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Recruiting Effective Math Teachers: How Do Math Immersion Teachers Compare?: Evidence from New York City
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ABSTRACT

School districts often struggle to recruit and retain effective math teachers. Alternative-route certification programs aim to expand the pool of teachers available; however, many alternate routes have not been able to attract large numbers of teacher candidates with undergraduate degrees in math. In response, some districts, including Baltimore, Philadelphia, Washington D.C., and New York City, have developed alternative programs with a math immersion component to recruit candidates who do not have undergraduate majors in math. Such programs provide potential math teachers with intensive math preparation to meet state certification requirements while, at the same time maintaining an early-entry approach in which individuals who have not completed a teacher preparation program can become qualified to teach with only five to seven weeks of coursework and practice teaching. Four years since its inception, the New York City Teacher Fellows Math Immersion program supplies 50 percent of all new certified math teachers to New York City public schools. In this study, we find that Math Immersion teachers have stronger academic qualifications than their College Recommending (traditionally certified) peers, although they have weaker qualifications than Teach for America teachers. However, despite stronger general academic qualifications Math Immersion teachers produce somewhat smaller gains in math achievement for middle school math students than do College Recommending teachers and substantially smaller gains than do Teach for America teachers.

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I. Introduction

For well over a decade school districts across the U.S. have struggled to recruit and retain effective math teachers. This problem appears to be more acute in schools serving high poverty student populations (Boyd et al., 2005; Boyd et al., 2009; Hanushek et al., 2004). Historically, this has meant that many middle and high school math 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 math 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 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 math 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 which 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 math 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 math major, which is not so different from the requirements in many other states. Few college graduates meet this requirement and even fewer of these graduates desire 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 math 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 math 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?

[1] For a detailed discussion of the sorting of teachers in New York see Lankford, Loeb and Wyckoff (2002). Research in other states has demonstrated very similar patterns ((Betts, Reuben & Danenberg , 2000; Clotfelter, Ladd, Vigdor & Wheeler, 2007; and Peske & Haycock 2006).

- 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

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; Boyd et al. 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 difference in requirements (Boyd et al, 2008). 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; Grossman and Loeb, 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. Boyd et al, 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. Boyd et al. 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. In anticipation of this, in 2000 the Regents had 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 Recommending teachers in recent years.

Figure 1 reflects the hiring of all teachers in New York City while, 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 Recommending 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

[2] Based on correspondence from Vicki Bernstein, New York City Department of Education, 9/14/09.

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 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 Recommending programs have shown strong growth in recent years, but as of 2008 still only supplied about 30 percent of new math teachers.

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. 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.[5] 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 math 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),

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[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] The mathematics exams in all grades are developed by CTB-McGraw Hill. New York State employs CTB-McGraw Hill for its 4th and 8th grade ELA exams. In 2003 New York City switched from CTB to Harcourt Brace for its 3rd, 5th-7th grade exams. At that time there was an equating study done to accommodate the switch in exams.

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 math 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 Recommending: We obtain indicators for whether an individual had completed a college-Recommending 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 Recommending teachers hired in NYC schools in recent years. Within these institutions, we concentrated on the pre-service preparation at 25 college-recommending 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 ask 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 interview 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. Because participants in these various pathways complete their coursework at different times, it is important to remember that students in the College Recommending 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 ask detailed questions about their preparation experiences, the mentoring they received in their first year, and their teaching practices and goals. Our overall response rate is 71.5 percent and the response rate fo 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. r each pathway is nearly or slightly above 70 percent.

The survey asked all respondents a variety of questions regarding their general teacher preparation, mentoring and current working environment. [6] In addition, we surveyed middle and high school math teachers specifically about several aspects of their current teaching and their preparation to teach math. We received completed surveys from 603 respondents including 210 Teaching Fellow Math Immersion teachers (NYCTF-MI), 130 Teaching Fellows (NYCTF), 22 Teach For America teachers

[6] The survey can be found at www.teacherresearchpolicy.org.

(TFA), 129 College Recommending 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 B. 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 Recommending 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 Recommending 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.

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 Recommending, 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. 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. 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. We estimate a variety of alternative specifications for Equation 1, including: using gains scores as the dependent variable while omitting lag scores as independent variables, employing student fixed effects rather than school fixed effects and by limiting the sample to only individuals who begin teaching in New York City in 2004 or after.

In addition to exploring the average effects of pathways, we are interested in a series of related questions. How does the effect 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 Math Teachers: There are meaningful differences between the attributes of math immersion teachers and teachers who enter through pathways other than NYCTF, particularly the College Recommending 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 Recommending 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 Math (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 math certified teachers.

Many of the Math Immersion teachers who become math certified either have a math related undergraduate major (49 percent) or math related work experience (19 percent).[7] Although it appears that a substantial percentage of Math Immersion teachers do not have math 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. As shown in Table 3, among Math Immersion teachers there are some differences between those with math related backgrounds and those without such backgrounds. On many measures, however, Math Immersion teachers who do not have math related backgrounds have qualifications that are at least as strong, and sometimes even stronger, when compared to those with math related backgrounds.

NYCTF math teachers and the subcomponent of Math Immersion teachers are prepared at several different institutions. Table 4 shows that four campuses are responsible for the vast majority of these teachers. There are many similarities, but some interesting differences across the attributes of math

[7] We obtain information about undergraduate major and work experiences based on a program information obtained from the New York City Teaching Fellows.

certified teachers prepared at these campuses.[8] Table 5 shows that many of the demographic characteristics are very similar across campuses, 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 math and verbal tests, Math Immersion teachers at Campus Z perform better, while those at Campus A appear to perform worse than the other campuses.

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

Differences in Preparation Between Math Immersion and College Recommending Pathways: Our reviews of program requirements across 25 College Recommending 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 6 shows the average number of courses and course credits required across several key components of pathways, where we have separated the graduate and undergraduate College Recommending programs. As these results show, the average Math Immersion program requires roughly as many or more courses and credit hour in most components of the programs, including math content and math methods, as either the average graduate or undergraduate College Recommending program. There are two exceptions. The undergraduate College Recommending programs require more classroom management and learning about learners 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 about learners). College Recommending graduate programs are between the other groups on each.

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 7 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 where all pathways are relative to the Math Immersion pathway as well as school context factors. As shown, teachers from College Recommending programs cite significantly greater general opportunities to learn about the teaching of math, preparation in specific

[8] Pseudonyms are provided for the campuses in order to protect the confidentiality of the institutions and participating faculty.

teaching strategies, greater quality of field experiences and more opportunities to learn preparation for working with special education students. There is no difference in perceptions of opportunities to learn math content between College Recommending teachers and Math Immersion teachers. It is also the case that Teach for America teachers report more opportunities to learn in specific strategies and better field experiences but less opportunity for math subject matter preparation, as was the case with regular Teaching Fellows. Regular Teaching Fellows also report fewer opportunities to learn teaching of math but more opportunities in the preparation of 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.

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

Variation Within Preparation Pathways: While Math Immersion is in some senses a single program, the preparation experiences of NYCTF-MI teachers can be quite different depending on which institution they attend. College Recommending 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 8 suggests, the programs vary in terms of their course requirements.[9] There are three telling aspects of this analysis. First, there are remarkable differences across campuses in their math content and math methods requirements, ranging from one 3-credit course in math content required by at Campus Z to 5 or more courses required by Campuses A, B and C. The range in requirements for math methods was smaller. In sum, Math Immersion Fellows could receive different emphasis on math content or math methods depending on the campus they attend. Second, there is a range of requirements in general pedagogy[10] across these programs. As seen in Table 8, 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

[9] 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.

[10] "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.

teacher education programs, only one campus required coursework in technology. Finally, of the five Fellows campuses, four programs required at least one course in learning or child development.[11] 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.

In sum, the most striking variation across programs lies with whether programs put greater emphasis on math 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 math and math methods. Campus Z has particularly weak requirements in Math 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, math methods and math content credits represent 30 of the required 47 credits, for 63 percent of the total requirements. Two campuses stand out for their curricular emphasis on math content and math methods in their course requirements: Campus C and Campus A.

We also examined program documents and interview program administrators of College Recommending programs in mathematics who supply the majority of math teachers from College Recommending programs for New York City public schools (See Table 9). 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. All of the institutions that offered NYCTF Math Immersion programs also offered College Recommending programs in mathematics.

We find a substantial range in requirements in mathematics content. For graduate programs in the teaching of mathematics, requirements ranged from *no* courses required in math content, to *five* courses in math content (See Table 9). In part, these lower requirements in math content may be due to the fact that a number of the graduate programs required math preparation prior to entry—in many of these programs, incoming applicants were required to have been math majors, although there is substantial variation among undergraduate programs in math content, too. In terms of math 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 math methods appears to be somewhat similar to the range seen in the Math

[11] 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.

Immersion programs. The variation in requirements for preparation in learning and learners and that in classroom management in College Recommending 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 Recommending programs (Table 6), 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 requirements rather than allowing for different requirements.

In light of our program analysis which reveals that one program, Campus Z, stands out as having the fewest requirements in math-related preparation to teach, 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 teachers' perspective on her preparation may be influenced by the context in which she is teaching at the time she completes the questionnaire, we also estimate models that include school context factors as controls.

As compared to teachers from Campus Z, Table 10 shows that teachers from other campuses score higher across survey factors measuring preparation program attributes. 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 (bottom row), teachers from all other campuses report having significantly more opportunities to learn teaching math and more preparation to use specific teaching practices, however there are no differences in their perceptions of opportunities to learn math. 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 Recommending 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 than math 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 Recommending 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 math achievement exams in grades 6-8.

We should note that to more fully examine math 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 math teachers between middle school and high school. There is anecdotal evidence that many math 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 math certified teachers by pathway in Table 2 and by program in Table 5.

As shown in Table 2, the qualifications of math certified teachers over the 2004-08 period is generally stronger for teachers in high school than those in middle schools across each pathway. For example, the College Recommending teachers in high school have SAT math scores that are 7.9 percent higher than College Recommending teachers in middle school, while comparable differences for Math Immersion and TFA are 4.6 percent and 9.6 percent respectively. The differences for the Content Specialty test are 4.4 percent for College Recommending, 2.4 percent greater for Math Immersion and no difference for TFA. To the extent that these measures of qualifications have some predictive ability of a teacher's value added, then we would expect high school teachers from each pathway to more effective. However, these differences do not suggest that one pathway is being systematically affected by teacher sorting to high school. Similar comparisons can be made among the Math Immersion programs. As shown in Table 5, each of the Math Immersion programs places teachers with somewhat stronger qualifications in high school relative to the teachers from their pathway who teach in middle school.[12] These differences vary but across every measure Program Z has the smallest difference between middle and high school teacher, suggesting the Program Z's middle school teachers may be relatively more effective compared other pathways than its high school teachers.

In general we find that most of the independent variables characterizing individual students, the class of the student, and the experience of teachers produce math achievement gains in grades 6 through 8

[12] It is also the case that Math Immersion teachers who do not meet internal acceptance standards but who were admitted due to excess demand are somewhat more likely to teach in middle school than high school compared to their colleagues who met internal recruitment standards (58 v. 52 percent). (Correspondence with Vicki Bernstein, New York City Department of Education, 9/14/09.)

as suggested by theory and found in most other research employing administrative data (see Table 11). All of the student attributes affect achievement. For example, prior achievement is an important predictor of current achievement, Asian students outperform whites, while Black and Hispanic students have lower achievement 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 equal. The attributes of class peers also influences student achievement in the expected ways. As has been found in several previous studies, increasing experience as a teacher improves student math 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 math classrooms then at least some of the gains to experience may reflect this attrition.

The focus of this research is the effect of the pathway through which a teacher enters teaching, and in particular the relative effect of math immersion, the omitted pathway in the estimates found in Table 11. These estimates suggest that on average, students of Math Immersion teachers in grades 6-8 have smaller gains in math achievement than students of teachers from the College Recommending, 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 (about 0.05). The additional achievement of students of College Recommending (0.016) and regular Teaching Fellows (0.021) relative to Math Immersion teachers is estimated to be about 40 percent as large as the first year of teaching experience, and in models with school fixed effects these estimates are statistically significant at the 10 percent level.

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.[13] 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

[13] 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 over adjusts the overall distribution of teacher effects. Even so, there is substantial overlap among the pathways.

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.

To explore the robustness of these findings, Table 12 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 result in only minor changes in the estimated effects of pathways (columns 1, 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 Recommending pathways are now statistically significantly different from Math Immersion at the 5 percent level or better (e.g., column 1 v. 5).

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 met 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 12, 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 Recommending 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 math teachers during those years plays a role in the differences between Math Immersion and other pathways.

Including teacher controls substantially reduces the magnitude of the pathway coefficient estimates (Table 12, 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 great controls for the characteristics that likely differentiate teachers at point of application. However, the effect of including the teacher controls that we can observe has the effect of reducing the

TFA pathway effect by more than half (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.[14] In addition, we estimate the same models presented in Table 12 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 12, however they indicate that College Recommending teachers outperform Math Immersion teachers (effect size =0.035).[15] To understand this result better, we explore the relationship between experience and pathway in more detail.

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 Recommending programs in New York. State certification requires both pathways to meet essentially the same requirements but at different points relative to becoming the teacher of record. While College Recommending teachers meet all of the requirements for an initial teaching license prior to becoming a classroom teacher, alternatively certified teachers in New York complete an intensive pre-service component during the summer prior to becoming a classroom teacher, then enroll in a masters program in education that is typically completed during the first two to three years as a teacher.[16]

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.[17] Table 13, shows the interaction effects of pathway and experience for a variety of model specifications. The comparison group is first year Math Immersion teachers. As is expected, the effectiveness of teachers in all pathways increases with experience.[18] Table 14 provides an easier means of comparing the relative effectiveness of each pathway at each level of experience. Table 14 shows 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 math achievement gains at every level of experience than those of College Recommending and Teaching Fellows teachers. However, these differences are typically not statistically significant at the 10 percent

[14] Boyd et al. 2008 explore the effect of teacher qualifications in detail.
[15] Full results available from the authors.
[16] For more details on certification requirements in New York State, see http://www.highered.nysed.gov/tcert/certificate/typesofcerts.htm
[17] In earlier work, we found precisely this result (Boyd et al, 2006).
[18] Based on these estimates we can distinguish whether these gains to experience reflect teachers becoming more adept at improving student achievement over time or a composition effect of less effective teachers leaving the workforce. Based on other work we believe that both explanations contribute to the results presented.

level. Math Immersion teachers are estimated to be less effective than TFA teachers at each level of experience, although 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. However, these differences largely disappear when we include variables intended to measure teacher qualifications. Math Immersion teachers appear to be more effective than teachers in the Other category, although these differences are statistically significant only in the first two years without the teacher controls.

Our earlier analysis of the structure and content of the preparation that Math Immersion Teachers received revealed substantive variation across the five programs that prepared the vast majority of Math Immersion Teachers. Further we found some differences in the students 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 15. 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 (Table 11) there are no differences between College Recommending, Teaching Fellows and Math Immersion teachers. Students of TFA teachers have substantially better math achievement than those of teachers from the other pathways.[19] Taken together, these results suggest that the specific implementation of Math Immersion in programs can importantly affect teacher preparation and resulting student achievement.

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 math and math methods of all the Math Immersion campuses, while Campus C had the greatest followed closely by A and B. Given the few programs training Math Immersion teachers, we can not hope to make causal statements of the effects of program design on outcomes, but these results do suggest that the relative focus on math content and math pedagogy offered by a program may influence a teacher's ability to improve math 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 math achievement gains that are somewhat lower than those of College Recommending and substantially lower than TFA teachers, other things equal. Most policy makers appropriately place great

[19] Results available from authors on request.

weight on student outcomes as means of evaluating alternative policies and programs. Increasingly, teacher attrition has become an important issue and 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—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, Boyd et al. 2008b) 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.[20] 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, quit or on leave and not returning for more than one year.[21]

Descriptive statistics characterizing the attrition rates for math-certified teachers by pathway in grades 6 through 12 are shown in Table 16. 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 meaningfully higher attrition than College Recommending 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

[20] 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.
[21] 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.

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.

H*ow 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 16. Teachers who leave are replaced by teachers with no prior experience from the same pathway. These new hires in turn age through the system. 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 Table 17. The most striking result is that the clear advantage that TFA teachers had at every level of experience (see the value added estimates from Table 13 replicated in the bottom panel of Table 18) 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 Recommending pathway develops a small advantage relative to the Math Immersion and is roughly equivalent to regular the Teaching Fellows and TFA pathways.

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 Recommending or alternatively certified teachers who met the existing math certification requirements were available to teach in New York City. Remarkably four years since its inception, the Math Immersion preparation pathway supplies 50 percent of all new certified math teachers to New York City public schools. Given the prominence of the Math Immersion pathway in supplying math teachers to NYC schools, 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 Recommending 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 math achievement for middle school math students than are College Recommending 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 Recommending 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 Recommending 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 Recommending teachers and looking to dismantle the Math Immersion program. However, such a conclusion ignores the fact that for many years prior to the creation Math Immersion New York City hired a very large number of uncertified teachers; many of these teachers taught middle and high school math classes precisely because there were insufficient numbers of College Recommending teachers certified in math who were willing to staff these low-performing schools. While the number of math teachers prepared through College Recommending 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 importantly to successful teachers and not whether one pathway outperforms another. Rather we believe that 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 math 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 this effort appears to account for a substantial portion of the difference between TFA and Math Immersion or College Recommending 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 Recommending pathways. However, other programs could learn from TFA regarding the selection of candidates who are effective teachers in low-performing classrooms.

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 math content and pedagogy may influence the math achievement of his/her middle school students. We found evidence regarding the positive influence of math content and the nature of field experiences when we examined the attributes of teacher preparation programs in childhood education (Boyd et al. 2009). The somewhat weaker performance of Math Immersion teachers relative to College Recommending 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 math content knowledge as well. In addition, the more circumstantial evidence on the impact of a program with limited content preparation suggested 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 math content, math 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. Another implication to explore is the notion that the availability of teachers from a variety of pathways benefits schools that have been traditionally difficult to staff because each pathway is able to recruit some good teachers for these schools. 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 math teaching in our schools will require more systematic and rigorous evaluation of the selection and preparation components of teacher education. State departments of education must take the lead in these efforts, given their role in determining teacher licensure requirements. The federal Race to the Top initiative provides states with the policy and financial leverage to embrace this challenge.

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

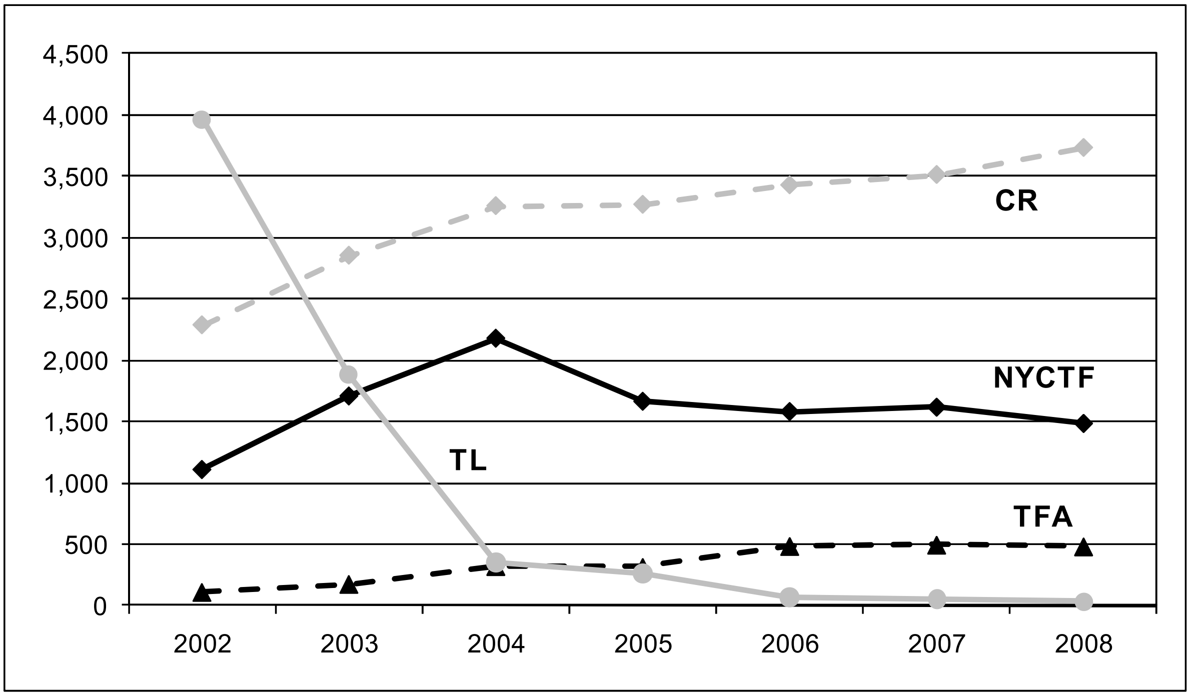

Figure 2: Number of Entering Math Certified Teachers New York City, by Pathway, 2002-2008

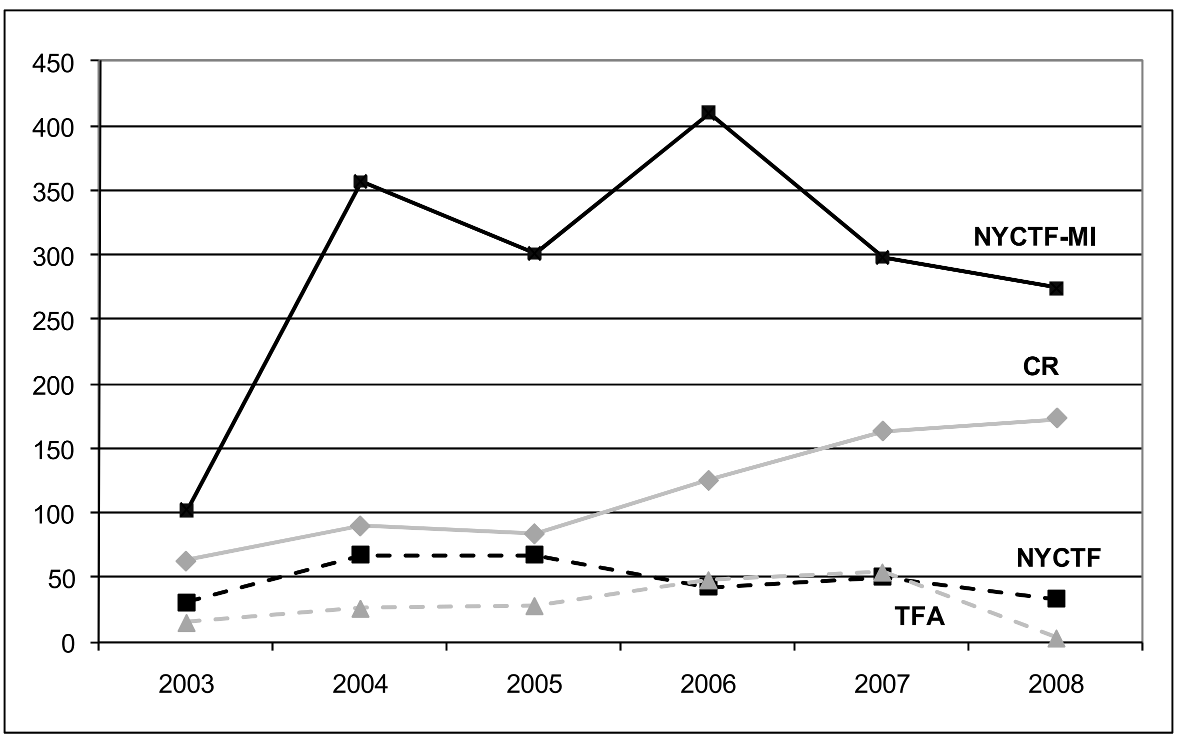

Figure 3: Distribution of Teacher Value Added by Pathway, with Empirical Bayes Shrinking, 2004-2008

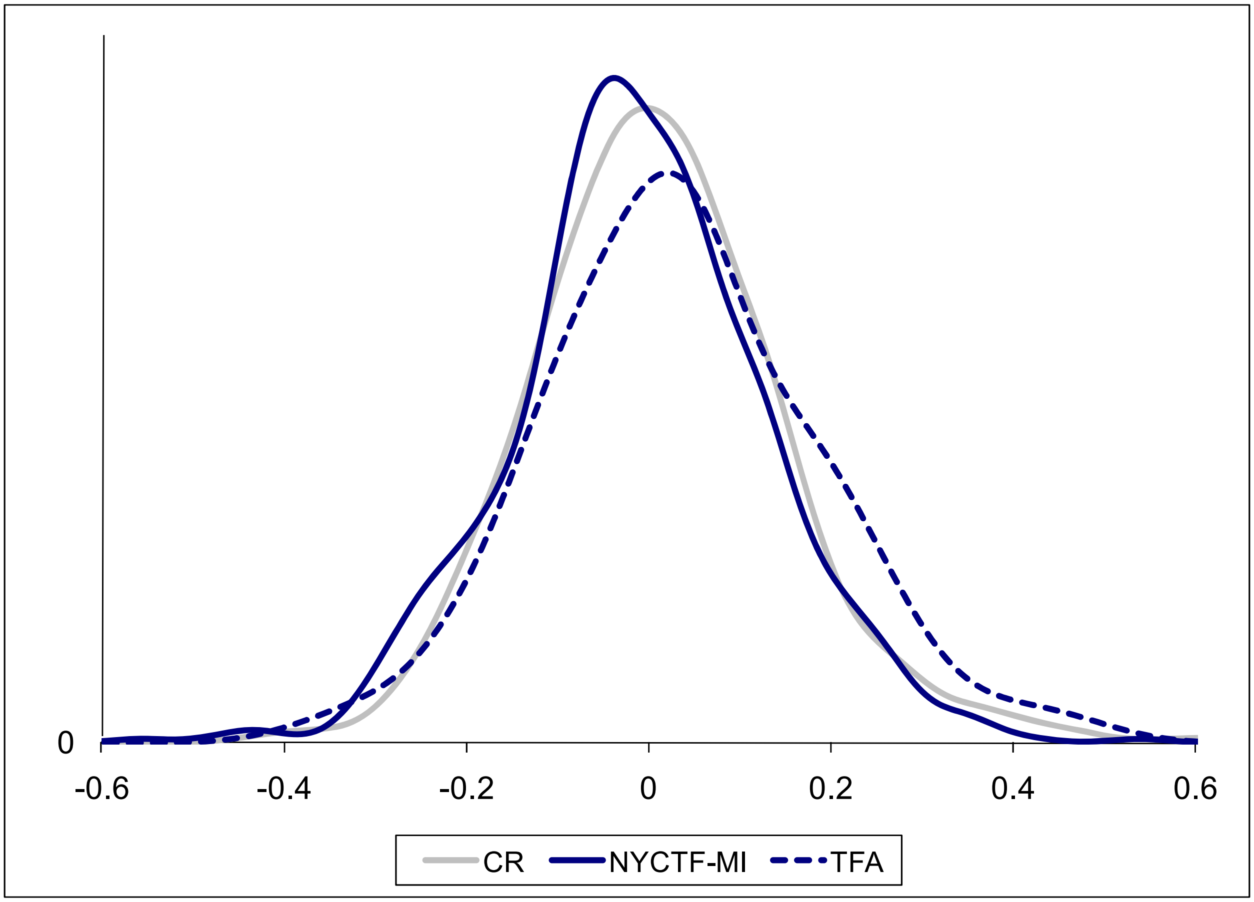

Table 1: Attributes of Students Taught by First-year Teachers by Pathway, Grade 8, 2006

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

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

Table 3: Attributes of Entering Math Certified Math Immersion Teachers by Whether They Had Math Related Major or Math Related Work Experience, 2004-2008*

Teacher Attributes	Math Related	Not Math Related
Female	0.444	0.556
Black	0.192	0.132
Hispanic	0.090	0.073
Age	32.0	29.5
Last Score	270	277
Last Science/math sub-score	275	283
CST Math Score	255	254
ATS Secondary Score	251	253
SAT Math	594	622
SAT Verbal	554	595

* Coded as math related if individual had either math related undergraduate major or math related work experience, not math related otherwise if not missing. Math related majors included: math, accounting astronomy, biochemistry, biology, business, chemistry, computer science, economics, engineering, finance, information systems, physics, and statistics. Math related work experiences included: engineering, financial, and public accounting.

Table 4: 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

Table 5: Attributes of Entering Math Certified NYCTF Teachers by Math Immersion Status and Preparing Campus, 2004-2008

Teacher Attributes	A		B		C		D		Z	
	High School	Middle School	High School	Middle School	High School	Middle School	High School	Middle School	High School	Middle School
Female	0.484	0.566	0.477	0.558	0.360	0.520	0.468	0.534	0.509	0.538
Black	0.222	0.320	0.139	0.209	0.082	0.240	0.108	0.165	0.125	0.127
Hispanic	0.032	0.062	0.123	0.086	0.102	0.080	0.088	0.046	0.069	0.093
Age	30.4	29.2	31.1	29.2	37.2	30.2	31.7	31.9	29.9	29.7
Last Score	274	270	275	272	271	268	272	268	277	276
Last Science/math sub-score	278	272	281	276	275	280	281	279	284	282
CST Math Score	259	251	255	250	258	243	255	249	257	257
ATS Secondary Score	241	241	262	250	247	276	253	256	245	254
SAT Math	611	563	609	589	633	582	271	262	625	616
SAT Verbal	567	542	578	576	566	594	618	586	589	586
							573	542		
Number of Teachers	191	99	371	165	50	25	154	116	322	119

Table 6: Required Courses and Credit Hours for Key Courses, College Recommending and Math Immersion Programs, Means and Standard Deviations

College Recommending 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 7: 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 Recommending	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.

Table 8: Math Immersion Programs: Key Course Requirements (Courses and Credits)

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 9. College Recommending Mathematics Teaching Programs: Key Course Requirements (courses and credits)

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 5 and 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 10: Math Immersion Teachers' Perceptions of Their Preparation by Program, 2005 Survey of First Year Teachers (All programs relative to Program Z)

	Preparation in Specific Strategies	Field Experience Quality	General Opportunities to Learn Teaching Math	Subject Matter Preparation in Math	Preparation for Special Ed Students
Campus A	0.274 [1.56]	0.329 [1.73]*	0.569 [3.57]***	0.115 [0.69]	0.235 [1.48]
Campus B	0.244 [1.35]	0.366 [1.85]*	0.265 [1.59]	0.177 [1.03]	0.173 [1.05]
Campus C	0.138 [0.62]	0.152 [0.63]	0.124 [0.60]	0.078 [0.37]	0.046 [0.23]
Campus D	0.562 [2.93]***	0.461 [2.24]**	0.319 [1.81]*	0.118 [0.64]	0.398 [2.28]**
All Other Campuses Combined Relative to Campus Z	0.313 [2.27]**	0.344 [2.31]**	0.355 [2.82]***	0.127 [0.99]	0.226 [1.82]*
Observations	209	201	206	206	210

* In addition to the program variables identified above, the regressions include teacher characteristics and school context variables. Teacher characteristics include survey items about age, income, college coursework in mathematics, whether teacher is a native English speaker, took community college coursework, is married or has a domestic partner, is a parent, and has prior teaching experience. School context factors include factors representing: teacher influence on planning and teaching, administrative quality, staff collegiality and support, student attitudes and behavior, school facilities, and school safety.

Table 11: 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	**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 sqrd	-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]**	ellperieplab_mclass	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 absent	-0.007		[6.51]**	year=2007	-0.029
English home	-0.060		[13.30]**	9th year	0.087		[4.97]**
	[31.51]**	Lag suspended	-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]**	**Pathways**	
Lagged absent	-0.005		[24.73]**	11th year	0.078	**College recomm**	0.016
	[64.92]**	Lag Math score	0.076		[5.54]**		[1.86]
Lag suspended	-0.024		[9.16]**	12th year	0.079	**Teaching Fellows**	0.021
	[12.20]**	Std Dev ELA score	0.043		[5.31]**		[1.87]
ellperieplab	-0.060		[4.78]**	13th year	0.058	**Teach for America**	0.055
	[13.27]**	Std Dev Math score	0.000		[3.91]**		[3.71]**
ellnotperiepu	-0.129		[0.03]	14th year	0.070	**Other**	-0.011
	[2.74]**	Grade=7	0.031		[4.78]**		[1.27]
ellentitledschool	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.

Table 12: 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 11. Observations clustered at the teacher level. All pathway effects are relative to the effect of the NYCTF Math Immersion pathway.

Table 13: Effect of Pathways with Experience Interactions on Value-Added Math Achievement, Grades 6-8, 2004-08, Various Model Specifications*

Pathway*Experience	Level	Gain	Level	Gain	Level	Gain	Level	Gain
NYCTF-MI*exp=2	0.051	0.051	0.064	0.063	0.045	0.057	0.047	0.075
	[5.08]**	[5.06]**	[5.51]**	[5.48]**	[4.79]**	[5.11]**	[4.19]**	[5.41]**
NYCTF-MI*exp=3	0.085	0.084	0.092	0.091	0.083	0.098	0.090	0.122
	[6.47]**	[6.45]**	[6.37]**	[6.35]**	[6.84]**	[7.02]**	[6.30]**	[7.40]**
NYCTF-MI*exp=4+	0.063	0.062	0.085	0.085	0.060	0.083	0.075	0.128
	[3.43]**	[3.40]**	[4.40]**	[4.37]**	[3.94]**	[4.90]**	[4.26]**	[6.57]**
College Rec*exp=1	0.018	0.018	0.006	0.006	0.034	0.030	0.024	0.034
	[1.60]	[1.58]	[0.44]	[0.42]	[3.34]**	[2.48]*	[1.75]	[2.18]*
College Rec*exp=2	0.075	0.075	0.065	0.064	0.071	0.100	0.056	0.098
	[6.43]**	[6.43]**	[4.53]**	[4.52]**	[6.95]**	[8.14]**	[4.28]**	[6.32]**
College Rec*exp=3	0.095	0.094	0.092	0.091	0.067	0.094	0.057	0.099
	[7.84]**	[7.81]**	[6.44]**	[6.41]**	[6.38]**	[7.36]**	[4.29]**	[6.06]**
College Rec*exp=4+	0.091	0.090	0.109	0.108	0.080	0.103	0.087	0.128
	[9.11]**	[9.03]**	[8.56]**	[8.50]**	[9.22]**	[9.97]**	[7.38]**	[9.28]**
NYCTF*exp=1	0.011	0.011	0.040	0.039	0.054	0.036	0.075	0.075
	[0.74]	[0.71]	[2.30]*	[2.22]*	[3.88]**	[2.33]*	[4.06]**	[3.65]**
NYCTF*exp=2	0.061	0.061	0.067	0.067	0.070	0.087	0.071	0.097
	[3.87]**	[3.90]**	[3.69]**	[3.72]**	[5.26]**	[5.60]**	[4.47]**	[4.96]**
NYCTF*exp=3	0.090	0.090	0.098	0.098	0.069	0.102	0.052	0.107
	[4.79]**	[4.79]**	[5.01]**	[5.03]**	[4.52]**	[5.36]**	[2.80]**	[4.72]**
NYCTF*exp=4+	0.128	0.128	0.135	0.135	0.097	0.156	0.091	0.177
	[7.11]**	[7.17]**	[6.68]**	[6.75]**	[6.50]**	[8.55]**	[4.71]**	[7.81]**
TFA*exp=1	0.054	0.054	0.042	0.038	0.038	0.054	0.016	0.047
	[3.13]**	[3.09]**	[1.66]	[1.53]	[2.48]*	[2.88]**	[0.65]	[1.55]
TFA*exp=2	0.107	0.107	0.066	0.065	0.149	0.144	0.110	0.102
	[5.20]**	[5.19]**	[2.29]*	[2.25]*	[9.16]**	[7.13]**	[4.85]**	[3.97]**
TFA*exp=3	0.126	0.125	0.094	0.093	0.124	0.157	0.074	0.140
	[3.43]**	[3.44]**	[2.25]*	[2.23]*	[4.11]**	[3.90]**	[1.90]	[3.09]**
TFA*exp=4+	0.111	0.110	0.122	0.120	0.145	0.168	0.130	0.166
	[3.30]**	[3.23]**	[3.74]**	[3.67]**	[5.10]**	[4.70]**	[3.68]**	[3.89]**
Other*exp=1	-0.028	-0.028	-0.014	-0.014	-0.008	-0.035	-0.002	-0.022
	[2.22]*	[2.20]*	[0.88]	[0.88]	[0.72]	[2.50]*	[0.10]	[1.17]
Other*exp=2	0.020	0.020	0.039	0.039	0.026	0.019	0.053	0.058
	[1.78]	[1.77]	[2.81]**	[2.81]**	[2.64]**	[1.55]	[3.83]**	[3.40]**
Other*exp=3	0.066	0.066	0.094	0.093	0.062	0.076	0.082	0.115
	[6.10]**	[6.05]**	[6.96]**	[6.92]**	[6.45]**	[6.60]**	[6.24]**	[7.28]**
Other*exp=4+	0.072	0.071	0.103	0.102	0.062	0.079	0.082	0.125
	[8.14]**	[8.08]**	[8.77]**	[8.74]**	[7.92]**	[8.58]**	[7.35]**	[9.72]**
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 11. Observations clustered at the teacher level. All pathway effects are relative to the effect of the NYCTF Math Immersion pathway.

Table 14: 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 11. Observations clustered at the teacher level.

Table 15: 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 11. 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.

Table 16: 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

Table 17: Simulation of Average Value Added by Pathway and Experience Accounting for Attrition*

Simulation Year	Average Value Added			
	NYCTF-MI	CR	NYCTF	TFA
1	0.000	0.018	0.011	0.054
2	0.045	0.068	0.053	0.103
3	0.066	0.086	0.072	0.086
4	0.052	0.081	0.088	0.088
	Value Added by Pathway and Experience (Table 13)			
Experience	NYCTF-MI	CR	NYCTF	TFA
1st year	0.000	0.018	0.011	0.054
2nd year	0.051	0.075	0.061	0.107
3rd year	0.085	0.095	0.090	0.126
4th year	0.063	0.091	0.128	0.111

* Calculations employing value added by experience from Table 13 and average leave rates by pathway and experience from Table 16.

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Appendix A
Courses and Credits required by Math Immersion Programs

Table 1. Math Content Requirements

- Campus A Middle Childhood Math/Math Immersion: 5 courses, 15 credits
- Campus A Adolescent Math Fellows: 6 courses, 18 credits
- Campus B Math Fellows: 3 courses, 9 credits
- Campus B Math Immersion Fellows—5 courses, 15 credits
- Campus C Math Fellows: 5 courses, 14 credits—plus additional two courses, 6 credits "as needed" for Math Immersion fellows
- Campus Z Math and Math Immersion: 1 course, 3 credits—
- Campus D Math and Math Immersion: 2 courses, 6 credits

Table 2. Math Methods Requirements

- Campus A Middle childhood: 3 courses, 9 credits
- Campus A Adolescent: 3 courses, 7 credits
- Campus B Math and Math Immersion: 3 courses, 9 credits
- Campus C: 4 courses, 12 credits
- Campus Z: 2 courses, 6 credits
- Campus D: 1 course, 6 credits

Table 3. General Pedagogy

- Campus A Middle childhood: 2 courses, 5 credits
- Campus A Adolescent: 0 courses
- Campus B: 1 courses, 3 credits
- Campus C: 1 courses, 3 credits
- Campus Z: 4 courses, 12 credits
- Campus D: 4 courses, 12 credits

Table 4. Preparation in Learners and Learning

- Campus A Middle childhood: 2 courses, 6 credits
- Campus A Adolescent: 3 courses, 9 credits
- Campus B: 2 courses, 6 credits
- Campus C: 1 course, 3 credits
- Campus Z: 3 courses, 9 credits
- Campus D: 1 course, 3 credits

Table 5. Fieldwork associated with coursework

- Campus A : 60 hours
- Campus B: 55 hours
- Campus C: 3 courses require FW but no hours mentioned
- Campus Z: 25 hours
- Campus D: 1 course requires FW but no hours mentioned

Appendix B

Table B-1: Summary of Survey Factors			
	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	…