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What Are the Effects of Teacher Education and Preparation On Beginning Math and Science Teacher Attrition?[1]

By

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This study examines whether the pre-employment education and preparation of math and science teachers impacts their retention in teaching. It addresses the question: do the kinds and amounts of education and preparation math and science teachers received before they began teaching have any impact on whether they remain in teaching after their initial year on the job? Our overall objective is to enhance our knowledge and understanding of how policy can assist schools in better ensuring that all classrooms are staffed with qualified mathematics and science teachers.

Our data source is the National Center for Education Statistics' nationally representative 2003-04 Schools and Staffing Survey, along with its' supplement, the 2004-05 Teacher Follow-up Survey. SASS/TFS is the largest and most comprehensive data source available on elementary and secondary teachers and schools. We focus on qualified math and science teachers, which we define as those with an undergraduate or graduate degree in math, in one of the sciences, or in related fields, such as engineering, math education, or science education. We do not count as qualified those who as assigned to teach math or science courses, or those with a certificate in math or science, absent having a degree in the field. We chose a major-based method of identification because it represents those teachers with a credential signifying human capital in the field – the subject of major policy concern. Hence, in our discussion to follow, the term "math and science teachers" refers to those with degrees in the field. Note that while we do not include measures of the performance or effectiveness of math and science teachers, we do use a proxy measure of teachers' academic ability – the selectivity ranking of their undergraduate college or university.

Using these data we first document the types and amounts of pre-service preparation, and education that new mathematics and science teachers acquire and how these compare to other teachers. A key area of debate in the education policy realm concerns the relative value of teachers' subject-matter knowledge (knowing what to teach) and their pedagogical skill (knowing how to teach). Here we include measures of both the subject-matter content education and the pedagogical preparation teachers acquire before teaching. We then use multilevel logistic regression analysis[2] to examine the effects of these different types and amounts of pre-service education and preparation on the likelihood that these beginning teachers stay in or leave teaching.

Results

Trends in the Teaching Force

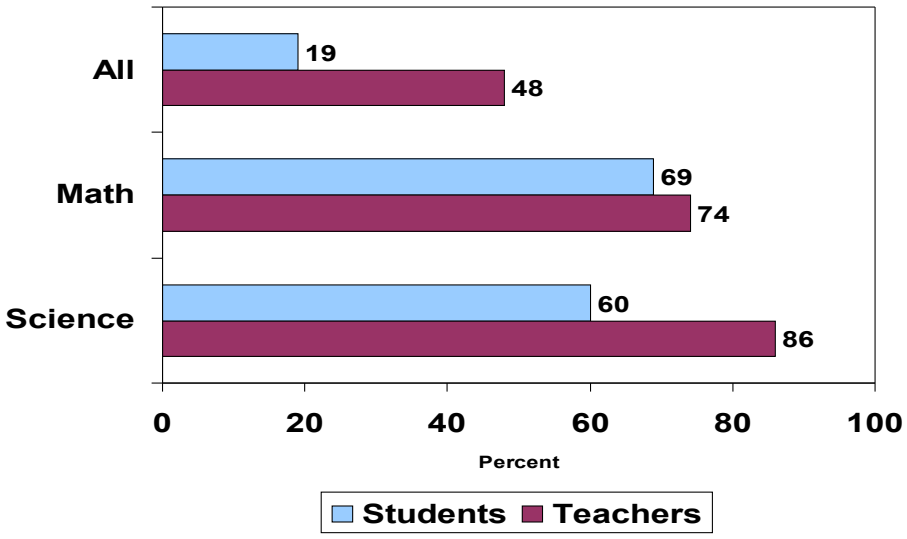
To set the context and background to our project, we began by examining the data on basic trends in the size of the qualified math and science teaching force. The data show the numbers of math and science teachers has dramatically grown in recent decades.

After a period of decline during the 1970s, elementary and secondary student enrollments began to steadily grow in the U.S. – during the 20 year period from 1988 to 2008 the number of

[2] Specifically, we use a generalized estimating equations (GEE) approach to multilevel logistic regression (Liang & Zeiger, 1986). This approach makes fewer distributional assumptions than hierarchical generalized linear models (HGLM) (see Raudenbush & Bryk, 2002), and is more appropriate when within-cluster sample sizes are small as in the case of the SASS data.

students in the nation increased by 19 percent (see Figure 1). Moreover, over the same period, high school graduation course requirements were increased across the nation in the core academic subjects – and more so for math and science than any other field. The latter trend led, in turn, to a dramatic rise in math and science course taking by students over these two decades, by 69 and 60 percent, respectively. Notably, the data also show that during this two decade period, the number of qualified math and science teachers employed more than kept pace with these student enrollment increases. The number of qualified math and science teachers employed increased by 74 percent and 86 percent, respectively. It appears that the many federal, state and district efforts to recruit more math and science teachers have, indeed, paid off. What kinds of education and preparation have these teachers received?

Figure 1: Percent Increase in Students and Qualified Teachers Employed, by Field from 1987-88 to 2007-08



Teacher Education and Preparation

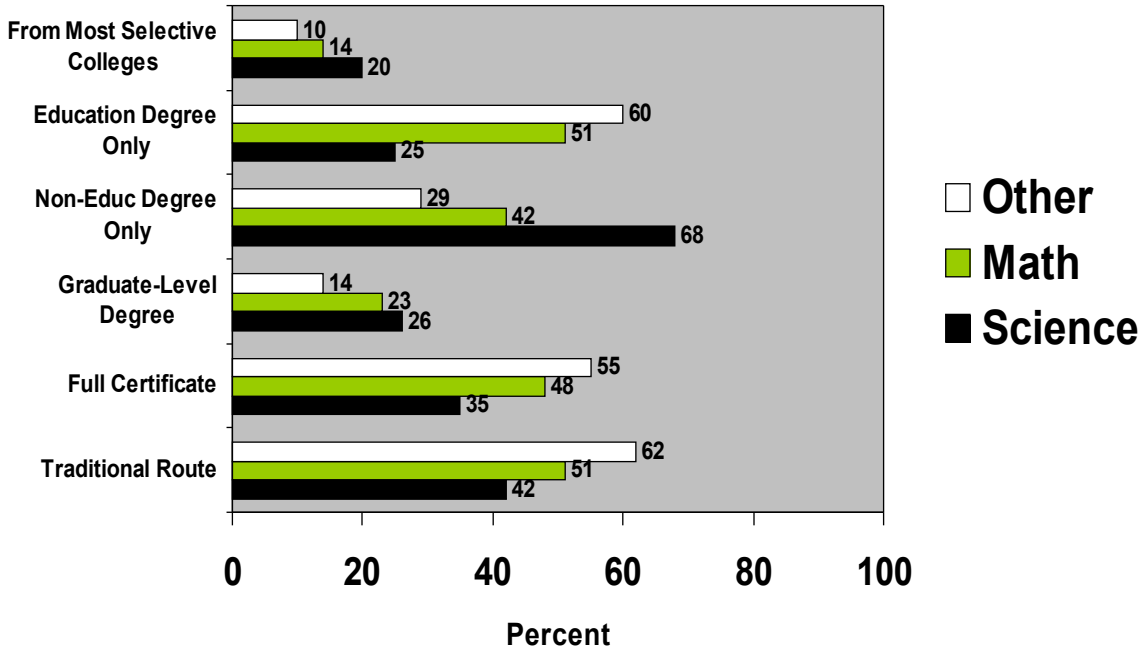
The data show that new math and science teachers in recent years have had different educational and preparation experiences and backgrounds than other teachers and also have differed from each other. In general, math, and especially science, teachers tended to have more subject-matter content education, more post-secondary education, and to have less pedagogical preparation than other teachers.

The data suggest that first-year science and math teachers on average tended to be of slightly higher academic ability than other teachers. We used a proxy measure of candidates' academic ability – Barron's rankings of the selectivity and competitiveness of the college or university where the teacher's bachelor degree was obtained. In 2003-04 about one tenth of

incoming teachers had obtained their bachelor degrees from the most selective colleges and universities; in contrast, this was true for 14 percent of new math teachers and 20 percent of new science teachers (see figure 2).

As mentioned, in this study we counted as qualified both those with subject-area education degrees (such as in math education or science education) and with non-education degrees (such as in math, biology or chemistry). In our analysis we disaggregated the data to discern what portions of new teachers held only non-education degrees, what portions held only education degrees, and what portions held both, and how this differed by teacher field. Interestingly, compared to other new teachers, first-year qualified math teachers, and especially science teachers, were less likely to hold subject-area education degrees and more likely to have obtained academic or non-education degrees. Also, first-year math and science teachers were more likely to have already completed a graduate-level degree (i.e. a masters or doctorate degree) than other new teachers.

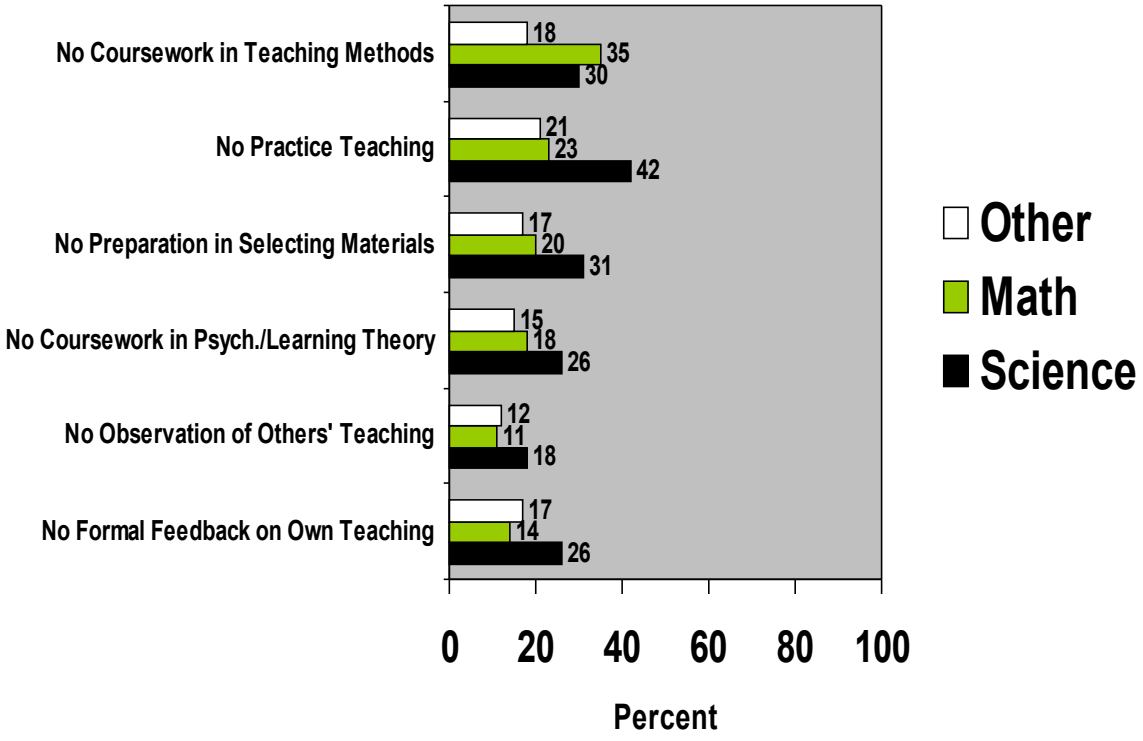
Figure 2: Percent Beginning Teachers' Who Graduated from the Most Selective Colleges, with Education and Non-Education Degrees, with Graduate-level Degrees, with Full Teaching Certificates, and Who Entered Through a Traditional Program, by Field: 2003-04



First-year science and math teachers also differed in their level of certification and the type of program or route by which they entered teaching. Type of certification and type of route are sometimes assumed the same. For instance, some assume that teachers who entered through an alternative route hold an alternative certificate. This is a misunderstanding. Alternative routes greatly vary across states, but in general these are programs in which candidates begin teaching while concurrently working on program coursework and requirements – in order to expedite entry into the teaching occupation. While candidates are enrolled in such a program

some states issue them a provisional or temporary certificate; after completing such a program most states usually issue these candidates a full standard certificate. However, provisional, emergency or temporary certificates are also issued in other situations, such as for candidates who have not yet completed all the requirements in a particular field, such as having passed certification tests, or completed sufficient coursework.

Figure 3: Percent Beginning Teachers without Different Types of Pedagogical Preparation, by Field: 2003-04



The data show that first-year math teachers and especially science teachers were less likely to hold a full regular teaching certificate and more likely to hold an emergency, temporary or provisional certificate than other teachers. First-year math teachers, and again especially science teachers, were less likely to have obtained their teacher preparation through a traditional teacher education program, and more likely to have entered via a non-traditional or an alternative route program or to have not entered through a formal program, but to have undertaken individual courses on their own before entering teaching.

Besides their types of college, degree, certificate and program, not surprisingly, first-year science and math teachers also differed in the actual pedagogical preparation they acquired before entering teaching.

In our study we examined several types of pedagogical preparation:

1.) coursework in teaching methods or teaching strategies
2.) practice teaching
3.) four other types of pedagogy:
    a.) preparation in how to select and adapt instructional materials
    b.) coursework in learning theory or child/youth psychology
    c.) opportunities to observe others' classroom teaching
    d.) formal feedback on their own teaching

Qualified first-year science teachers tended to have undertaken less of these types of pedagogical preparation; this was also true for math teachers but less so (see figure 3). For instance, both new math and science teachers were less likely to have taken formal coursework in teaching methods and teaching strategies. First-year science teachers, in particular, had less practice teaching than others prior to taking their first teaching job. Over 40 percent had none, as compared to 21 percent of other teachers. In addition, new science teachers, in particular, were less likely to have had all of the four other types of pedagogical preparation: coursework in how to select and adapt instructional materials; coursework in learning theory and child psychology; opportunities to observe others' classroom teaching; and formal feedback on their own teaching. In contrast, math teachers tended to be more similar to other teachers in their likelihood of receiving these latter four types of pedagogy.

The Effects of Education and Preparation on Teacher Attrition

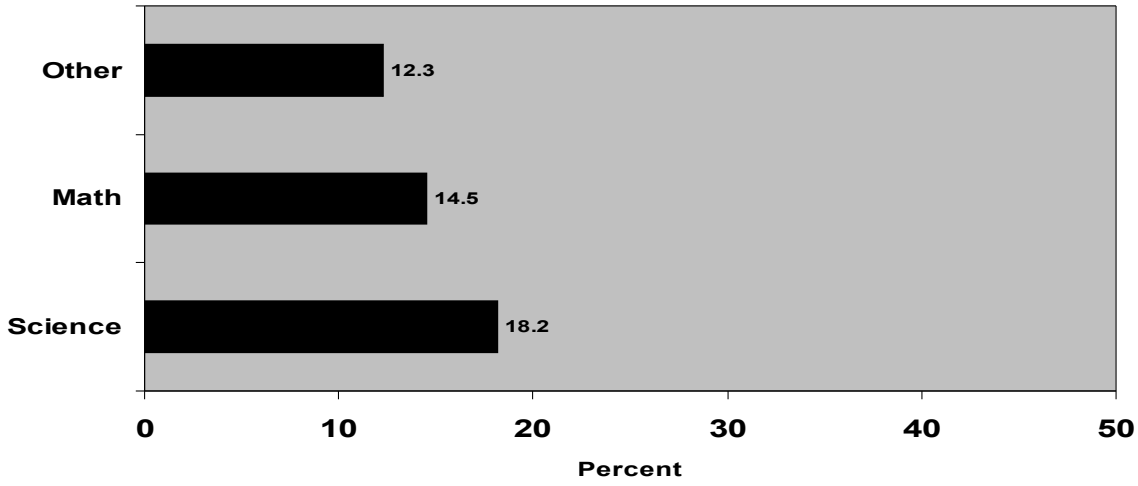
Beginning math and science teachers left teaching at higher rates than other new teachers – after their first year, over 18 percent of science teachers left, 14.5 percent of math teachers left, while 12.3 percent of others did so (see figure 4). Our multiple regression analyses also show that, after controlling for the background characteristics of both the teachers (gender, race-ethnicity, age) and their schools (poverty, size, urbanicity, level, sector), a number of aspects of beginning teachers' educational and preparation experiences were significantly associated with their attrition.

In general, in our background analyses we have found that teachers who attended more selective undergraduate institutions tend to quit at higher rates. However, we found that not to be the case for first-year teachers. Overall, beginning teachers who attended more selective undergraduate institutions, were not significantly more, or less likely, to return for a second year of teaching.

While new teachers' types of degrees, certificates and preparation routes were often associated with their likelihood of leaving in background bivariate analyses, once we controlled for teacher and school background characteristics, most of these relationships became small and/or statistically insignificant.

For instance, once we controlled for background characteristics, beginning math and science teachers who held an education degree, such as in math education or science education, did not differ in their likelihood of attrition from those with a non-education degree, such as in math or biology.

Figure 4: Percent Beginning Teacher Attrition After First Year, by Field: 2004-05



Likewise, those with a less-than-full teaching certificate were no more or less likely to depart after their first year. However, the 19 percent who had no certificate at all were more likely to leave. Moreover, those who entered through a traditional program were also slightly less likely to leave teaching after their first year than those who entered via a non-traditional or alternative route program.

However, while their types of college, degree, certificate, and preparation route often had little bearing on the likelihood of new teachers leaving teaching after one year, this was not true for the amount and type of pedagogical preparation they undertook. Pedagogy was strongly related to attrition.

First-year teachers who took more courses in teaching methods and strategies were significantly less likely to depart. For instance, those who took 3 or 4 methods courses had a 36 percent lower odds of leaving as those who had taken no such courses.

The amount of prior practice teaching new teachers had undertaken was also strongly related to their durability. First-year teachers who had a semester (12 weeks or more) of practice teaching prior to their employment were over three times less likely to depart than those who had no practice teaching at all.

In addition, having each of the four other types of pedagogical preparation – preparation in how to select and adapt instructional materials; coursework in learning theory or child psychology; observation of other's classroom teaching; and formal feedback on their own teaching – were significantly and strongly related to whether new teachers left teaching or not. For instance, those whose preparation included observation of others' classroom teaching had an odds of leaving 65 percent lower than those who had not had such preparation.

Notably, after controlling for their pedagogical preparation, the positive regression estimate for first-year science teachers – indicating higher attrition – decreased by almost half – suggesting that part of their higher attrition is accounted for by their lower levels of pedagogical preparation.

The data also revealed that the above types of pedagogical preparation (practice teaching, courses in teaching methods, the four other types of pedagogy) do not exist in isolation; teachers with higher or lower levels of some were also likely to have higher or lower levels of others. Some new teachers enter having had numerous courses in teaching methods, a full semester of practice teaching, opportunities to observe other's classroom teaching, and received formal feedback on their own teaching. On the other hand, some new teachers enter having had no courses in teaching methods, no practice teaching, little or no chance to observe other's classroom teaching, and received no formal feedback on their own teaching. How much pedagogical background new teachers have acquired is partly a factor of the program or route by which they entered teaching – i.e. through a traditional or alternative route. But, we also found large variations in pedagogical preparation both within and between these routes. For instance, there were large differences among those coming in through alternative routes in what pedagogy preparation they received and there was also substantial overlap in preparation between traditional and alternative routes.

To more accurately empirically distinguish teachers according to their degree of pedagogical preparation, we used a statistical clustering technique. This empirically divided the teachers into four groups receiving different "packages" of pedagogical preparation:

1.) Little or No Pedagogy: This group entered having had at most one course in teaching strategies and methods, little or no practice teaching, and little or none of the four other types of pedagogical preparation (preparation in how to select and adapt instructional materials; coursework in learning theory and child psychology; observation of other's classroom teaching; and formal feedback on their own teaching).

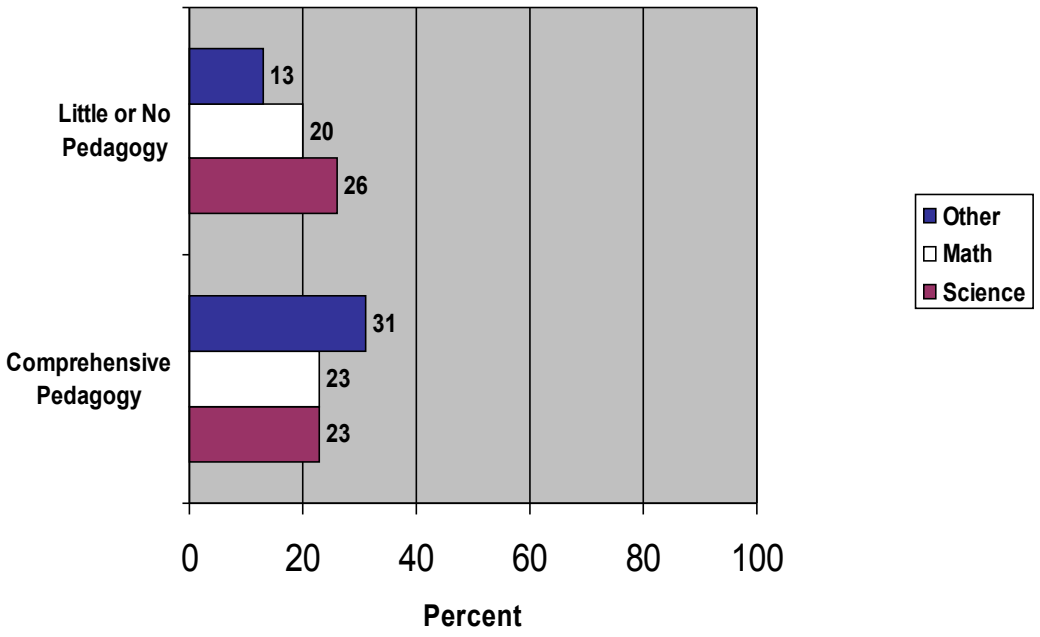
2.) Basic Pedagogy: This group entered having had no courses in teaching strategies and methods, but usually had a full semester of practice teaching, and also had most of the four other types of pedagogical preparation (preparation in how to select and adapt instructional materials; coursework in learning theory and child psychology; observation of other's classroom teaching; and formal feedback on their own teaching).

3.) Basic Pedagogy Plus: This group entered having the same as group # 2, but with the addition of 1-4 courses in teaching methods or teaching strategies.

4.) Comprehensive Pedagogy: This group entered having the same as group # 2, but with the addition of 5 or more courses in teaching methods or teaching strategies.

Consistent with the earlier data, compared to other teachers, beginning math and science teachers tended to have less comprehensive pedagogical preparation. For instance, new math and science teachers were more likely to have received package #1 (Little or No Pedagogy) and less likely to have received package # 4 (Comprehensive) than other new teachers (see figure 5).

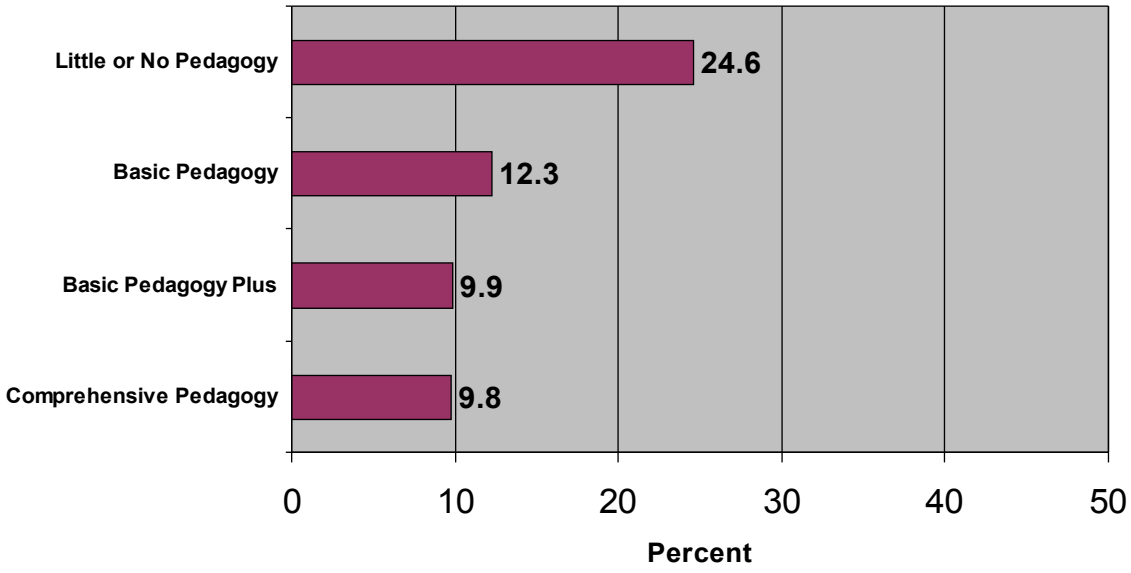
Figure 5: Percent Beginning Teachers Who Received Different Pedagogical Preparation Packages, by Field: 2003-04.



To get a sense of the collective impact of having received these multiple types of pedagogical preparation we estimated the likelihood of turnover for each of these packages. The results showed a very large cumulative impact of pedagogy on turnover. For instance, after controlling for other factors, those receiving Little or No Pedagogy were 3 times more likely to leave after one year as those who received a Comprehensive Pedagogy package (see figure 6). The predicted probabilities also suggest that some kinds of pedagogy have greater impact on retention than others. The largest reductions in attrition were associated with the Basic Pedagogy package – this group usually had a full semester of practice teaching, and most of the four other types of pedagogy, but had no courses in teaching strategies and methods. Adding

more of the latter methods courses, as in the Basic Plus and Comprehensive packages, was associated with much less reduction in attrition.

Figure 6: Predicted Probability of Attrition of Beginning Teachers, by Various Pedagogy Packages: 2004-05



Statistical analyses such as ours are, of course, subject to selection bias. Relationships found between attrition and our variables of interest could be partly a result of unobserved factors not included in the analysis. Even after controlling for teacher and school background characteristics, the lower attrition of teachers with substantial pedagogical preparation, might not be due to the effect of that preparation, but to teacher-selection effects that influenced the type of preparation received. For instance, it could be the case that those who enroll in a traditional type of preparation program and obtain more pedagogical preparation are more likely to view teaching as a career, or as an investment, to which they are committed, than those who do not obtain such training and preparation before entering teaching. Moreover, it could also be the case that those that acquire an education degree may be more committed to teaching simply because they have fewer other career options than those who acquire a non-education degree, such as in math or in one of the science disciplines. Hence, there could be bias in those "selected" into different levels of our variables of interest – preparation. As a result, low attrition of such teachers could be a result, not of their levels of preparation, but of their pre-existing

commitment to teaching.

It is not possible to fully control for such factors, but to further explore these issues we undertook two additional analyses. First, we estimated our same models, with the inclusion of a measure of teacher's job commitment. The latter was based on an item in the SASS questionnaire that asked teachers, at midpoint in the year, how long they plan to remain in teaching. Answer options included: as long as able; until eligible for retirement; will probably continue until something better comes along; definitely plan to leave as soon as possible; undecided at this time. Our purpose was to investigate whether pedagogical preparation still effects attrition, after holding constant how long first-year teachers planned to stay in teaching. As expected, teachers who reported little or no commitment (i.e. they reported they definitely plan to leave as soon as possible) were significantly more likely to leave after one year. However, in those models the effects of pedagogical preparation did not significantly change; they remained strongly related to attrition. In other words, after controlling for whether first-year teachers planned to remain in teaching or not, those with more pedagogical preparation were significantly more likely to continue in teaching.

A second additional analysis we undertook was to estimate our models on a subset of those first-year teachers who had only education degrees, i.e. we dropped those with academic and non-education degrees. Our purpose was to investigate whether pedagogical preparation affects attrition, even among those ostensibly most committed to staying in teaching – those with only degrees in education. Again, our results did not greatly change. We found that among those with only education degrees, those with more pedagogical preparation continued to be significantly more likely to continue in teaching. For instance, 10 percent within this group had had no practice teaching before their first year on the job – and our estimates showed the latter were almost 3 times as likely to leave after one year on the job. These two additional analyses, of course, cannot fully address the issue of selection bias. But, they do indicate that our finding that pedagogy is related to attrition is robust.

Conclusion and Implications

Some turnover of mathematics and science teachers is, of course, normal, inevitable, and beneficial. For individuals, departures leading to better jobs, either in teaching or not, can be a source of upward mobility. For schools, departures of low-performing employees can enhance organizational outcomes. For the educational system, teacher outflows, such as temporary attrition, or those leaving classroom teaching for other education-related jobs, do not represent a permanent or net loss of human capital to the education system as a whole and can be beneficial to the system.

However, none of these types of departures are cost free, whether permanent or to other education jobs. All have the same effect; they typically result in a decrease in classroom mathematics and science instructional staff in that particular organization – staff that usually must be replaced.

For beginning teachers, in particular, one possible consequence of attrition is the loss of new teachers before they are able to fully develop their skills. Recent research has documented

that teacher's effectiveness—as measured by gains in their students' test scores— increases significantly with each additional year of experience for the first 5 to 10 years in teaching (e.g., Kane, Rockoff, & Staiger, 2006).

Moreover, in our earlier research (e.g. Ingersoll & Perda 2010; Ingersoll 2011; Ingersoll & May 2012), we have documented that mathematics and science teacher turnover is a major factor behind the mathematics and science teacher shortage. The No Child Left Behind Act (NCLB) mandates that all students in core courses be taught by qualified teachers. If schools are to meet this NCLB mandate, the data make clear that many schools will need to focus on improving teacher retention, especially in math and science.

This present study follows up by examining the effects of pre-service education and preparation on the attrition of math and science teachers. Our analyses of data from the 2003-05 SASS/TFS data set show that there are large differences in the types and amounts of education and preparation that teaching candidates receive. Math and science teachers, in particular, were more likely than other teachers to have graduated from highly selective colleges and universities, more likely to hold non-education degrees, and less likely to have entered teaching through a traditional teacher education program or route. On the other hand, while they tended to have more subject-matter education, math and especially science teachers tended to have less pedagogical preparation than other teachers. They had completed fewer courses in teaching methods and science teachers, in particular, had had far less practice teaching before entering the teaching job.

Our analysis also showed that these differences in education and preparation were significantly related to the degree to which teachers stay in or leave teaching. However, these effects varied by the type of education and preparation. Interestingly, the type of college, degree, or certificate mattered little. The selectivity of ones' college, the name of one's degree or certificate, or the label associated with their route or program all had small or insignificant relationships with attrition. What did matter was the substance of new teacher's preparation – especially the pedagogical preparation teachers acquired. Those with more pedagogy were far more likely to stay in teaching after their first year on the job.

These findings are especially pertinent for math and science teachers. The same types of preparation associated with better retention are the same types of preparation that math and especially science teachers are less likely to have. This has large implications for policy.

It is widely believed that a key strategy to improve mathematics and science student performance is to ensure students are taught by qualified math and science teachers. Our earlier research shows that ensuring the latter is enhanced by improving the retention of mathematics and science teachers. In turn, this new study shows that one method to enhance retention is to ensure new teachers have received basic pedagogical preparation. It is widely held that it is important for math and science teachers to have adequate subject-matter content knowledge. And, our research shows that, in fact, math and science teachers are more likely to hold degrees in their discipline. But our data suggests it is also important to have adequate preparation in pedagogical methods and skills – the "how" of teaching – and in these areas of preparation math and science teachers are disadvantaged.

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