Is Less More? Outcomes for Subject-Area Specialists in Elementary Grades

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Abstract

While subject-area specialization is common practice in secondary grades, little is known about its incidence and impact in elementary schools. In this study we use data from North Carolina elementary schools to assess which teachers specialize and whether specialization benefits student achievement. We find that specialization is prevalent in upper elementary grades—approximately 25 percent of 4^{th} grade teachers and 37 percent of 5^{th} grade teachers specialize—and that schools assign relatively more effective teachers to specialize. Student achievement results indicate that specialization is not leading to its theorized benefits in mathematics and reading. Specialists are no more effective than their generalist peers and are less effective than they were before specializing. School-level achievement in mathematics and reading does not improve with more specialization. Science results are different and show benefits to specialization. These findings question the use of specialization but invite continued research to more fully assess its impact.

Introduction

Research evidence shows the importance of teachers to a range of short and longer-term student outcomes (Chetty, Friedman, & Rockoff, 2014a, 2014b). Teachers matter, and as such, policymakers and school officials are interested in finding policies and practices that boost teacher performance and ensure that more students are taught by highly-effective instructors. Many proposals designed to accomplish these goals—e.g. revising teacher education programs, changing teacher tenure protections, overhauling teacher evaluation systems—are expensive, controversial, and/or challenging to implement at scale (Jacob & Rockoff, 2011). These high-profile reforms may succeed, but they do not replace the need for districts and schools to implement improvement strategies that they control and that allow them to leverage the talent of their existing teacher workforce.

Within this realm, subject-area specialization stands out as a potentially promising practice to benefit elementary school students and teachers. Rather than teaching all four academic content areas in a self-contained classroom, specialization means teaching the subset of subjects in which elementary school teachers have an advantage. Specifically, specialization relies upon two conditions: comparative advantage, such that a teacher can produce an outcome (e.g. student achievement in reading) at a lower opportunity cost than other teachers and absolute advantage, such that teachers are more effective in particular subject-areas. Research shows that elementary school teachers are often more effective in particular subjects (Goldhaber, Cowan, & Walch, 2013). Schools can leverage these existing performance data to make evidence-based teacher assignments. This strategic assignment process offers elementary schools two ways to improve student achievement: connecting teachers who are highly-effective in a particular subject-area to more students and providing teachers opportunities to acquire job-specific human capital and improve their effectiveness (Atteberry, Loeb, & Wyckoff, 2017; Bastian & Janda, 2017; Cook & Mansfield, 2016; Ost, 2014).

While subject-area specialization is a common practice in middle and secondary schools—as teachers take charge of increasingly complex subject matter—less is known about its incidence in elementary schools, where state licensure policies[1] and typical assignment patterns encourage teachers to be generalists in self-contained classrooms. As such, little is known about the effects of specialization on elementary school students and teachers. If elementary schools want to adopt subject-area specialization as a low-cost approach to boost student outcomes, further research is necessary to assess whether schools assign more effective teachers to specialize and whether specialization benefits student achievement. With this motivation, we used administrative data on student test scores and teacher assignments from North Carolina public schools (NCPS) to answer the following questions:

(1) Which elementary school teachers specialize?

(2) Is the specialization of elementary school teachers associated with student achievement?

Overall, these analyses make several inter-related contributions to policy and research on teacher effectiveness. First, our results have a direct bearing on subject-area specialization and its use in elementary schools. To the extent that specialization benefits students and teachers, it stands out as a promising practice to strategically manage human capital. Second, in an era focused on data use and human capital management, subject-area specialization is part of a larger movement to provide effective teachers opportunities for leadership and advanced roles (Backes

[1] In North Carolina, elementary school teachers typically hold a K-6 license that certifies them to teach all four academic content areas. Licenses for middle school and high school teachers apply to a single subject/content-area (e.g. mathematics, biology).

& Hansen, 2018). Finally, this work connects to existing research on job-specific human capital and ways to improve the effectiveness of existing teachers through assignment practices.

Prior Literature

The foundation for subject-area specialization rests upon long-established economic principles and recent analyses of teacher effectiveness in elementary grades. In schools, teachers can have a comparative advantage in teaching certain subjects because they produce an outcome—e.g. student learning—at a lower opportunity cost than other teachers. Likewise, teachers can have an absolute advantage in teaching certain subjects because they are the best at producing an outcome. Recent empirical analyses show that these advantages exist within elementary schools. For example, Goldhaber and colleagues (2013) find cross-subject (mathematics and reading) correlations of 0.70 to 0.80 in the effectiveness of elementary grades teachers. Despite these relatively high correlations, their simulation analyses suggest that specialization can result in meaningful student achievement gains. Fox (2016) reaches a similar conclusion after simulating the reassignment of elementary school teachers based on their comparative advantage. To the extent that schools can leverage and coordinate these effectiveness differences, students and teachers may benefit.

Subject-area specialization offers several potential benefits to elementary school students and teachers. Possible direct benefits to students include receiving instruction from more effective teachers, exposure to multiple teaching styles, preparation for the transition to middle school, and allowing students to move through subject-areas by ability level (Chan & Jarmon, 2004). In the present study we assess benefits to students through scores on state achievement tests; we acknowledge that there may be other outcomes that we do not examine here.

For teachers, subject-area specialization presents an opportunity to acquire job/subject-specific human capital. By teaching a smaller number of subject areas, teachers should be able to plan for and use their instructional time more efficiently and have more time for professional development and collaboration with colleagues (Chan & Jarmon, 2004; Markworth, Brobst, Ohana, & Parker, 2016). Furthermore, specializing teachers should have a deeper understanding of their content area through increased repetition in teaching that material and more targeted and in-depth professional development (Ball, 1990; Fryer, 2016). While specialization should contribute to job-specific human capital, it is important to note that teachers do not entirely control this process: districts and schools need to offer the coaching and professional development resources that allow teachers to fully realize the benefits of specialization.

Recent research shows that job-specific human capital contributes to teacher effectiveness and that teaching assignments help teachers acquire this human capital. For example, Ost (2014) finds that elementary school teachers who always repeat grade-level assignments improve 35 percent faster than teachers who never repeat grade assignments. Comparably, Blazar (2015) shows that grade-switching adversely impacts student achievement and is particularly harmful when elementary school teachers switch to non-adjacent grades. At the high school level, Cook and Mansfield (2016) decompose teacher effectiveness into general and task-specific components and find that a meaningful proportion of returns to experience are attributable to subject-specific (rather than general) human capital. These results signal that subject-area specialization may be a way to increase the effectiveness of teachers.

Although subject-area specialization has several theorized benefits, there are concerns with elementary schools adopting the practice. Anderson (1962) argues that it is challenging for subject-area specialists to consistently enforce rules and procedures across multiple classrooms.

Furthermore, he contends that subject-area specialists will be less skilled in tailoring lessons to the needs and learning styles of students. These concerns are echoed by Fryer (2016), who argues that specialization can lead to inefficient pedagogy—fewer interactions with and less individualized attention given to students. To date, Fryer (2016) is the only researcher to assess the impact of subject-area specialization on elementary school student achievement. In a randomized experiment in Houston—where elementary schools were randomly assigned to treatment and teachers were picked to specialize based on prior measures of effectiveness—Fryer found that specialization had a negative impact on student achievement. The average effect was -0.042 standard deviations in mathematics and -0.034 standard deviations in reading. These negative effects were larger in the first year of the experiment and for special education students. While Fryer (2016) could not directly test the mechanism(s) explaining the negative results, specialized teachers reported giving less individualized attention to their students.

A randomized experiment provides internally valid estimates but comes with potential concerns about generalizability to other settings and implementation strategies. As such, there is a need for continued research on subject-area specialization, especially given the theoretical benefits of specializing and the surprising findings from Houston. Our study addresses this need with statewide data from a large number of elementary schools (nearly 1,400) across diverse settings. These data allow us to examine specialization as elementary schools have decided to implement it. Relative to Fryer (2016), the present study has several unique features, including models to predict which teachers specialize, estimating impacts for one and two-subject specialists separately, examining how experience with specialization influences teacher effectiveness, and assessing how the concentration of specialization predicts achievement. These analyses broaden our understanding of subject-area specialization in elementary schools.

Data and Sample

Research Sample

The research sample for the present study includes content area teachers (i.e. mathematics, reading, science, and social studies) in grades K-5 in NCPS during the 2011-12 through 2015-16 academic years. In particular, many of our analyses focus on teachers in grades 4 and 5, as these are the grade levels at which we can assess value-added to student achievement on the state's End-of-Grade (EOG) exams in mathematics, reading, and science (5th grade only). Furthermore, these are the elementary grades with the highest concentrations of subject-area specialization. Overall, our sample includes 55,054 unique teachers in grades K-5 (169,501 teacher-year observations) and 23,552 unique teachers in grades 4 and 5 (55,538 teacher-year observations). During our study period these 4th and 5th grade teachers taught nearly 665,000 unique students and are linked to more than 2.5 million student test scores in mathematics, reading, and science.

[Insert Table 1 about here]

Table 1 displays teacher and school-level descriptive data for our sample. We present these data for grades K-5 and for grades 4 and 5, separately; likewise, we provide data for all teachers and for subject-area specialists versus generalist teachers. Focusing on the teacher-year records for all 4th and 5th grade teachers, we note that 91 percent are female, 16 percent are a racial/ethnic minority, and the average age is over 40. These teachers average over 11 years of experience, 36 percent have earned a graduate degree, and over 12.5 percent are Nationally Board Certified (NBC). Nearly 33 percent of these teacher-year records are for subject-area specialists, with approximately 11 percent specializing in a single subject-area (e.g. reading only) and 20 percent specializing in two subject-areas (e.g. math and science). These teachers work in schools where more than 50 percent of the students are a racial/ethnic minority, nearly 61 percent of the students qualify for subsidized school meals, and almost 59 percent of the state assessments (performance composite) are passed. Comparing subject-area specialists to generalists, we see that the two groups of teachers are similar across most individual and school-level characteristics. One notable difference is the urban-rural classification of schools: while 55 percent of the observations for all 4th and 5th grade teachers are for schools located in rural/town locations, over 67 percent of the observations for subject-area specialists are in these environments. Although the mechanisms explaining this difference are unclear, the higher concentration of specialists in these environments may suggest challenges in attracting personnel for rural schools.

Coding Subject-Area Specialization

To determine whether an elementary grades (K-5) teacher was a subject-area specialist, we used classroom roster data from the North Carolina Department of Public Instruction (NCDPI). This process began by keeping classroom roster records for K-5 teachers and using state course codes to limit our sample to those teaching courses listed as mathematics, English language arts/reading, science, and/or social studies.[2] For this sample of teachers we continued to use the state course codes to count the unique number of academic subject-areas (1 to 4) that they taught in a given year. We define generalists as those teaching three or four subject-areas and specialists as those teaching one or two subject-areas. Beyond these broad categories of generalist and subject-area specialist, we created an indicator for teaching one subject-area only, an indicator for teaching two subject-areas, and a set of indicators for the specific subject-area

[2] State course codes beginning with '1' are for English/reading and foreign language courses, those beginning with '2' are for mathematics and computer science courses, those beginning with '3' are for science courses, and those beginning with '4' are for social studies courses. From this set of courses we excluded foreign language courses and computer science courses.

combinations in which teachers specialized (e.g. teaching mathematics only, teaching reading and social studies).

[Insert Table 2 about here]

For grades K-5, Table 2 displays the percentage of teacher-year records for generalists and specialists and the percentage of teacher-year records for those specializing in different subject-areas. Not surprisingly, we see the percentage of subject-area specialists rising across grade levels. The incidence of specialization is low in grades K-2—approximately three to five percent of the teacher-year records—and then dramatically increases in the upper elementary grades. Fourteen percent of the teacher-year records in 3rd grade, 25 percent of the teacher-year records in 4th grade, and 37 percent of the teacher-year records in 5th grade are for subject-area specialists. For 4th and 5th grade teachers, the most common forms of subject-area specialization were teaching reading only, teaching reading and social studies (non-STEM courses), and teaching math and science (STEM courses).

Our main analyses examine whether a teacher specializes in a given subject-area and the associations between specializing and student achievement. To expand upon the student achievement analyses we created two additional specialization measures. First, we constructed a series of indicators for teachers in their first year of specialization, teachers in their second year of specialization, and teachers with three or more years of specialization.[3] This coding allows us to assess whether teacher effectiveness changes with more experience as a subject-area specialist. Second, we constructed a continuous measure for the concentration of subject-area

[3] Censoring is a potential concern with this approach if we cannot accurately identify teachers' experience with specialization prior to the beginning of our study period in 2011-12. To mitigate this concern we took two steps. First, we coded subject-area specialization using roster data from a pre-analysis year (2010-11). Second, we excluded observations for teachers who were specializing in 2011 (as it is possible that these teachers were specializing in preceding years). This leaves us with a sample of elementary school teachers that we observe specializing for the first time in 2012 or beyond.

specialization at elementary schools. To do so, we kept records for 4th and 5th grade mathematics teachers and then calculated the percentage of teachers specializing in mathematics at each school in a given year. We followed the same procedure to get the percentage of 4th and 5th grade teachers specializing in reading and the percentage of 5th grade teachers specializing in science. These percentages, which we standardized within subject-area, allow us to assess whether the intensity of subject-area specialization at a school is related to student achievement.

Outcome Measures

To examine which elementary grades teachers are subject-area specialists we create indicators for specializing in mathematics, specializing in reading, and specializing in science.[4] We code these variables as a '1' if teachers teach that subject-area only or if they teach that subject-area plus one other academic content area (any specialization). Teachers are coded as a '0' for these indicators if they are not subject-area specialists. Within this coding framework, our initial models focus on the first time that a teacher specializes in the analyzed subject-area. That is, we exclude observations for teachers after they have specialized for the first time. This approach allows us to predict the likelihood of specializing among generalist teachers. Additional models include all of the specialization records for teachers. This allows us to predict the likelihood of specializing among generalists and those who have previously specialized.

To assess whether subject-area specialization predicts student achievement, the outcome measure is students' standardized test scores (standardized within subject, grade, and year) on North Carolina's EOG exams in elementary mathematics, reading, and 5th grade science. As the measure of prior student achievement, we control for standardized mathematics and reading

[4] We also created an indicator for specializing in social studies. However, this is not an outcome measure for our first research question because there are no achievement tests for social studies. As such, we cannot predict whether a teacher's prior effectiveness in social studies predicts her likelihood of specializing in the subject-area.

scores from the previous school year. In additional analyses we assess whether the intensity of subject-area specialization predicts *school-level* achievement. To do so, we aggregate students' standardized test scores in mathematics, reading, and science to the school-by-year level.

Analyses

Which Elementary School Teachers Specialize?

If the goal of subject-area specialization is to improve student achievement, then success is strongly connected to teacher assignment decisions: principals and schools need to ensure that more effective mathematics, reading, and science teachers specialize in those subject-areas. This will expose more elementary grades students to more effective teachers and may allow these specialists opportunities to further refine and strengthen their content knowledge and pedagogical skills. With this motivation we estimated models to determine whether measures of prior teacher performance, teacher credentials, and teacher demographics predict subject-area specialization. Specifically, we estimated models with two different analytical samples: (1) models that exclude observations for teachers after they specialized for the first time and (2) models that include all of the specialization records for teachers. These approaches allow us to predict the initial assignment to specialization and annual teacher assignments.

Although we have a dichotomous outcome, we estimate linear probability models to ease interpretation of our results (Hellevik, 2007). Our coefficients express how teacher performance, credentials, and demographics predict the likelihood of being a subject-area specialist in percentage point units. Importantly, the linear probability model also provides greater flexibility—relative to logistic regression approaches—to include school-by-year fixed effects. We prefer this fixed effect specification as it allows us to compare the specialization status of teachers working in the same schools at the same time. Essentially, this approximates a choice set that principals and schools face when making teacher assignment decisions. We estimate these models in mathematics, reading, and science and cluster standard errors at the school-by-year level. Equation one displays our approach to predict specializing for the first time; equation two displays our approach to predict any instance of specialization.

$$Specialist_{it} = \beta_1 Perform_{it-1} + \beta_2 Cred_{it} + \beta_3 Demo_t + \delta_{st} + \varepsilon_{it} \quad (1)$$

$$Specialist_{it} = \beta_1 Specialist_{it-1} + \beta_2 Perform_{it-1} + \beta_3 Cred_{it} + \beta_4 Demo_t + \delta_{st} + \varepsilon_{it} \quad (2)$$

In these models $Specialist_{it}$ is an indicator for teacher *i* in school year *t* being a subject-area specialist in the analyzed subject-area. $Specialist_{it-1}$ (equation two only) captures whether the teacher specialized in the analyzed subject-area in the previous year while $Perform_{it-1}$ consists of teacher *i's* prior year evaluation ratings on North Carolina's Leadership and Facilitating Student Learning standards and their prior year value-added estimate (standardized) in the analyzed subject-area.[5] Leadership and Facilitating Student Learning are the two evaluation standards for which all North Carolina teachers receive ratings from their principal at the end of the school year. Principals rate teachers as either developing, proficient, accomplished, or distinguished.[6] $Cred_{it}$ is a vector of the following teacher credentials—experience, NBC status, having a graduate degree, and entering teaching through an alternative route—and $Demo_t$ consists of indicators for being a female and a racial/ethnic minority. Finally, δ_{st} is the school-by-year fixed effect and ε_{it} represents the subject and time specific error associated with each observation.

[5] To be in these models teachers do not have to be teaching grades 4 or 5 in the analyzed year. Rather, the sample for these analyses focuses on teachers who have a value-added estimate from the previous year. A large majority of these individuals are 4^{th} or 5^{th} grade teachers in the analyzed year.
[6] For the Leadership evaluation standard the distribution of ratings is 1.3% (developing), 36.3% (proficient), 49.9% (accomplished), and 12.4% (distinguished). For the Facilitating Student Learning Standard the distribution of ratings is 2.0% (developing), 37.6% (proficient), 52.5% (accomplished), and 7.9% (distinguished).

Is the Specialization of Elementary School Teachers Associated with Student Achievement?

Subject-area specialization can serve two purposes: to expose a greater number of elementary grades students to effective teachers and to provide these instructors opportunities to deepen their content knowledge and sharpen their pedagogical skills through targeted professional development, coaching, and more time to focus on the specialized subject. By acquiring subject-specific human capital, specialists may improve their effectiveness. With these aims our initial student achievement analyses assess whether subject-area specialists are more effective than their within-school peers and whether these teachers are more effective after becoming subject-area specialists.

To compare within schools, we estimate a covariate adjustment regression model with a school-by-year fixed effect. This allows us to compare the adjusted-average achievement of students taught by specialists with that of their peers taught by generalist teachers. One concern with the school-by-year fixed effect is the composition of the analytical sample, as elementary schools with high concentrations of specialists may not contribute to estimates. Despite this concern, we prefer a school-by-year fixed effect, relative to a school fixed effect, for two reasons: (1) with a school fixed effect teachers can switch from generalist to specialist (and contribute to estimates for both groups) during our study period and (2) time-varying school characteristics may influence decisions to adopt different intensities of subject-area specialization. To assess how teachers' effectiveness changes after becoming a specialist, we estimate a covariate adjustment regression model with a teacher fixed effect. This allows us to examine the adjusted-average achievement of students taught by specialists with that of students taught by the same instructor when she was a generalist. A potential concern with this model is how many teachers switch their specialization status during the study period. To provide more information about our analytical sample, Appendix Table 1 displays unique counts of the teachers contributing to our focal estimates. In all these analyses we cluster standard errors at the school-by-year level. Equations three and four display our school-by-year and teacher fixed effect models.

$$Y_{ijst} = \beta_1 Specialist_{jt} + \beta_2 Student_{ijst} + \beta_3 Class/Teach_{jst} + \delta_{st} + \varepsilon_{ijst} \quad (3)$$

$$Y_{ijst} = \beta_1 Specialist_{jt} + \beta_2 Student_{ijst} + \beta_3 Class/Teach_{jst} + \beta_4 School_{st} + \mu_j + \varepsilon_{ijst} \quad (4)$$

In equations three and four Y_{ijst} represents the standardized EOG exam score for student *i* with teacher *j* in school *s* at time *t*. We enter our focal specialization variables ($Specialist_{jt}$) in two ways: (1) a single indicator for being any subject-area specialist in the analyzed subject-area and (2) separate indicators for only teaching the analyzed subject-area or teaching the analyzed subject-area plus one additional subject. $Student_{ijst}$ includes prior year test scores in mathematics and reading, the average prior year test scores of a student's classroom peers, and indicators for race/ethnicity, economic disadvantage, gender, limited English proficiency, giftedness, disability, overage and underage for grade, student mobility (structural, between-year and within-year), and grade fixed effects. $Class/Teach_{jst}$ includes class size, the heterogeneity of prior student achievement in the classroom, teacher experience and experience squared, and indicators for NBC, holding a graduate degree, entering teaching alternatively, being a female and being a racial/ethnic minority. Time-invariant teacher characteristics—alternative entry, gender, race/ethnicity—are not included in the teacher fixed effect specification. $School_{st}$ (equation 4 only) includes school size, measures of school orderliness (short-term suspension and violent acts rates), measures of financial resources (total per-pupil expenditures and average teacher salary supplements), the percentage of minority and economically-disadvantaged students, and an indicator for being located in an urban environment. Finally, δ_{st} and μ_j

represent school-by-year and teacher fixed effects, respectively, and ε_{ijst} captures unexplained variation in student achievement.

To deepen our understanding of the relationship between subject-area specialization and teacher effectiveness, we perform two additional analyses. First, we remove the specialization indicators in equations three and four and include a series of indicators for how many years a teacher has specialized in the analyzed subject-area—first-year, second-year, and three or more years. This approach recognizes that there may be a short-term shock when teachers are assigned to specialize. Furthermore, this approach allows us to test whether teacher effectiveness increases with more experience as a specialist.

Second, we estimate models to assess how the concentration of subject-area specialization predicts school-level achievement. This approach recognizes that there are two 'units' for principals and schools to consider when making specialization decisions—how specialization impacts individual teachers and how it impacts the performance of the school as a whole. Subject-area specialization can adversely influence individual teacher effectiveness—as seen in Fryer (2016)—and still have a null or positive impact on aggregate school-level achievement if more effective teachers are assigned to specialize. To test this, we make school-level achievement the outcome measure and regress it on the set of school characteristics in equation four, a measure of specialization intensity at the school, and a school fixed effect. This allows us to assess whether changes in the concentration of subject-area specialists predicts school-level achievement.

Results

Which Elementary School Teachers Specialize?

Before discussing our main results, we start this section by reporting the associations between teacher effectiveness and specialization status. Specifically, we estimated additional models in which we regressed a teacher's lagged value-added estimate on an indicator for specializing in the analyzed subject-area for the first time and a school-by-year fixed effect (no other covariates included). This basic model indicates whether first-time specialists have higher lagged value-added than their within-school generalist peers. Overall, we find that first time mathematics specialists have lagged value-added 20 percent of a standard deviation higher in mathematics; first time reading specialists have lagged value-added 11 percent of a standard deviation higher in reading; and first time science specialists have lagged value-added 16 percent of a standard deviation higher in science. All of these effectiveness differences between first time specialists and their generalist peers are statistically significant.

To further these analyses, the left panel of Table 3 displays results from models that predict specializing for the first time. These models include the full set of described control variables and school-by-year fixed effects. To provide context for the magnitude of these coefficients, the bottom of Table 3 details the proportion of first-time specialists in our analytical sample— approximately 9.5 percent in mathematics, 9 percent in reading, and 10 percent in science. Consistent with the results reported above, we find that teachers with higher lagged value-added estimates are significantly more likely to specialize than their within-school peers. For example, a one standard deviation increase in a teacher's lagged value-added estimate in mathematics is associated with a 1.3 percentage point increase in the likelihood of specializing in mathematics for the first time. Beyond value-added, we find that lagged evaluation ratings on the

Facilitating Student Learning standard predict specializing in reading for the first time. Regarding teacher credentials and demographics, estimates indicate that more experienced teachers are more likely to be first time specialists in mathematics and that those with a graduate degree are less likely to be first time specialists in mathematics. Relative to their within-school peers who are male, female teachers are more likely to be first time specialists in reading and less likely to be first time specialists in STEM fields.

[Insert Table 3 about here]

The right panel of Table 3 presents results from models predicting any specialization. These analyses capture the annual nature of teacher assignments: on a year-to-year basis principals need to evaluate evidence and decide whether teachers will be subject-area specialists. These results show that previously serving as a subject-area specialist is the strongest determinant of specializing in the current year. For example, teachers who specialized in reading during the prior school year are 49 percentage points more likely to specialize in reading in the next year. Beyond prior assignments, many of the results for teacher performance, credentials, and demographics are similar to those from the left panel of Table 3. Relative to their within-school peers, teachers with higher lagged value-added estimates are significantly more likely to specialize in a given school year. Prior year evaluation ratings on the Leadership standard are not associated with specialization; however, previous ratings on the Facilitating Student Learning standard predict specialization in mathematics and reading. A one unit increase in prior ratings—e.g. moving from proficient to accomplished—is associated with a 1.5 percentage point increase in the likelihood of any mathematics specialization. Since the Facilitating Student Learning standard captures competencies related to classroom instruction and student assessment, this further suggests that teachers' instructional skills predict subject-area specialization. As with the models predicting first time specialization, we find that more experienced teachers are more likely to specialize in mathematics and that female teachers' likelihood of specializing differs across STEM and non-STEM subject-areas.

Is the Specialization of Elementary School Teachers Associated with Student Achievement?

Results for our first research question indicate that more effective teachers (as measured by student achievement) are more likely to become subject-area specialists. Now, we assess whether subject-area specialists are more effective than their within-school peers (post-specialization) and whether teachers are more effective after becoming subject-area specialists than they were as generalist teachers. Regarding our school-by-year fixed effect estimates, the middle column of Table 4 indicates that subject-area specialists are generally no more or less effective than their generalist peers in mathematics and reading. The exception to this is specializing in mathematics only—students taught by these instructors have adjusted average achievement nearly three percent of a standard deviation lower than students taught by generalist mathematics teachers. Within-school comparisons are different for the 5th grade science EOG exam. Here, estimates indicate that specialists in science are more effective, with the largest results for those teaching science only. These estimates show that students taught by any science specialist have adjusted-average achievement three percent of a standard deviation higher than similar students taught by a generalist; students taught by an instructor teaching science only have adjusted-average achievement eight percent of a standard deviation higher. To put these results into perspective, we note that in our analyses the average gain in effectiveness between the first and second-year of teaching for 5th grade science teachers is nearly 10 percent of a standard deviation in adjusted-average student achievement.

[Insert Table 4 about here]

Building on theory and prior empirical work regarding the benefits of job-specific human capital (Atteberry, Loeb, & Wyckoff, 2017; Blazar, 2015; Cook & Mansfield, 2016), the right column of Table 4 presents estimates as to whether teachers are more effective after becoming subject-area specialists. Results in mathematics and reading return clear evidence that teachers are less effective as specialists than they were as generalists. For example, students taught by an instructor teaching mathematics only have adjusted-average achievement six percent of a standard deviation lower than students taught by that same instructor when she was a generalist. These negative results are larger in magnitude—roughly double the size—for those teaching mathematics or reading only versus those specializing in two subject-areas. The overall tenor of these mathematics and reading results echo those of Fryer (2016) and his randomized experiment in Houston elementary schools. Furthermore, these results (particularly in mathematics) may offer some support for Fryer's hypothesis that inefficient pedagogy—having fewer interactions with each student—caused the negative specialization findings. In our analytical sample, generalists taught an average of 27 unique students during the school year. Those teaching mathematics only taught an average of 58 unique students while those teaching mathematics and one other subject-area taught an average of 45 unique students. As such, those who specialize the most may have the fewest interactions with each student. Lastly, we note that the science results differ from those in mathematics and reading—on average, science specialists are no more or less effective than they were as generalist teachers.

The previous analyses do not assess the extent to which teacher effectiveness improves with specialization experience. It is possible that specialization results in a short-term shock to teacher performance that dissipates as teachers become accustomed to the practice and/or receive more subject-specific supports. Therefore, Table 5 displays results from school-by-year and teacher fixed effect models in which we control for the number of years a teacher has specialized. We consider the teacher fixed effect results to be most relevant, as this approach captures a teacher's effectiveness trajectory. Nonetheless, the school-by-year fixed effect estimates return a noteworthy pattern across subject-areas: coefficients are monotonically increasing with more specialization experience, such that teachers who have specialized for three or more years are more effective, on average, than generalist teachers in the same school and year. Considering the preferred teacher fixed effect models, we see a mixed pattern of results across subject-areas. In mathematics, the negative effects of specialization persist. Even after specializing for multiple years, adjusted-average student achievement is approximately four percent of a standard deviation lower than in years when the teacher was a generalist. In reading, teachers appear to struggle during their second year of specialization, with evidence that their effectiveness subsequently rebounds towards pre-specialization levels. Trajectory estimates in science do not reveal any adverse shocks and instead, suggest that experience with specialization may aid teacher effectiveness.

[Insert Table 5 about here]

Our results show that principals assign more effective teachers to specialize and that teachers are less effective in mathematics and reading after becoming subject-area specialists. Given this evidence, it is unclear whether higher concentrations of specialization will have a net positive or negative effect on *school-level* achievement. We address this question by regressing school-level achievement in mathematics, reading, and science on a set of school covariates, a standardized measure of specialization intensity at the school, and a school fixed effect. This allows us to test whether changes in subject-area specialization are related to school-level achievement. Results in Table 6 indicate that subject-area specialization is unrelated to school-level achievement in mathematics and reading—the adverse effect of specialization for individual teachers is balanced by assigning more effective teachers to specialize. The school-level result for science shows that schools are higher-performing as more teachers specialize in science. Specifically, a one standard deviation increase in the percentage of science specialists is associated with a two percent of a standard deviation increase in aggregate achievement.

[Insert Table 6 about here]

Discussion

We contribute to knowledge on the strategic assignment of teachers by documenting the incidence of subject-area specialization in elementary schools. As expected, we find that specialization is more prevalent in upper elementary grades, with approximately 25 percent of 4th grade teachers and 37 percent of 5th grade teachers specializing. Among specialists, 40 percent teach only one subject-area, with the most common forms of specialization being teaching reading only, teaching reading and social studies, and teaching mathematics and science. These descriptives provide data on the uptake of specialization for national and state-level comparisons. More importantly, these descriptives convey the practical significance of our student achievement results by showing that specialization is a widely used practice in North Carolina elementary schools.

Our empirical results show that principals and schools assign relatively more effective teachers to specialize in mathematics, reading, and science. For example, first-time specialists in mathematics have lagged value-added 20 percent of a standard deviation higher than their generalist peers in the same school. This finding is consistent with research showing that principals can accurately identify highly-effective teachers (Jacob & Lefgren, 2008) and is good news in the sense that schools appear to have some capacity to leverage human capital data.

After becoming specialists, we find that teachers are no more effective than their generalist peers in mathematics and reading—in fact, those teaching mathematics only are significantly less effective. This discrepancy between assigning more effective teachers to specialize and those teachers going on to be no different than generalists is likely explained by our teacher fixed effect results. Mathematics and reading teachers are significantly less effective as specialists than they were as generalists. Further evidence suggests that mathematics teachers do not return to their pre-specialization levels of effectiveness. From a broader, school-level perspective, results show that more intensive specialization does not predict aggregate achievement in mathematics or reading. Specialization may adversely impact the effectiveness of individual teachers but not the school as a whole. This story is entirely different for 5th grade science. Science specialists are more effective than their generalist peers and do not experience decreases in effectiveness after specializing. This connects to our school-level results, which show that schools are higher-performing as more teachers specialize in science. It is unclear why the results differ so markedly for science versus mathematics and reading. One possibility is that the nature of science instruction differs from other subjects—for instance, Henry and colleagues (2012) show that returns to experience are much larger for secondary science courses than for mathematics and non-STEM courses. This is an area for continued research, as it is possible that lessons from science could improve the results in mathematics and reading.

So how should policymakers and school officials interpret these results? This is the second study—in different locations and with different research designs—to show some negative results for subject-area specialization. From these early findings it is fair to conclude that specialization is not yet leading to its theorized payoff. In particular, it appears that individual teachers in mathematics and reading are not acquiring more job-specific human capital or that any gains in human capital are outweighed by unintended consequences. Highlighting these unintended consequences is important because they suggest the value of relationships and frequent student-teacher interactions to the achievement of upper elementary grades students.

Despite the tenor of these results, there are two reasons why elementary schools should not necessarily abandon specialization. First, current research on specialization has not assessed intentionality: whether districts and schools are providing coordinated and in-depth supports to help teachers capitalize on their specialization status. Teachers may improve with the opportunity to teach the same content more frequently; however, it is likely that teachers will improve more when this opportunity is paired with targeted coaching, evaluation, and development. As such, specialization may represent an effective human capital management strategy in these types of environments. Second, there is more to learn about subject-area specialization and other policy relevant outcomes. Our initial analyses (not presented here) show that specialists in upper elementary grades are more likely to return to the same school than their generalist peers; likewise, these teachers are more likely to return to the same school after becoming specialists. These results echo those of Ost and Schiman (2015)—who find that elementary school teachers with stable grade assignments have lower levels of turnover—and suggest that subject-area specialization may be an effective and low-cost approach for retaining teachers. With further research, districts and schools can fully assess whether subject-area specialization is an improvement strategy that benefits elementary school students and teachers.

References

Anderson, R. C. (1962). The case for teacher specialization in the elementary school. *The Elementary School Journal*, *62*(5), 253-260.

Atteberry, A., Loeb, S., & Wyckoff, J. (2017). Teacher churning: Reassignment rates and implications for student achievement. *Educational Evaluation and Policy Analysis, 39*(1), 3-30.

Backes, B. & Hansen, M. (2018). Reaching further and learning more: Evaluating Public Impact's Opportunity Culture initiative. Calder Institute Working Paper No. 181.

Ball, D. (1990). Prospective elementary and secondary teachers' understanding of division. *Journal for Research in Mathematics Education, 21*(2), 132-144.

Bastian, K.C. & Janda, L. (2017). Does quantity affect quality? Teachers' course preparations and effectiveness. In press, *Journal of Research on Educational Effectiveness.*

Blazar, D. (2015). Grade assignments and the teacher pipeline: A low-cost lever to improve student achievement? *Educational Researcher, 44*(4), 213–227.

Chan, T. C., & Jarman, D. (2004). Departmentalize elementary schools. *Principal, 84*(1), 70-72.

Chetty, Raj, John N. Friedman, and Jonah E. Rockoff. 2014a. Measuring the impacts of teachers I: Evaluating bias in teacher value-added estimates. *The American Economic Review* 104(9): 2593-2632.

Chetty, Raj, John N. Friedman, and Jonah E. Rockoff. 2014b. Measuring the impacts of teachers II: Teacher value-added and student outcomes in adulthood. *The American Economic Review* 104(9): 2633-2679.

Cook, J.B. & Mansfield, R.K. (2016). Task-specific experience and task-specific talent: Decomposing the productivity of high school teachers. *Journal of Public Economics, 140*, 51-72.

Fox, L. (2016). Playing to teachers' strengths: Using multiple measures of teacher effectiveness to improve teacher assignments. *Education Finance and Policy, 11*(1), 70-96.

Fryer, R.G. (2016). The 'pupil' factory: Specialization and the production of human capital in schools. *NBER Working Paper w22205*.

Goldhaber, D., Cowan, J., & Walch, J (2013). Is a good elementary teacher always good? Assessing teacher performance estimates across subjects. *Economics of Education Review, 36,* 216-228.

Hellevik, O. (2007). Linear versus logistic regression when the dependent variable is a dichotomoy. *Quality & Quantity, 43*(1), 59-74.

Henry, G.T., Fortner, C.K., & Bastian, K.C. (2012). The effects of experience and attrition for novice high school science and mathematics teachers. *Science* 335: 1118-1121.

Jacob, B.A. & Lefgren, L. (2008). Can principals identify effective teachers? Evidence on subjective performance evaluation in education. *Journal of Labor Economics, 26*(1), 101-136.

Jacob, B.A. & Rockoff, J.E. (2011). Organizing schools to improve student achievement: Start times, grade configurations, and teacher assignments. *The Hamilton Project.* Discussion Paper 2011-08.

Markworth, K.A., Brobst, J., Ohana, C., & Parker, R. (2016). Elementary content specialization: Models, affordances, and constraints. *International Journal of STEM Education*, *3*(1), 16.

Ost, B. (2014). How Do Teachers Improve? The Relative Importance of Specific and General Human Capital. *American Economic Journal: Applied Economics*, *6*(2), 127–51.

Ost, B. & Schiman, J.C. (2015). Grade-specific experience, grade reassignments, and teacher turnover. *Economics of Education Review, 46*, 112-126.

Table 1: Teacher and School Level Descriptives for our Analytical Sample

	Grades K-5			Grades 4 and 5		
	All Teachers	**Subject-Area Specialists**	**Generalists**	**All Teachers**	**Subject-Area Specialists**	**Generalists**
Female	94.84	92.35	95.24	90.96	91.33	90.79
Minority	15.76	15.67	15.77	16.01	15.69	16.16
Age	40.17	41.24	39.99	40.42	41.47	39.93
Teacher Experience	11.21	12.04	11.07	11.16	12.13	10.71
Graduate Degree	32.91	36.14	32.37	35.97	35.95	35.97
National Board Certification	12.12	13.28	11.92	12.61	13.14	12.36
Alternative Entry	6.37	6.85	6.29	7.47	6.81	7.77
Any Specialist	14.24	100.00	---	31.37	100.00	---
One Subject Specialist	5.80	40.76	---	11.40	36.33	---
Two Subject Specialist	8.44	59.24	---	19.97	63.67	---
City/Suburb	47.20	35.50	49.14	45.76	32.83	51.68
Rural/Town	52.80	64.50	50.86	54.24	67.17	48.32
Minority Percentage	51.74	51.27	51.82	51.21	50.74	51.42
Economically-Disadvantaged	60.98	61.05	60.97	60.89	61.49	60.61
Performance Composite	58.90	58.71	58.93	58.70	58.18	58.94
Exceeds Expected Growth	27.99	27.62	28.05	28.08	27.02	28.62
Meets Expected Growth	49.71	48.28	49.96	48.40	47.54	48.84
Does Not Meet Expected Growth	22.31	24.09	21.98	23.51	25.44	22.54
Teacher-Year Observations	169,501	24,141	145,360	55,538	17,425	38,113

Note: This table displays descriptive statistics on elementary grades teachers and the schools in which they work. The left panel presents results for all elementary grades teachers; the right panel is limited to teachers in grades 4 and 5.

Table 2: The Incidence of Subject-Area Specialization by Grade

	Kindergarten	1st Grade	2nd Grade	3rd Grade	4th Grade	5th Grade
Generalists	96.48%	95.23%	94.56%	85.46%	74.30%	62.73%
Specialists	3.52%	4.77%	5.44%	14.54%	25.70%	37.27%
Read Only	1.88%	2.90%	2.84%	4.40%	5.37%	5.94%
Math Only	0.27%	0.32%	0.43%	1.40%	2.70%	5.35%
Science Only	0.28%	0.31%	0.32%	0.44%	0.78%	2.31%
Social Studies Only	0.19%	0.14%	0.17%	0.30%	0.44%	0.91%
Read and Math	0.77%	0.81%	0.86%	1.56%	2.46%	2.46%
Read and Science	0.00%	0.03%	0.03%	0.24%	0.69%	0.71%
Read and Social Studies	0.05%	0.11%	0.35%	2.85%	6.02%	9.02%
Math and Science	0.05%	0.09%	0.33%	2.50%	5.24%	6.33%
Math and Social Studies	0.00%	0.04%	0.04%	0.32%	0.74%	1.26%
Science and Social Studies	0.02%	0.02%	0.08%	0.53%	1.26%	2.97%
Count	31932	33257	32588	32990	31409	30912

Note: This table displays the combinations of subject-area specialization by grade level.

Table 3: Predicting Subject-Area Specialization in Elementary Grades

	Models to Predict Specializing for the First Time in the Analyzed Subject-Area			**Models to Predict Any Specialization in the Analyzed Subject-Area**		
Teacher Characteristics	**Mathematics**	**Reading**	**Science**	**Mathematics**	**Reading**	**Science**
Specialist in the previous year	---	---	---	**0.455**** (0.015)	**0.491**** (0.013)	**0.369**** (0.036)
Previous year value-added estimate in the analyzed subject-area (Std)	**0.013**** (0.003)	**0.006**** (0.002)	**0.014*** (0.006)	**0.022**** (0.003)	**0.009**** (0.002)	**0.023**** (0.007)
Previous year evaluation rating: Leadership Standard	0.002 (0.005)	-0.001 (0.004)	0.008 (0.009)	-0.000 (0.005)	0.006 (0.004)	0.009 (0.010)
Previous year evaluation rating: Facilitating Student Learning Standard	0.008 (0.005)	**0.011*** (0.005)	0.001 (0.009)	**0.015**** (0.006)	**0.017**** (0.005)	0.007 (0.010)
Minority Teacher	-0.005 (0.006)	0.002 (0.006)	-0.006 (0.013)	-0.004 (0.007)	0.005 (0.006)	0.002 (0.014)
Female Teacher	**-0.019*** (0.008)	**0.023**** (0.007)	**-0.029*** (0.014)	-0.016 (0.008)	**0.020**** (0.007)	**-0.043**** (0.015)
National Board Certification	-0.007 (0.007)	0.009 (0.006)	-0.016 (0.013)	-0.004 (0.008)	-0.004 (0.006)	-0.017 (0.014)
Teacher Experience	**0.003**** (0.001)	-0.000 (0.001)	-0.001 (0.002)	**0.003**** (0.001)	0.000 (0.001)	-0.000 (0.002)
Teacher Experience Squared	**-0.000*** (0.000)	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Graduate Degree	**-0.011*** (0.005)	0.001 (0.004)	-0.000 (0.009)	-0.009 (0.005)	-0.004 (0.004)	-0.002 (0.009)
Alternative Entry	-0.017 (0.010)	0.001 (0.009)	-0.029 (0.022)	-0.006 (0.011)	0.005 (0.010)	-0.025 (0.022)
Observation Count	20,585	24,545	8,999	22,939	27,518	10,361
Proportion of Subject-Area Specialists in Analytical Sample	0.095	0.087	0.102	0.174	0.164	0.198

Note: This table displays results from linear probability models predicting whether teachers will specialize in math, reading, or science during a given school year. The left panel focuses on the first-time that a teacher specializes in the analyzed subject-area; the right panel predicts any specialization in the analyzed subject-area. All models include school-by-year fixed effects to compare teachers to their peers working in the same schools. Cluster-adjusted standard errors are displayed in parentheses. * and ** indicate statistical significance at the 0.05 and 0.01 levels, respectively.

Table 4: Subject-Area Specialization and Student Achievement

Specialist Type	School-by-Year Fixed Effect	Teacher Fixed Effect
Elementary Grades Mathematics		
Any Specialist in Math	-0.012 (0.006)	**-0.040**** (0.004)
Teaching Math Only	**-0.027**** (0.008)	**-0.063**** (0.006)
Teaching Math and One Other Subject	-0.003 (0.008)	**-0.029**** (0.005)
Observation Count	1,271,427	1,271,427
Elementary Grades Reading		
Any Specialist in Reading	-0.002 (0.004)	**-0.010**** (0.003)
Teaching Reading Only	-0.008 (0.006)	**-0.018**** (0.006)
Teaching Reading and One Other Subject	0.000 (0.005)	-0.007 (0.004)
Observation Count	1,401,367	1,401,367
5th Grade Science		
Any Specialist in Science	**0.030*** (0.012)	0.000 (0.009)
Teaching Science Only	**0.081**** (0.024)	0.018 (0.015)
Teaching Science and One Other Subject	0.019 (0.012)	-0.003 (0.009)
Observation Count	607,344	607,344

Note: This table displays associations between teachers' subject-area specialization status and adjusted-average student achievement. Models control for a rich set of covariates and include a school-by-year fixed effect (middle column) or a teacher fixed effect (right column). Cluster-adjusted standard errors are displayed in parentheses. * and ** indicate statistical significance at the 0.05 and 0.01 levels, respectively.

Table 5: Subject-Area Specialization and Student Achievement—Teacher Trajectory Analyses

Specialist Type	School-by-Year Fixed Effect	Teacher Fixed Effect
Elementary Grades Mathematics		
First-Year Specializing	**-0.035**** (0.007)	**-0.043**** (0.005)
Second-Year Specializing	-0.004 (0.010)	**-0.043**** (0.007)
Third or More Years Specializing	**0.036*** (0.014)	**-0.036**** (0.010)
Observation Count	1,171,698	1,171,698
Elementary Grades Reading		
First-Year Specializing	-0.009 (0.005)	-0.007 (0.004)
Second-Year Specializing	-0.005 (0.006)	**-0.021**** (0.005)
Third or More Years Specializing	**0.020*** (0.008)	-0.005 (0.007)
Observation Count	1,294,651	1,294,651
5th Grade Science		
First-Year Specializing	-0.007 (0.012)	0.000 (0.010)
Second-Year Specializing	**0.067**** (0.016)	**0.032*** (0.012)
Third or More Years Specializing	**0.090**** (0.024)	0.016 (0.018)
Observation Count	552,823	552,823

Note: This table displays results from models assessing adjusted-average student achievement by teachers' number of years of experience with subject-area specialization. Models control for a rich set of covariates and include a school-by-year fixed effect (middle column) or a teacher fixed effect (right column). Cluster-adjusted standard errors are displayed in parentheses. * and ** indicate statistical significance at the 0.05 and 0.01 levels, respectively.

Table 6: Subject-Area Specialization and School-Level Achievement

Specialization Intensity	Average Math Achievement	Average Reading Achievement	Average Science Achievement
Percentage of Specializing Teachers (Standardized)	-0.000 (0.004)	0.001 (0.003)	**0.020**** (0.006)
Observation Count	6,563	6,535	6,194

Note: This table displays results from models examining the associations between school-level achievement in mathematics, reading, and science and the concentration of subject-area specialist teachers. Models control for school characteristics and include a school fixed effect. Cluster-adjusted standard errors are displayed in parentheses. * and ** indicate statistical significance at the 0.05 and 0.01 levels, respectively.

Appendix Table 1: Counts of Teachers Contributing to Specialization Estimates

Specialist Type	School-by-Year Fixed Effect	Teacher Fixed Effect
Elementary Grades Mathematics		
Any Specialist in Math	11555	2078
Teaching Math Only	8065	1050
Teaching Math and One Other Subject	9777	1793
Elementary Grades Reading		
Any Specialist in Reading	13853	2138
Teaching Reading Only	10468	940
Teaching Reading and One Other Subject	10836	1922
5th Grade Science		
Any Specialist in Science	3937	894
Teaching Science Only	1671	275
Teaching Science and One Other Subject	3378	881

Note: This table displays counts of the unique teachers contributing to our subject-area specialization estimates in our school-by-year fixed effect and teacher fixed effect analyses.