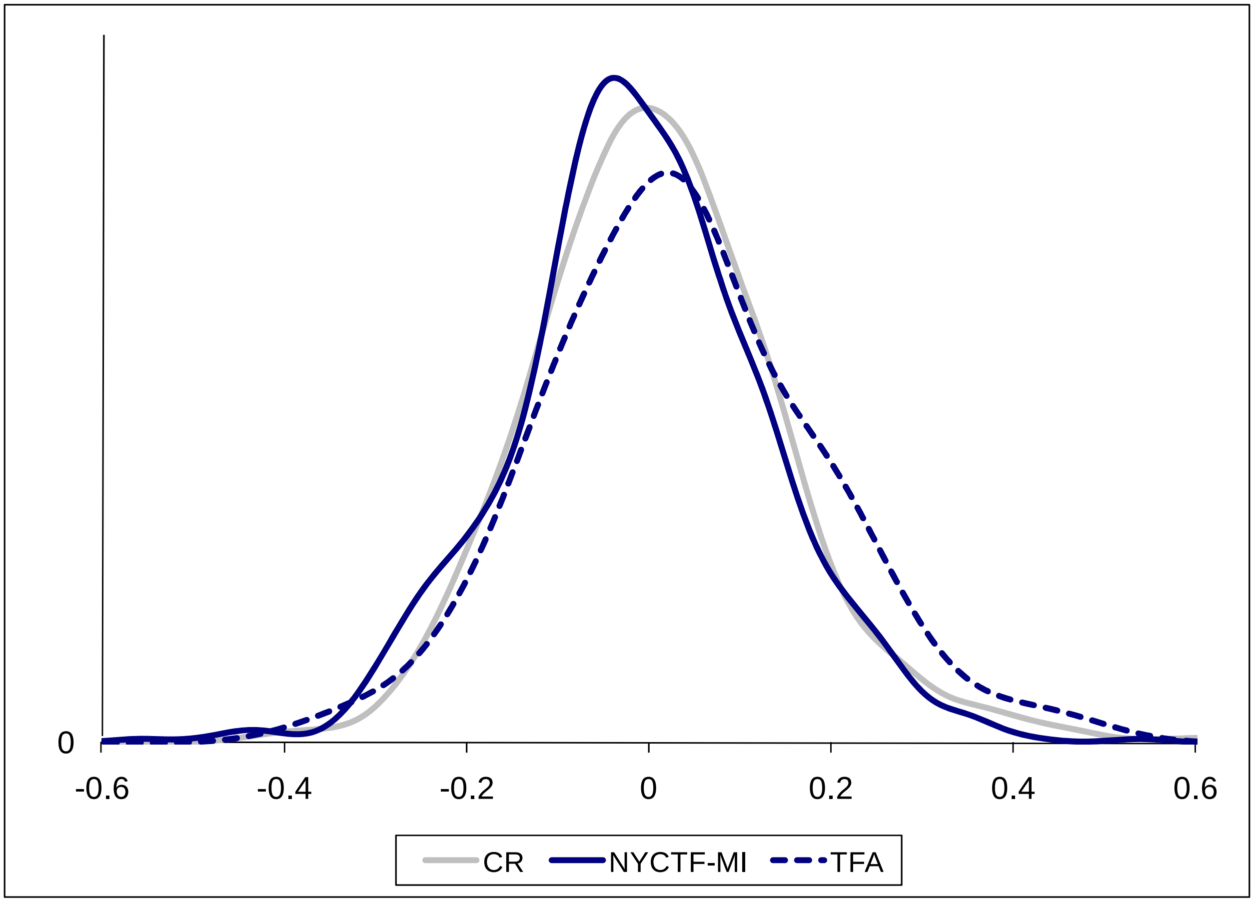
* CR: College Recommended, NYCTF: New York City Teaching Fellows, TFA: Teach for America, TL: Temporary License (uncertified).

Figure 2: Number of Entering Math Certified Teachers New York City, by Pathway, 2002-2008*



* CR: College Recommended, NYCTF: New York City Teaching Fellows, NYCTF-MI: New York City Teaching Fellows, Math Immersion, TFA: Teach for America.

Figure 3: Distribution of Teacher Value Added by Pathway, with Empirical Bayes Shrinking, 2004-2008*



* CR: College Recommended, NYCTF-MI: New York City Teaching Fellows, Math Immersion, TFA: Teach for America.

Table 1: Attributes of Students Taught by First-year Teachers by Pathway, Grade 8, 2006*

Student Attributes	CR	NYCTF	NYCTF-MI	TFA	other
Lagged Math Achievement	0.238	-0.125	-0.051	-0.139	-0.061
Proportion Black	0.292	0.277	0.322	0.442	0.403
Proportion Hispanic	0.358	0.496	0.493	0.527	0.372
Proportion Free Lunch	0.547	0.664	0.635	0.619	0.66
Classsize	27.6	27.8	26.9	26.3	26.1
Lagged Student Absences	12.3	13.4	13.1	14.8	13.5
Lagged Suspensions	0.037	0.064	0.062	0.023	0.042

* CR: College Recommended, NYCTF: New York City Teaching Fellows, NYCTF-MI: New York City Teaching Fellows, Math Immersion, TFA: Teach for America, Other: all other pathways.

Table 2: Attributes of Entering Math Certified New York City Teachers by Pathway, 2004-2008*

Teacher Attributes	CR		NYCTF		NYCTF-MI		TFA	
	High School	Middle School	High School	Middle School	High School	Middle School	High School	Middle School
Female	0.648	0.732	0.446	0.563	0.479	0.546	0.492	0.551
Black	0.073	0.105	0.130	0.197	0.142	0.200	0.082	0.141
Hispanic	0.065	0.046	0.068	0.066	0.085	0.074	0.066	0.043
Age	29.7	28.9	30.4	29.1	31.1	30	23.6	23.5
LAST Score	255	251	273	268	274	271	279	279
CST Math Score	262	251	268	263	257	251	268	269
SAT Math	600	556	626	611	616	589	710	648
SAT Verbal	506	483	580	545	577	564	627	623
Number of Teachers	478	157	195	64	1098	542	61	98

* CR: College Recommended, NYCTF: New York City Teaching Fellows, NYCTF-MI: New York City Teaching Fellows, Math Immersion, TFA: Teach for America.

Table 3: Number of New York City Teaching Fellows Prepared by Various Campuses by Math Immersion and Math Certification Status, 2004-2007*

Math Immersion Status	All Teachers by Institution				
	A	**B**	**C**	**D**	**Z**
NYCTF-MI	290	536	75	270	441
NYCTF-Not MI	1082	1077	751	185	1431
Total	1372	1613	826	455	1872
	Math Certified Teachers by Institution				
	A	**B**	**C**	**D**	**Z**
NYCTF-MI	290	536	75	270	441
NYCTF-Not MI	46	78	19	35	75
Total	336	614	94	305	516

***** A, B, C, D, and Z represent individual teacher preparation institutions.

Table 4: Required Courses and Credit Hours for Key Courses, College Recommended and Math Immersion Programs, Means and Standard Deviations

College Recommended Programs	Math Courses	Math Methods	Classroom Management	Learning	Assess-ment	Special Ed	Diversity
Graduate programs							
Courses							
Mean	1.64	2.00	0.29	1.29	0.50	0.57	0.50
Standard deviation	1.78	1.11	0.61	0.73	0.52	0.65	0.65
Credits							
Mean	4.93	5.79	0.86	3.75	1.29	1.71	1.36
Standard deviation	5.34	3.29	1.83	2.16	1.44	1.94	1.91
Undergraduate programs							
Courses							
Mean	3.82	1.36	0.64	1.73	0.00	0.36	0.36
Standard deviation	3.76	0.50	0.67	0.90	0.00	0.50	0.67
Credits							
Mean	11.00	4.71	1.75	4.50	0.25	1.33	1.58
Standard deviation	11.29	1.38	2.26	2.70	0.00	1.66	2.46
Math Immersion Programs							
Courses							
Mean	4.20	2.80	0.33	1.00	0.40	0.40	0.25
Standard deviation	1.92	0.84	0.58	0.00	0.55	0.55	0.50
Credits							
Mean	12.60	8.40	0.60	2.40	1.20	1.20	0.60
Standard deviation	5.77	2.51	1.34	1.34	1.64	1.64	1.34

Table 5: Teachers' Perceptions of Their Preparation by Preparation Pathways, 2005 Survey of First Year Teachers*

Pathway	Preparation in Specific Strategies	Field Experience Quality	General Opps to Learn Teaching Math	Subject Matter Preparation in Math	Preparation for SPED students
College Recommended	0.331	0.441	0.386	0.038	0.358
	[2.99]***	[3.91]***	[3.54]***	[0.33]	[3.13]***
Teaching Fellows	0.274	-0.052	-0.350	-0.462	0.215
	[2.50]**	[-0.46]	[-3.32]***	[-4.12]***	[1.91]*
Teach For America	0.604	0.810	-0.007	-0.561	0.272
	[2.74]***	[3.65]***	[-0.03]	[-2.48]**	[1.22]
Other Path	0.004	0.230	0.371	0.320	0.436
	[0.04]	[1.87]*	[3.31]***	[2.74]***	[3.73]***
N	558	528	543	541	551

* In addition to the pathway indicator variables each regression contains school context factors, which include a factor representing: teacher influence on planning and teaching, administrative quality, staff collegiality and support, student attitudes and behavior, school facilities, and school safety. t statistics in brackets, significance: *= .05, **=.01, ***= .001.

Table 6: Math Immersion Programs: Key Course Requirements, Courses and Credit Hours (in parentheses)

Campus	Math Course	Math Methods	Classroom Mgt	Learning	Assessment	Special Education	Diversity	Technology	Total Req'd Credits
Campus A Middle School	5 (15)	3 (9)	1 (3)	1 (3)	0	0	0	0	46-49
Campus B	5 (15)	3(9)	0	1(3)	0	0	0	0	48
Campus C	6 (18)	4 (12)	0	1(3)	0	0	0	0	47
Campus D	2 (6) + 2 courses (6 credits) prior to entering program*	1 (6)	0	0	1(3)	1 (3)	0	1 (3)	39
Campus Z	1 (3)	2 (6)	0	1 (3)	1 (3)	1 (3)	1 (3)	0	39

*Program does not pay for or provide for these two prior mathematics courses.

Table 7. College Recommended Mathematics Teaching Programs: Key Course Requirements, Courses and Credit Hours (in parentheses)

Program*	Math Course	Math Methods	Classroom Management	Learning	Assessment	Special Ed	Diversity
Campus 1 Grad	3 (9)	3 (9)	0	2 (6)	1 (3)	1 (3)	1 (3)
Campus 2 Grad	0	1 (2)	0	2 (5)	1 (3)	0	0
Campus A Grad	4 (12)	4 (11)	2 (6)	2(6)	0	0	2 (6)
Campus A Undergrad	3 (9)	2 (4)	0	2(4)	0	0	1 (3)
Campus B Grad	2 (6)	2 (6)	0	1 (3.5)	0	2 (6)	0
Campus B Undergrad	2 (6)	1 (3.5)	2 (7)	1 (4)	0	0	1 (3)
Campus 3 Undergrad	3 (9)	1 (3)	0	1 (4)	0	0	0
Campus 4 Grad	1 (3)	1 (3)	1 (3)	1 (3)	1 (1)	1 (3)	0
Campus 5 Grad	0	2 (6)	0	1(3)	0	1 (3)	0
Campus 5 Undergrad	1 (3)	2 (6)	1 (3)	1 (5)	0	1 (3)	0
Campus 6 Grad	4 (12)	2 (5)	0	1(2)	1 (2)	0	1 (3)
Campus 6 Undergrad	2 (6)	1 (3)	1 (3)	2 (6)	0	0	0
Campus C Grad	5 (15)	4 (12)	0	1 (3)	0	0	1 (3)
Campus C Undergrad	2 (6)	1 (4)	1 (2)	1 (3)	0	0	2 (6)
Campus 7 Grad	2 (6)	1 (3)	0	0	1 (3)	1 (3)	1 (3)
Campus 7 Undergrad	2 (6)	1 (3)	0	1 (3)	0	1 (3)	0
Campus 8 Grad	0	1 (3)	0	2 (6)	0	0	0
Campus 9 Undergrad	9 (27)	2 (7)	1(4)	4 (12)	0	1 (4)	0
Campus Z Grad	0	1 (3)	0	2 (6)	0	0	0
Campus Z Undergrad	4 (12)	1 (4)	0	2 (7)	0	0	0
Campus 10 Grad	0	2 (6)	0	1 (3)	0	0	0
Campus 10 Undergrad	13 (39)	2 (6)	0	2 (6)	0	0	0
Campus D Grad	0	1 (3)	1 (3)	2 (6)	1 (3)	1 (3)	0
Campus D Undergrad	1 (3)	1 (3)	1 (3)	1 (3)	0	1 (3)	0
Campus 11 Grad	2 (6)	3 (9)	0	0	1 (3)	1 (3)	1 (1)

* Pseudonyms are provided for each campus. Those campuses which also offer Math Immersion programs have the same letters as they did in Table 6 (i.e. Campus A, B) so they can be identified as such in this table, and the other campuses have been given numerical pseudonyms.

Table 8: Base Model, Value Added Effects of Pathways on Math Achievement, Grades 6-8, All Teachers 2004-08, School Fixed Effects*

Student Measures		% Black	-0.152	**Teacher Experience**		17th year	0.080
Lag score	0.593		[6.11]**	2nd year	0.050		[5.75]**
	[269.33]**	% Asian	0.099		[8.92]**	18th year	0.049
Lag score squared	-0.005		[3.71]**	3rd year	0.082		[3.67]**
	[3.70]**	% Other ethnicity	-0.024		[12.70]**	19th year	0.051
Female	0.010		[0.26]	4th year	0.091		[2.85]**
	[6.58]**	Class size	0.000		[12.22]**	20th year	0.065
Asian	0.126		[0.85]	5th year	0.100		[3.34]**
	[35.45]**	% ELL	0.214		[12.64]**	21st or more	0.085
Hispanic	-0.059		[14.00]**	6th year	0.096		[4.25]**
	[19.07]**	% English home	-0.026		[11.01]**	year=2005	-0.019
Black	-0.060		[1.48]	7th year	0.088		[4.07]**
	[18.21]**	% Free lunch	0.014		[9.07]**	year=2006	-0.036
Change school	-0.078		[1.57]	8th year	0.068		[6.81]**
	[16.22]**	Lagged absences	-0.007		[6.51]**	year=2007	-0.029
English home	-0.060		[13.30]**	9th year	0.087		[4.97]**
	[31.51]**	Lag suspensions	-0.002		[6.99]**	year=2008	-0.045
Free Lunch	-0.017		[0.15]	10th year	0.082		[6.91]**
	[10.46]**	Lag ELA score	0.194		[6.47]**	**Teacher Pathway**	
Lagged absent	-0.005		[24.73]**	11th year	0.078	**CR**	**0.016**
	[64.92]**	Lag Math score	0.076		[5.54]**		**[1.86]**
Lag suspended	-0.024		[9.16]**	12th year	0.079	**NYCTF**	**0.021**
	[12.20]**	Std Dev ELA score	0.043		[5.31]**		**[1.87]**
ELL-1	-0.060		[4.78]**	13th year	0.058	**TFA**	**0.055**
	[13.27]**	Std Dev Math score	0.000		[3.91]**		**[3.71]****
ELL-2	-0.129		[0.03]	14th year	0.070	**Other**	**-0.011**
	[2.74]**	Grade=7	0.031		[4.78]**		**[1.27]**
ELL-3	0.049		[5.24]**	15th year	0.059		
	[1.62]	Grade=8	-0.008		[4.17]**	Constant	0.260
Class Average Measures			[1.17]	16th year	0.056		[9.36]**
% Hispanic	-0.161				[4.01]**		
	[6.81]**					N	651191

* Dependent variable is the current achievement level. Observations clustered at the teacher level. t statistics in brackets, significance: * =.05, **=.01, ***= .001.

** CR=College Recommended, NYCTF=New York City Teaching Fellows, TFA=Teach for America.

Table 9: Effect of Pathways on Value-Added Math Achievement, Grades 6-8, All Teachers 2004-08, Various Model Specifications*

Pathways	1 Level	2 Gain	3 Level	4 Gain	5 Level	6 Gain	7 Level	8 Gain	9 Level
College Recommend	0.016	0.016	0.005	0.005	0.017	0.021	0.004	0.003	0.006
	[1.86]	[1.86]	[0.47]	[0.47]	[2.60]**	[2.56]*	[0.40]	[0.32]	[0.55]
NYC Teaching Fellows	0.021	0.021	0.022	0.022	0.023	0.034	0.015	0.030	0.012
	[1.87]	[1.92]	[1.68]	[1.73]	[2.74]**	[3.28]**	[1.38]	[2.36]*	[0.85]
Teacher for America	0.055	0.054	0.018	0.016	0.068	0.071	0.032	0.030	0.046***
	[3.71]**	[3.69]**	[0.86]	[0.79]	[5.74]**	[4.80]**	[1.88]	[1.58]	[2.77]
Other	-0.011	-0.011	-0.003	-0.003	-0.004	-0.013	0.002	-0.005	-0.020*
	[1.27]	[1.26]	[0.28]	[0.26]	[0.66]	[1.68]	[0.27]	[0.52]	[-1.74]
NYCTF-MI Below									-0.044
									[-1.52]
NYCTF-MI NA									-0.014
									[-1.04]
Teacher controls			✓	✓			✓	✓	
School fixed effects	✓	✓	✓	✓					✓
Student fixed effects					✓	✓	✓	✓	

* Level models use current student achievement levels as dependent variable with lagged achievement and its square as independent variables. Gain models use the achievement gain as the dependent variable. In addition all models include the other independent variables included in the base specification shown in Table 8. Observations clustered at the teacher level. All pathway effects are relative to the effect of the NYCTF Math Immersion pathway. t statistics in brackets, significance: * .05, **.01, *** .001.

Table 10: Effect of Pathways and Experience on Value-Added Math Achievement, Grades 6-8, 2004-08*

	No Teacher Controls				**Teacher Controls**			
	Experience				**Experience**			
Pathway**	**1**	**2**	**3**	**4+**	**1**	**2**	**3**	**4+**
College Recommend	0.018	0.024	0.010	0.028	0.006	0.001	0.000	0.024
	[1.60]	[1.90]	[0.65]	[1.53]	[0.44]	[0.06]	[0.00]	[1.22]
NYCTF	0.011	0.010	0.005	0.065	0.040	0.004	0.006	0.049
	[0.74]	[0.58]	[0.24]	[2.76]**	[2.30]*	[0.19]	[0.29]	[1.98]*
TFA	0.054	0.056	0.041	0.048	0.042	0.002	0.003	0.037
	[3.13]**	[2.64]**	[1.09]	[1.29]	[1.66]	[0.08]	[0.06]	[1.02]
Other	-0.028	-0.032	-0.018	0.009	-0.014	-0.025	0.002	0.017
	[2.22]*	[2.61]**	[1.29]	[0.50]	[0.88]	[1.68]	[0.12]	[0.91]

*Coefficients indicate difference with Math Immersion effect at that experience level.
Statistical significance is for the difference in the Math Immersion and other pathway effect. Model is the level model with school fixed effects and all of the other variables included in Table 8. Observations clustered at the teacher level. t statistics in brackets, significance: * .05, **.01, *** .001.

** NYCTF: New York City Teaching Fellows, TFA: Teach for America, Other: all other pathways

Table 11: Effect of Pathways and Math Immersion Programs on Value-Added Math Achievement, Grades 6-8, 2004-08, Various Model Specifications*

Pathway and Program	Level	Level	Level	Level
College Recommend	0.057	0.033	0.046	0.025
	[3.94]**	[1.89]	[3.70]**	[1.57]
NYC Teaching Fellows	0.062	0.047	0.052	0.037
	[3.81]**	[2.54]*	[3.93]**	[2.24]*
Teacher for America	0.096	0.031	0.101	0.059
	[4.96]**	[1.21]	[6.30]**	[2.62]**
Other	0.030	0.027	0.025	0.027
	[2.12]*	[1.55]	[2.02]*	[1.72]
Campus A	0.034	0.018	0.015	-0.021
	[1.50]	[0.71]	[0.85]	[0.97]
Campus B	0.051	0.029	0.060	0.043
	[2.66]**	[1.28]	[3.99]**	[2.14]*
Campus C	0.048	0.035	0.074	0.080
	[1.71]	[1.16]	[3.58]**	[3.31]**
Campus D	0.055	0.037	0.019	0.014
	[2.99]**	[1.72]	[1.28]	[0.76]
Campus E	0.091	0.094	0.049	0.035
	[2.59]**	[2.77]**	[2.17]*	[1.30]
Teacher controls		✓		✓
School fixed effects	✓	✓		
Student fixed effects			✓	✓

* Level models use current student achievement levels as dependent variable with lagged achievement and its square as independent variables. In addition all models include the other independent variables included in Table 8. Observations clustered at the teacher level. All pathway and program effects are relative to the effect of the NYCTF Math Immersion program at Program Z.
t statistics in brackets, significance: * .05, **.01, *** .001.

Table 12: Cumulative Teacher Attrition Rates by Pathway for Math Certified New York City Teachers, 2004 to 2009*

	NYCTF-MI		CR		NYCTF		TFA	
Experience	**Transfer**	**Leave**	**Transfer**	**Leave**	**Transfer**	**Leave**	**Transfer**	**Leave**
1	12.2	12.4	9.6	13.4	8.9	15.7	5.0	8.2
2	18.7	26.5	12.3	19.1	16.2	29.6	9.9	58.8
3	23.6	36.4	16.0	27.7	19.2	42.3	12.1	75.6
4	26.5	42.1	18.0	31.4	24.4	47.5	13.2	78.7

* CR: College Recommended, NYCTF: New York City Teaching Fellows, NYCTF-MI New York City Teaching Fellows, Math Immersion, TFA: Teach for America.

Table 13: Simulation of Average Value Added by Pathway and Experience Accounting for Attrition*

Simulation	**Average Value Added**			
Year	**NYCTF-MI**	**CR**	**NYCTF**	**TFA**
1	0.000	0.018	0.011	0.054
2	0.047	0.069	0.054	0.102
3	0.068	0.086	0.072	0.082

* Calculations employing value added by experience from Table 10 and average leave rates by pathway and experience from Table 12. CR: College Recommended, NYCTF: New York City Teaching Fellows, NYCTF-MI New York City Teaching Fellows, Math Immersion, TFA: Teach for America.

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Appendix A

Table A-1: Summary of Survey Factors, Their Component Survey Items and Alpha Scores

	Factor	**Survey Items***	**Alpha**
Student Objectives Factors	General Emphasis on Student Objectives	Loads positively on GM6a-i,k,m,n	0.87
	Skills & Assessment High/ Mathematical Thinking Low	loads positively on GM6b,c,d,e,m,n; negatively on a,f,g,j,l,k	
Pedagogy Factors	General Emphasis on Pedagogy	Loads positively on GM7a,e,f,g,h,j,k,l,m	0.75
	Direct/Rote Pedagogy High, Discovery Low	Loads positively on GM6 a,f,g,j; lloads negatively on GM6 m,h,k,l,e	
	Pedagogical emphasis on technology	Loads positively on GM7n-p	0.94
TEP Attributes Factors	Program Coherence & Quality	loads negatively on a11a; positively on b-d	0.72
	Preparedness for Specific Strategies	Loads positively on a12b-f	0.78
	Field Experience Quality (Supervision & Feedback)	Loads positively on a23a-e	0.76
	General Opportunities to Learn	Loads positively on GM3a-s	0.96
	Subject Matter-Specific Preparedness	Loads positively on GM4c-f,j	0.91
	Preparedness for Special Needs Students	Loads positively on GM4a,g-i	0.77
School Context Factors	Teacher Influence on Planning/ Teaching	loads positively on b1a-e	0.76
	Administration Quality and Support	Loads positively on b2a-e	0.88
	Opinion of Staff Relations (collegiality/support)	Loads positively on b3a-e	0.75
	General Perception of Student Body (attitudes, behavior, habits)	Loads negatively on b4a,b; positively on c,e	0.66
	School Facilities (cleanliness, supplies, conducive to learning)	Loads positively on B7a,d-f; negatively on c	0.7
	School Safety	B5 & B6 (categorical) variable	…

* The survey of Teachers in First Year of Teaching, School Year 2004- 2005can be found at www.teacherpolicyresearch.org under the Survey tab.

[1] For a detailed discussion of the sorting of teachers in New York see Author (2002). Research in other states has demonstrated very similar patterns ((Betts, Reuben & Danenberg , 2000; Clotfelter, Ladd, Vigdor & Wheeler, 2007; and Peske & Haycock 2006).
[2] Based on correspondence from Vicki Bernstein, New York City Department of Education, 9/14/09.
[3] Based on correspondence from Vicki Bernstein, New York City Department of Education, 9/14/09.
[4] For purposes of this graph a teacher is defined as having math certification if at the time she entered teaching she held either an elementary/middle school or a secondary school math certification.
[5] In general, there is little missing data in any of our analyses. Although the survey response rate is high at 72 percent, it represents a potential source of bias. In other analyses (Author, 2009), we document that there is no evidence of bias associated with the missing survey data. Some variables in our administrative data are missing. Here again, based on analyses in other work (Author, 2008) , we believe there is little evidence that missing data systematically influence the analysis. When data are missing, we eliminate those observations from the analysis. In all cases our sample sizes are very large and we believe doing so has a negligible effect on the analysis.
[6] New York State employs CTB-McGraw Hill as the vendor for all of its assessments. .
[7] In a separate manuscript, we will be reporting on the qualitative analyses of these data.
[8] The survey of Teachers in First Year of Teaching, School Year 2004- 2005can be found at www.teacherpolicyresearch.org under the Survey tab.
[9] We obtain information about undergraduate major and work experiences based on program information received from the New York City Teaching Fellows Program.
[10] Pseudonyms are provided for the campuses in order to protect the confidentiality of the institutions and participating faculty.
[11] Our categorization of the courses (whether they are considered subject matter content courses or methods; whether they are general pedagogy courses, or courses about learners) is based upon and consistent with an earlier analysis we conducted on childhood education programs at many of these same institutions.
[12] "General pedagogy" in our analysis refers to any courses that were not specific to the teaching of a content area, but rather had to do with general issues of teaching—such as coursework in technology, assessment; interdisciplinary or general methods courses that did not focus upon a particular discipline; courses in literacy *across* the content areas.
[13] In this category, consistent with prior analysis, we included courses that focus upon learners and learning; courses on child development; courses on classroom management; courses on diverse learners or diverse language learners; and courses on children with special needs.
[14] It is possible that our measures characterizing schools do not fully control for such differences, e..g., a principal who is particularly difficult. To the extent that such differences are systematically related to preparation programs the survey results may not accurately reflect on the preparation at such programs.
[15] The results of these regressions are available from the authors upon request.
[16] These results are available from authors.
[17] However, due to excess demand from 2004-08, the NYCTF program accepted some applicants who fell below their internal selection standards. During this period, 9 percent of the Math Immersion teachers who taught students in our value-added analysis did not meet these standards (NYCTF-MI Below), 51 percent met these criteria (above) and 40 percent did not receive a rating (NYCTF-MI NA). As shown in column 9 of Table 9, these ratings identify meaningful differences in Math Immersion teachers. The comparison group is now the Math Immersion teachers who exceeded the selection threshold. These teachers are on average relatively more effective that their colleagues who were rated below the threshold (0.044), although the difference is not statistically significant. The difference between Math Immersion and College Recommended is eliminated when compared to the Math Immersion teachers who exceeded the threshold and the difference with TFA is reduced. Our best estimates of the effect of Math Immersion are those presented in column 1, but the results of column 9 indicate that excess demand for mathematics teachers during those years plays a role in the differences between Math Immersion and other pathways.
[18] The figure plots the persistent component of a teacher's effectiveness by employing an empirical Bayes estimator similar to that suggested in Kane, Rockoff and Staiger (2008). The estimate of teacher effectiveness results from a regression of student math achievement identical to equation 1 with teacher experience as the only measure of teacher attributes. The residuals from this regression are shrunken to adjust for the measurement error associated with the estimates. We should note that while the estimates of effectiveness for each individual teacher are

unbiased, the estimates by pathway taken together to form the distribution of teacher effectiveness shrinks the estimates too far back to the mean. Even so, there is substantial overlap among the pathways.

[19] Author(2008) explores the effect of teacher qualifications in detail.

[20] Full results available from the authors.

[21] In earlier work, we found precisely this result (author, 2006).

[22] This definition would exclude individuals in a year who may be teaching under some other title, such as a substitute teacher; those who are not teachers, and an individual who began teaching in a given year after October 15th. Individuals who began after October 15th and who continued as a teacher in the subsequent year are included for that year.

[23] There are cases where individuals are not teachers in NYC public schools for more than a year and subsequently return to teach, but these cases are relatively rare. It is also true that teachers who have left teaching in NYC may be teaching in other school districts or in an administrative position in NYC.