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Portraying Secondary Science Teacher Retention with the Person-Position Framework: An Analysis of a State Cohort of First-Year Science Teachers

The moment that a new science teacher enters their classroom for the first time symbolizes the fruition of an extraordinary commitment of time and resources, both of their own as well as that of their employer. As evidenced by decades of this journal's published research, the teaching and learning of science is often a specialized affair (e.g. Anderson, 2000; Feldman et al., 2009; Gawley, 1965; Reynolds & Park, 2021; Rutt et al., 2021). Someone who has an advanced understanding of their science subject matter along with a sense of how they intend to teach it, coupled with the ability and willingness to teach in a secondary science classroom, is someone who deserves the attention and care of our field. Some are rigorously-prepared science teachers who are recent graduates of teacher preparation programs, while others are individuals who have followed circuitous pathways into science teaching from careers in the private sector or public service and earned their teaching credential in their first years as a novice teacher (Larkin, 2014; Olson et al., 2015). Many of the first-year science teachers walking into their classroom for the first time will go on to have long careers, and some will not stay in the profession long enough to become a second-year teacher.

The issue of teacher retention has been particularly important in efforts to address teacher shortages in the United States, and a lack of enough teachers certified to teach in secondary science subject areas—physics, chemistry, biology, earth science, etc.—has been steadily reported for the past three decades (Aragon, 2016; Cross, 2016; Sutcher et al., 2019). The retention of novice science teachers in particular remains a pressing issue for policymakers, funding agencies, and school districts alike.[1] The research suggests that an unknown number of promising novice science teachers have had experiences in their work contexts that contributed to a decision to leave the profession (Borman & Dowling, 2008; Geiger & Pivovarova, 2018; Rinke, 2014; Santoro, 2018), and the specialized needs of secondary science teachers likely magnify the influence of variations in school and district contexts in their career decisions. New science teachers who may flourish in some environments might find it difficult to continue in others.

It is worth noting that construction of the "problem" of teacher retention is firmly situated in national systems of both education and labor (Darling-Hammond et al., 2017; Strong, 2011). In countries such as Germany or Taiwan (Blömeke et al., 2017), where there is both high regard and support for teaching as a profession, as well as a workforce with limited flexibility compared with other countries, the issue of teacher selection is far more important than teacher retention. Yet wherever teacher shortages are endemic and the teacher workforce has more mobility, stemming the flow of qualified teachers out of the profession remains a key effort of national and state education systems, even though this goal may not always be reflected in policy (Ingersoll, 2001; Schwille & Dembélé, 2007). Even so, the discourse outside the United States around

[1] In the United States, the National Science Foundation (NSF) spends over $50 million per year on the preparation and development of teachers of science, mathematics, and other STEM areas through its Robert Noyce Teacher Scholarship program. The American Association for the Advancement of Science has partnered with NSF and the U.S. Department of Education to fund the Advancing Research & Innovation in the STEM Education of Preservice Teachers in High-Need School Districts (ARISE) program, with one of its goals being to "understand effective ways to recruit, train, and retain a quality STEM teacher workforce" (American Association for the Advancement of Science, 2021). Other science education stakeholders, such as curriculum developers (Bintz et al., 2017), science education leaders (Pirkle, 2011), advocacy groups like 100Kin10 (100Kin10, 2019), and foundations (Galosy & Gillespie, 2013) have focused resources and efforts on improving science teacher retention.

teacher retention is often of a different character entirely, focusing instead on retention in the profession over a lifetime rather than in a specific local job setting. For example, in 2021 the Organization for Economic Co-operation and Development (OECD) reported on a 16 country survey of teacher retention in the following manner:

> Across the OECD and partner countries and economies with comparable attrition rates estimated with the proposed method, attrition rates of all teachers from pre-primary to upper secondary public institutions range from 3.3% in Israel to 11.7% in Norway. In a half of these countries and economies, attrition rates exceed 8%: Brazil, Chile, England (United Kingdom), Finland, the Netherlands, Norway and Sweden. (OECD, 2021, p. 427)

The highest of these lifetime attrition rates (e.g. 11.7%) is comparable to the annual attrition rates of U.S. teachers (Ingersoll et al., 2014).

The primary purpose of this article is to refine our field's current understanding of the early-career retention of secondary science teachers, so that science teacher educators might better prepare and support science teachers in ways that ultimately serve the aims of science learning for all students. Though the main arguments of this paper apply to issues of teacher retention across subject areas and grade levels, our specific intention here is to use an empirical study on secondary science teacher retention in a single U.S. state to suggest a conceptual model for early-career teacher retention. The specific research questions guiding this study are as follows:

1. How should descriptors of secondary science teacher retention, mobility, and attrition be conceptualized so that knowledge can be generated and accumulated across studies?

2. Using these descriptors, what are the retention characteristics of a state-level cohort of first-year secondary science teachers over a six-year period?
3. How do different ways of framing teacher retention impact the conclusions that may be drawn from teacher retention data?

Background and Literature Review

What does it mean for a teacher to be retained? To the school or district administrator who hires a teacher for a particular position, retaining a teacher means having that person available for a new teaching assignment each year (Ingersoll & May, 2012; Ingersoll & Perda, 2010). Yet from the perspective of the teacher, being retained likely refers more to the profession rather than to any one individual school or district (Rinke, 2013). An even more inclusive definition of retention would also refer to those who continue in the field of education in capacities other than as a classroom teacher, such as administrator, guidance counselor, university professor, or museum educator (Cochran-Smith, 2004).

In the United States, research on teacher retention has tended to draw upon either large-scale surveys of teachers produced by the National Center for Education Statistics (e.g. Ingersoll, 1997; Ingersoll & May, 2012; Ingersoll et al., 2016; Marvel et al., 2007; Nguyen & Redding, 2018; Suárez & Wright, 2019; Tai et al., 2006), or from smaller-scale qualitative studies that track relatively few teachers longitudinally (e.g. Bang & Luft, 2014; Ceven McNally, 2016; Luft et al., 2011; McGinnis et al., 2004; Roehrig & Luft, 2006; Saka et al., 2013). However, in the past decade, the push at the federal level for better designed state data systems (Boser, 2012; Workforce Data Quality Campaign, 2016) has led to state-level school staffing reports as a third type of data source with the potential to reshape the landscape for research in teacher retention.

Indeed, a growing number of researchers have gained access to these or similar state-level (or even large district-level) data to research teacher retention.

For the past two decades in the United States, a great deal of scholarly effort has been applied to understanding the nature and dimensions of teacher retention (Carver-Thomas & Darling-Hammond, 2017; Goldring et al., 2014; Ingersoll, 2001). Many portray the attrition rate for novice teachers at between 10-15% annually, and the 5-year retention rate around 50% (Rinke, 2014). Yet in many cases, it may be difficult to compare findings because of key differences in how the terminology associated with teacher retention is defined and characterized.

Duration of Retention

There does not appear to be any broad agreement in the literature as to the duration of time required to be considered retained, and in large part this variable seems to have been an artifact of the available data and measures, rather than as a theoretically informed demarcation of a certain employment interval. As noted above, some studies define retention as first-year teachers becoming second-year teachers (Ronfeldt & McQueen, 2017; Smith & Ingersoll, 2004; Wood et al., 2012), while many other studies frame teacher retention as extending beyond the second year (Bang et al., 2007; Randi, 2017; Zumwalt et al., 2017). Zhang and Zeller (2016), noting a gap in the research about long-term teacher retention, suggest that studies should direct their attention to retention of over 8–20 years or even longer.

Others suggest a more cautious view of retention, noting that in many circumstances the retention of a teacher in a school or in the profession may not be desirable (e.g. Holtom et al., 2013; Kiazad et al., 2015; Simon & Johnson, 2015). Smith and Ingersoll (2004) describe turnover as “normal, inevitable, and even beneficial” (p. 706). Luft et al. (2011) argue that attrition is inevitable because mobility between careers—within and beyond education—has increased over past decades. The literature also makes distinctions between *voluntary* and *involuntary* turnover, marking differences between those who choose to leave a position and those who leave as a result of termination by their employers (Johnson & Birkeland, 2003). Examples of such involuntary teacher movement would include reductions in force (Strunk et al., 2018) or the dismissal of teachers deemed "ineffective" or "unsatisfactory" (Simon & Johnson, 2015), even if such a teacher remains in the profession and obtains a new teaching position elsewhere.

Mobility and Attrition

Ingersoll (2001) noted the tendency for empirical research to focus on the teachers who leave the teaching profession altogether and do not return, referring to this as teacher *attrition.* Ingersoll and May (2012) looked across data for all teachers in five separate School and Staffing Survey (SASS) reports from 1988 to 2005, and found that the annual attrition rate for all teachers varied between 3.5% and 9% of teachers per year. A more detailed study of the SASS and Teacher Follow-up Survey (TFS) data (Gray & Taie, 2015) suggests that 17% of new teachers leave the profession within their first five years. As noted above, teachers who move from one position to another are important to understanding teacher shortages (Ingersoll, 2001; Ingersoll & May, 2012), but unless the data actually capture this movement, teacher mobility may be mislabeled as attrition.

There are other examples of imprecision in descriptions of teacher changes in location and position worth noting. Smith and Ingersoll (2004), used the term *leavers* to describe "beginning teachers who leave the teaching occupation at the end of their first year" (p. 688). These individuals are added to those counted in the *attrition* category, as would any others who left teaching after the first year. They defined *movers* as those teachers who remain in teaching but “move to a different school at the end of their first year” and *stayers* as those who not only remain in the profession but “stay in the same school to teach a second year” (p. 688). Another group of teachers in the literature has been designated as *returners*. Although a small number of studies use the language of returning to describe a teacher being retained and staying at the same school for a second year or as individuals from urban areas returning to their community to teach (e.g. Irizarry & Donaldson, 2012), many use the term *returner* to describe teachers who leave the profession for a period of time and then re-enter the teacher workforce (e.g. Vagi et al., 2017).

Characterizing Teacher Retention

Creed and Nacey (2021) note the central role of metaphors in the ways in which people conceptualize their working lives. Metaphors serve a foundational role in human cognition, and are important in scaffolding learning by connecting the unknown to the known (Hofstadter & Sander, 2013; Lakoff & Johnson, 1980). Yet as commonly deployed in the retention literature, the uncritical use of metaphor may contribute to continuing conceptual imprecision in the field (Creed & Nacey, 2021). For example, the literature draws upon survival metaphors—such as *sinking or swimming* (Wood et al., 2012; Zhang & Zeller, 2016)—where being retained is analogous to remaining alive. The use of the term *migration* as used by Ingersoll (2001) fits into this category as well, because the term implies that in order to continue to live, an organism must travel to a new location. Economic metaphors for retention evoke systems and mechanisms, with teachers as a product for which there is *turnover*, as well as *supply and demand* (Guarino et al., 2006; Ingersoll & May, 2012). Originating from agriculture and manufacturing, the idea of a *reserve pool* (Ingersoll & Perda, 2010) is used in the teacher retention literature to refer to certified teachers who are currently not teaching. Metaphors such as the *revolving door* image used to describe teachers who are hired and then quickly leave a specific position or the profession altogether evoke the movement of a person through physical space, as do terms such as *stayers, leavers,* and *movers,* as popularized by Ingersoll (2003).

As tools for sensemaking, metaphors and analogies often work best when their limitations are recognized. In the empirical literature, retention labels often reflect a distillation, explanation, or even a statement of value about the people in a given category while obscuring important differences. This can create imprecision in both directions—if a group is labeled as *stayers*, it may be implied that staying is the same as being retained, even if there is no clarity about whether the individual has stayed in a school or a profession. Such language may also carry an implication that staying is desirable, even though it might not be so. It also seems possible that someone who finds themselves labeled as a *leaver* in any number of studies reviewed above could resist such a categorization, particularly if the act of leaving implies a nonexistent sense of agency or otherwise has a negative connotation. In eschewing metaphorically-laden labels like *stayers, leavers,* and *movers,* we aim to avoid the potential for imprecise and potentially condescending euphemisms (American Psychological Association, 2020).

A common approach to researching teacher retention draws upon identifying correlations between specific factors and measures of teacher retention (Achinstein et al., 2010; Borman & Dowling, 2008; Carver-Thomas & Darling-Hammond, 2017). We highlight the theoretical connection to conceptualizations of teacher quality, such those described by Strong (2011) and Kennedy (2010), which attend to both teacher characteristics and situational characteristics as specific groups of factors that impact teacher quality. Looking across the literature on teacher retention, we note this same division of characteristics. In the state-level staffing data analyzed in this study, these two broad categories of factors, *teacher background* and *school contexts*, are readily apparent. Teacher background encompasses age, sex, race/ethnicity, preparation, and subject area certification. School contexts include salary and specific school characteristics that include socioeconomic indicators. Following this section, we briefly review and synthesize the larger literature on teacher retention, and highlight studies related specifically to the retention of science teachers that promise to inform the present study. Given that the current study focuses primarily on describing patterns and trends in science teacher retention, we recognize that there are likely important factors, such as school leadership in STEM (e.g. Campoli, 2017), that are excluded from this review because there is currently no standardized mechanism for reporting such empirical data.

Teacher Background and Science Teacher Retention

Age and Retention

Ingersoll and Perda (2010) found that age was a strong predictor of teacher turnover, with those younger than 30 and older than 50 most likely to leave. Borman and Dowling (2008) found that younger teachers were more likely to leave teaching regardless of when they entered the profession. Tai et al. (2006) found that older teachers had higher levels of retention among math and science teachers.

One way to make sense of these findings is to consider the twenty-year span of greatest rate of retention, from age 30 to 50, as representing individuals who made a conscious decision to enter teaching as a career-change, and thus perhaps having a greater investment—and perhaps more at stake—than younger teachers who may look at teaching as the first of many jobs they may have over a longer career.

Gender and Retention

Rushton et al. (2014) identified a demographic increase in the percentage of female STEM teachers, who now comprise the majority of STEM teachers in the United States. This mirrors the increase in the percentage of female teachers in the teacher workforce overall (Ingersoll & Merrill, 2010). Borman and Dowling's (2008) meta-analysis of teacher attrition and retention literature found a statistically significant effect of gender on teacher retention, with female teachers more likely to leave the profession. We were unable to identify any large-scale studies that specifically examined new science teacher retention by biological sex or gender.

Race/Ethnicity and Retention

Although the U.S. student population has steadily diversified with respect to race and ethnicity over the past few decades, the teacher workforce has remained overwhelmingly White (McFarland et al., 2019; Nguyen & Redding, 2018). Borman and Dowling (2008) found that White teachers were more likely to leave the profession than were teachers from other racial categories, and that there was a negative correlation between the percentage of minority students in a school and the retention of White teachers (Kokka, 2016; Renzulli et al., 2011). However, subsequent and more detailed analyses of the SASS and TFS data have shown that the attrition rate for teachers of color has surpassed that of White teachers in recent years (Achinstein et al., 2010; Ingersoll, 2015; Marvel et al., 2007). Teachers of color are more likely to work in high-minority, urban areas, which are settings with among the lowest retention of teachers, particularly in math and science (Kokka, 2016). Other work by points to the unique challenges faced by novice teachers of color (Kohli, 2018), a finding echoed in a wide range of STEM fields, including teaching (Mandel et al., 2018; McGee, 2021).

Preparation Pathway and Retention

We draw upon the distinction between traditional and alternate route programs made by Grossman and Loeb (2008), whereby *alternate route* teachers are those who learn to teach while drawing a full-time salary as a teacher of record. In contrast, *traditional* preparation pathways involve some sort of apprenticeship with a mentor teacher (as internship, residency, student teaching, etc.) prior to taking on the responsibility of being a teacher of record. The scholarship on the relationship between preparation routes and retention has been mixed, and provides different results depending on the time frame examined for retention. Some studies suggest that teachers pursuing traditional certification pathways have similar retention outcomes to teachers who become certified through alternate route pathways (Grissom, 2008). Others suggest that traditionally prepared teachers are retained at slightly higher rates (Grossman & Loeb, 2010; Zhang & Zeller, 2016). However, Achinstein et al. (2010) noted that attrition rates are higher for teachers of color in either pathway.

Subject Area Certification and Retention

Borman & Dowling (2008) noted that attrition was twice as likely for teachers holding a math or science degree as compared with others. Though we were unable to identify any studies that specifically examined the retention of science teachers disaggregated by the subject area certification of the teacher, there were a number of studies that examined demographic trends of science teachers by subject area. For example, Rushton et al. (2014) reported that the number of chemistry teachers is increasing more rapidly than the total teacher population and STEM teacher population, and yet more than half of all chemistry teachers do not hold a degree in chemistry. Rushton et al. (2017) reported a similar finding in physics.

A great deal of retention research has sought to understand whether the assignment of a teacher beyond their area of expertise—commonly known as teaching out-of-field—is a factor in the attrition or retention of teachers. Typically, a subject-area certification by a state is used to determine whether a teaching assignment is in-field or out-of-field, though some studies focus more on degree major and less on certification, which may vary widely across state contexts, and the out-of-field teaching may be near or far from teachers' subject matter knowledge (Luft et al., 2020). Ingersoll and May (2012) explicitly warn against using subject area assignments to determine teacher qualification because of the distorting effects of out-of-field teaching. Indeed, a study by Taylor et al. (2020) recently showed that out-of-field teaching in U.S. middle schools was pervasive, with 88% of all middle school science classes being taught by an out-of-field teacher. Out-of-field teaching itself has been claimed as a factor in teacher attrition (Patterson et al., 2003), though this finding has been challenged (Nixon et al., 2017) and remains an open question.

School Context and Teacher Retention

Salary and Retention

Across all teachers, salary has been shown to be a significant predictor of retention, with the highest effect sizes seen among older teachers later in their careers (Borman & Dowling, 2008; Carver-Thomas & Darling-Hammond, 2017). However, it was also found that increasing salary may not be sufficient to retain teachers, if other policies and conditions also produce dissatisfaction (Ingersoll, 2003). Both traditional and alternate route teachers in the long-term cohort study by Zumwalt et al. (2017) most frequently cited "substantial salary increases" as an incentive for retention. Ingersoll and May (2012) noted that science teachers in particular were most likely to state that their decision to leave teaching was heavily influenced by the maximum potential salary they could earn in their districts, and hypothesized that the higher attrition rate of science and mathematics teachers was influenced by the existence of alternative career options with higher salary potential.

School Characteristics and Retention

School characteristics such as setting, socioeconomic status, and student demographics have all been found to correlate with measures of teacher retention (Nguyen, 2020). Ingersoll and May (2012) found a statistically significantly higher rate of teacher turnover in high-poverty schools. Nguyen and Reading (2018) conducted a detailed analysis using SASS data and found that STEM teachers with graduate degrees were more likely to leave high-minority or high-poverty schools but not low-minority or low-poverty schools. Simon and Johnson (2015) noted that attrition of new teachers is more severe in urban and low-income communities, stating, "Teachers who leave high-poverty schools are not fleeing their students. Rather, they are fleeing the poor working conditions that make it difficult for them to teach and for their students to learn" (p.1).

Summary of the Science Teacher Retention Literature

The range of definitions currently applied to teacher retention as a field, and to science teacher retention specifically, presents a barrier to meaningful synthesis of the literature primarily due to the conflation of retention of the person in a position with retention of the person in the profession. While many of the studies described above do not explicitly commit the fundamental attribution error as described by Kennedy (2010), nearly all of them describe retention in terms that treat the person in a specific position as the unit of study, which limits what might be learned about an individual's retention in the teaching profession over time.

Many of the studies reviewed above defined retention implicitly as continuation in the same position from the first to the second year, rather than explicitly state the duration of retention measured. We claim that this is an impoverished view of teacher retention, not least because of the presentation of retention solely from the perspective of the employer. Robust research on teacher retention by teaching context beyond first-year retention is nearly non-existent as a result, and yet the above literature demonstrates the insights possible from longitudinal measures of retention.

A stronger conceptual model of early career teacher retention would certainly serve the field by use of common definitions and measures, but perhaps more importantly, would usefully frame teacher retention in a manner that separates *retention-by-employer* from *retention-in-profession*. Such a framework would then be better able to apply these ideas to make sense of broad patterns in science teacher retention, for example, by subject area certification, demographic group, or identifiable school context factors. A better conceptual model would also be more effective in leveraging the opportunities presented by the emergence of newer and more powerful state data systems in order to address questions of importance related to teacher retention—a topic we take up in the conclusion.

The Person-Position Conceptual Framework

In educational research, it is not uncommon for the results of data analysis to inform the ongoing analytical process in an iterative cycle, which then further refines the inquiry through the development of a conceptual or theoretical framework. This is particularly true when this process helps to make analytical categories more useful and definitive. This study began using the *a priori* categories developed by Ingersoll and colleagues (e.g. *movers, leavers, etc.*) to describe the early career characteristics of the science teachers in the cohort under study.

However, we quickly found that these categories were insufficient to describe the data, and as a consequence we engaged in a process of theoretical sampling (Charmaz, 2000) in order to ultimately develop the framework described here, which we introduce as the *person-position* framework. Though largely built by theoretical considerations, this framework is also a product of this research in that it is informed by the limitations of interpreting retention data that we encountered in the initial stages of our data analysis. In particular, existing models of retention analyses were particularly ill-suited in capturing and portraying breaks in service and multiple job changes.

The person-position framework for teacher retention introduced here builds upon the literature reviewed above, and fosters a degree of conceptual clarity by making distinctions between the individual person and their teaching position. This framework is shown in Figure 1 with its four elements: employment status, action, effect on position, and retention descriptors. It seems likely that this framework could have much broader applicability beyond the science teacher population examined here, as each of these elements is specifically tailored to the body of research on teacher retention.

(insert Figure 1 approximately here)

Employment status

We suggest that only three descriptors are necessary to describe employment status. *Active* teachers are those who are currently working as P-12 teachers in schools. While researchers may choose to make distinctions between categorical descriptions of schools employing teachers in a given sample (e.g. public, private, charter), where their schools are located (local, state, international, etc.), or between full-time and part-time employment, the fact that an individual is actively employed as a teacher is the defining feature of this descriptor.

Individuals in a sample who are not actively teaching may be described as *attritted* if they are no longer willing or able to be employed as a P-12 teacher. If there remains a possibility that an individual could one day return to employment as a P-12 teacher, they are described as *reserve* teachers, or collectively as the *reserve pool* (Ingersoll & Perda, 2010).

In practice, it may actually be very difficult to distinguish between individuals in the reserve pool and those who have attritted, primarily because the designation hinges on a return to teaching that may or may not ever happen in the future. For this reason, it may be prudent to categorize an individual in a sample as attritted only when a standard of reasonable certainty is met. In the population of 231 science teachers described in our study below, we found that one was deceased, and two others had abrupt ends to their careers with incidents described in public reports that led to their dismissal—all three had attritted without question. If someone leaves the profession without the capacity to return, an attrition designation is certainly warranted.

For some others in our study, it was apparent from publicly available resumés that they were currently working full-time in a non-education field, and it seemed reasonably correct to identify them as having attritted from teaching. Even so, teaching as a career is forgiving of individuals' notions of "professional exploration" (Rinke, 2013), and may be full of "planned happenstance" (Mitchell et al., 1999). Career paths in teaching may be non-linear and complex, and therefore there is always the possibility that an attempt to designate someone as attritted from the profession may be premature, because a person's intent and opportunities for a return to teaching may change over time (Lindqvist et al., 2014).

Action

In this framework there are six possible actions on employment status, and all are viewed from the perspective of the employee: retention in position, retention with reassignment, transfer, break in service, advancement, and attrition. Given that the available data are collected annually by researchers and government agencies on employment status, the unit of analysis for this action is typically a year, though this need not be the case. Indeed, in the population described in this study, many of the first-year teachers were hired after the start of the school year and sometimes as late as after half of a year, making it difficult to standardize what was actually meant by “years experience” reported in the data.[2] In contrast, the publicly available New Jersey state pension data that was used to triangulate individuals’ entry into the teacher workforce was measured in months of service. Regardless of whether years or some other duration is used to track employment, one of these six actions must take place at the end of one interval and before the beginning of the next.

Retention in position

This refers to the renewal of employment in the same or an equivalent teaching position at the same location. Depending on the nature of the research, there is variability in how a “position” might be defined, but the definition we suggest is that a teacher retained in a position does not create the need for a new hire.

Retention with reassignment

This refers to renewal of employment by the same employer in a new teaching location. This category may include major changes in teaching assignment within a site—for example, in the case of a health education teacher who earns a life science teaching certification and is subsequently assigned to teach biology—as well as shifts between schools in a district. Though school-based budgeting is common in many large school districts in the United States, we

[2] In contrast, the North Carolina Department of Public Instruction reports months of service (rather than years) in their data systems, permitting more precise measures of teacher experience.

suggest here that the more important unit of analysis is what is commonly referred to as the local education agency, or LEA, because that is the entity defined by the U.S. government as the legally constituted administrative agency for public schools. Other schools in and beyond the United States may have different organizational structures, but the rule we suggest (unless the research question under consideration demands otherwise) is that if the employer and job title does not change when a teaching assignment does, then the teacher has been retained, either in position or with reassignment. This does not apply to changes in job title and responsibilities beyond teaching, as discussed in the *advancement* section below.

Transfer

Throughout his work, Ingersoll and his co-authors have used the term *migration* to describe a teacher’s move from one employer to another (e.g. Ingersoll & Perda, 2010). We have chosen to use the term *transfer* instead to avoid confusion with the category of teachers who cross international borders—migrating in a truer sense of the word—for employment as a teacher (e.g. American Federation of Teachers, 2009; Savva, 2013). We categorize an action as a transfer when a teacher starts employment in a new teaching position with a new employer.

Break in service

Of all the terminology used to describe teacher employment, none appears to have caused more conceptual confusion in the literature than those used to describe teachers who leave a position temporarily with intent to return to the same or a similar position. Less common in the teacher retention literature, but more widely used elsewhere is the concept of a *break in service*, which is typically used for pension and benefit calculations by U.S. governmental agencies (e.g. "Breaks in service," 2007). For clarity, we use the term *break in service* and consider it synonymous with a leave of absence from the profession (i.e. not just a school district) in which someone is not teaching for one or more years but then returns to an active teaching position.

One's status as a teacher in the reserve pool may be for a well-defined and limited duration, or it may be open-ended, spanning years or even decades. This status may be either voluntary or involuntary, and its defining feature is simply that the individual is not teaching during that particular time interval.

Advancement

The literature on teacher retention has been inconsistent in its characterization of individuals who leave employment as a P-12 teacher for work in education-related positions. For example, many teachers earn additional credentials to continue working in their current school district in a different capacity, such as a school administrator or counselor. By this framework, these teachers would not be considered retained because they would not be in a P-12 teaching position, yet it would be incorrect to say that they have attritted. Drawing from the work of teacher education scholars who frame such a career trajectory as not only positive but necessary for the field of teaching (Cochran-Smith, 2004; Nieto, 2003), we use the term *advancement* here to indicate that teacher certification has value that may be recognized and built upon for an individual's subsequent employment. Other forms of advancement may include (but are not limited to): work as an informal or museum educator, positions in higher education, education-adjacent employment such as educational publishing or test preparation, and governmental service. Advancement does not necessarily imply a hierarchy or status within education, rather, it describes a movement to the next stage in a career from the perspective of the person to whom it applies.

Attrition

This is discussed in greater detail above, but in summary, we define attrition as leaving the profession of teaching with no intent or capacity to return.

Effect on Position

In contrast to the above framework element of *action*, *effect on position* takes the perspective of the immediate employer of the teacher. As noted above, use of the term *turnover* has been both wide and imprecise, impeding comparisons between studies in the empirical literature on teacher retention. Within this framework, the term *turnover* is strictly limited to descriptions of the position itself, rather than as a referent to groups of individuals who may in fact have widely divergent pathways in the profession. When turnover is applied solely to positions, rather than to people, it becomes apparent that turnover happens only when an individual leaves a given teaching position. A person who is reassigned to a new school within a district, and leaves an administrator the task of hiring someone new for that position, contributes to turnover. From this perspective, the only action on employment status that does not count as turnover is retention-in-position.

It is fair to argue that the general concept of turnover remains essential from a human resources perspective, and ought not to be abandoned completely. Indeed, understanding how many positions need to be filled in a given school or district is often one of the highest priorities of administrators throughout the school year. Even so, there remains a conceptual volatility to the term *turnover* that emerges whenever it is modified. The phrase “teacher turnover” is worth highlighting as problematic because of the way it conflates the problems of a vacant position with the reasons why a given teacher is no longer in that position. Teachers do not turn over, positions do, and we discourage future use of the phrase “teacher turnover” for this reason.

Retention Descriptors

Empirical descriptions of retention that refer to both location and measure are of greatest use when informed by research aims. Our view is that one must be specific about where a teacher has been retained, and for how long, in order for it to be possible for comparisons to be made to other groups of teachers. A teacher who is *retained-in-position* is someone who is working for the same employer in the same (or similar enough) position at two different points of time *(t)*. In describing such individuals, we would say that they have been *retained-in-position for (t) years*. If research were conducted on teacher mobility within positions across a large school district, such a measure would likely be the most appropriate.

Note that such a description need not be concerned with breaks in service, as long as the ($t_{initial}$) measure and the (t_{final}) measure identify the individual in the same position with the same employer. While reasonable objections to this definition can certainly be raised, we claim that defining retention in this manner is consistent with viewing retention from the perspective of the person being retained. Indeed, having one's position held during a break in service is itself may be viewed as an attribute of retention.

A teacher reassigned to a new position—or location—by their employer would then be described as *retained-by-employer for (t) years* because the employer did not change. In this study, the *retained-by-employer for 5 years* measure was the most beneficial unit of analysis in characterizing individual teacher employment retention as stated in the first research question. Note that in order to calculate a 5-year retention rate, 6 years of data are typically required, especially when data is collected during the first two months of the school year, as is the case in New Jersey data used in the present study.

The descriptor *retained-in-profession* encompasses those retained in position and by employer, those who move to new districts, as well as teachers in the reserve pool who either hold out the possibility of returning to teaching or are advancing their careers beyond the foundation of their work as P-12 teachers. For teachers in the reserve pool, this categorization features the same uncertainty that troubles the boundary between *attrition* and *break in service*, and any analytical decision to categorize someone as retained in the profession is almost certain to contain some instances of false positives and false negatives.

Methodology

This study employs a descriptive quantitative analysis approach (Loeb et al., 2017) to data analysis in order to suggest a conceptual model for understanding and portraying early-career teacher retention. Our specific aim is to characterize novice secondary science teacher retention during the first five years of employment. This methodology is consistent with our aim to build "a more general understanding of patterns across a population of interest," (p.1) particularly with respect to science teachers in our sample. In this article, we draw from our ongoing National Science Foundation-funded Noyce Teacher Scholarship Research project that uses state-level employment data to study teacher retention.

Though the state of New Jersey was selected for the context of both this study and the larger project because of the availability and completeness of the staffing data, as well as the familiarity of its teacher policy environment to the authors. Therefore the selection of New Jersey as the state context for this study is admittedly somewhat arbitrary, but given analogous data from any U.S. state, it would be possible to conduct the analysis shown here on any sufficiently large population of teachers. We further suggest, as is detailed in the conclusion, that the methodology employed here to build the resulting conceptual framework for teacher retention could be implemented throughout state data systems to produce regular detailed reports on teacher retention. The selection of New Jersey as a context for this study permits for the construction of this result as an existence proof in the present.

New Jersey as the State Context for this Study

New Jersey Teachers

New Jersey has a highly unionized and professional workforce of over 140,000 teachers, about 7,500 of whom are certified to teach science. The New Jersey state Department of Education has maintained rigorous standards for teacher certification, even prior to the provisions in the 2002 No Child Left Behind legislation that established federal reporting requirements concerning highly qualified teachers. In 2009, the median starting pay for a teacher in New Jersey with a Bachelor's degree was $46,413, and the overall median salary was $65,130 (Mooney, 2010). This was significantly higher than the national starting salary average of $37,267 and median teacher salary that same year of $55,595 (OECD, 2012), though the cost of living is somewhat higher in New Jersey than the national average (Aten et al., 2012).

In 2010, all New Jersey teachers at the secondary level were required to have at least a Bachelor's degree with a major or minor in their content area, and have graduated with a minimum 2.75 grade point average (equivalent to a B- in letter-grade systems). For over two decades, science teacher candidates in both the state's traditional and alternate route certification pathways have been required to pass tests of professional knowledge, general science, as well as their subject specialization. The largest alternate route teacher certification program was run directly by the state until it was closed in 2013, though other alternate route programs have continued to be run by 4-year institutions and private providers (Weber, 2020). Approximately one third of all NJ teachers become certified through an alternate route program (New Jersey Department of Education, 2009).

Secondary science teachers in New Jersey must be specialized in the subject area of biological science, chemistry, earth science, physics, or physical science. The physical science certification is essentially a combination of the physics and chemistry certifications, requiring a major in one of the areas and a minor (or 15-credit equivalent) in the other. The state previously offered a comprehensive general science certificate, but this was discontinued in 1992. However, many who earned this certification are still practicing NJ science teachers, and therefore this general science certification remains an active code in staffing data.

Since the 1980s, New Jersey has had three stages of teacher licensure requirements: *certificate of eligibility*, *provisional*, and *standard*. Teacher candidates earn either a certification of eligibility (CE) if enrolled in an alternate route program, or a certification of eligibility with advanced standing (CEAS) upon completion of a traditional teacher preparation program. Both permit the recipient to be hired as a teacher of record in a classroom, at which point a Provisional teaching certificate is issued that is valid for two years. Upon successful completion of the Provisional Teacher Process, teachers are issued a Standard Certificate that does not require renewal. During the provisional period, teachers from both alternate route and traditional pathways are required to receive mentoring by a mentor teacher (New Jersey Department of Education, 2021b). These requirements for new teachers during this provisional period have been in place for nearly three decades.

New Jersey Schools

The state of New Jersey has a long history of economic and racial segregation in housing patterns, as well as a tradition of local governance—two historical facts that are intertwined in the operation of its schools (Burkholder, 2021; Rothstein, 2017). As a result, New Jersey has over 580 individual school districts along with approximately 60 state-supervised charter schools that essentially function as single-school districts. For the past half-century, there have been ongoing legal battles to ensure equitable funding for school districts, and as a consequence New Jersey currently has one of the fairer school finance systems in the United States (Baker, 2018; Baker et al., 2018; Education Law Center, 2020). In this study, we make use of the district factor group (DFG) terminology unique to New Jersey, which is a construct originally created for the resolution of school finance litigation, and is still in common use today as a shorthand way to characterize the socioeconomic differences between school districts. The DFG group designation "A" has the lowest household incomes and tax base, through increasing socioeconomic levels "B," "CD," "DE," "FG," "GH," with district "I" as the highest.

In the 2010-11 school year, there were 1,364,495 public school students in the state, and 52% of the students were identified as White, 16% as Black, 22% as Hispanic, 9% as Asian, and 1% as two or more races. Using free and reduced lunch eligibility as an indicator, 33% of the students in the states lived in low-income households (New Jersey Department of Education, 2021a). Nationally in the same year, 62% of students identified as White, 17% as Black, 16% as Hispanic, 4% Asian, and 1% American Indian, with 47.5% of all students eligible for free/reduced lunch (National Center for Education Statistics, 2011).

Data Sources

The data in this study were obtained through an Open Public Records Act request made directly to the State of New Jersey for the "NJ Certificated Staff" data sets for years 2010–2016. These data were supplied in database format, and each yearly file—containing the annual staffing information of approximately 145,000 teachers in NJ—was subsequently converted to a Microsoft Excel spreadsheet for aligning data categories and easier manipulation. Additional data sources, such as school board meeting minutes, union contracts, school district web pages, LinkedIn profiles, and state pension data, were used for triangulation as needed.

Each file contained a listing of individual personnel that included the following fields: county, district, school, last name, first name, middle initial, race/ethnicity, sex, year of birth, job code, total years experience, total years experience in NJ, total years in the LEA, teacher preparation pathway (traditional or alternate route), and annual base salary, as well as a number of additional data fields not used in this analysis.[3]

These data are an element of the required reporting by New Jersey state regulatory obligations, many of which are informed by federal reporting requirements. These data are entered annually at the school level, aggregated and submitted by each individual LEA, and reported by the state. The reliability and validity of the data used here was therefore dependent upon its correctness at the point of entry. There were instances of obvious violations of face validity in the data where fields were clearly incorrect—such as where a teacher was listed as a first year teacher with zero years for five years in a row—but in most cases these data were easily cleaned by triangulation with other sources.

Finally, in this study, we use the term *gender* in line with the guidance of the American Psychological Association (2020), which states: "*Gender* refers to the attitudes, feelings, and behaviors that a given culture associates with a person's biological sex," (p. 138). The APA 7th edition also advises use of the term *gender* whenever referring to social groups of people. Given

[3] For example, though the educational attainment level of each teacher was included as a field, we elected not to include it in this analysis because of an abundance of contradictory and missing information that could not be resolved in cleaning the data.

that the term *sex* was used by the state of New Jersey in its data collection efforts, we will use *sex* when referring to the state data, and *gender* when discussing the broader results.

Data Analysis

The purpose of any data analysis is to understand what the data reveal about underlying systems or processes, and the primary use of Microsoft Excel as a data analysis tool (Guerrero, 2019) in the present study served this purpose well. To prepare the analysis, each of the six separate "NJ Certificated Staff" datasets (2010-2011 through 2015-2016) was aligned into a parallel data structure using block structuring techniques (Garrett, 2015). The next step was to identify first-year teachers in each cohort with a certification—through the proxy of job code—in biological science, chemistry, physics, earth science, physical science, or general science. Teachers with only elementary science or middle school science certifications were excluded, though teachers with a secondary science certification teaching at any grade level were included. This procedure was followed for each subsequent year for all six years of data.

Next, the six datasets were merged into a single Excel file, and each first-year teacher from the 2010 cohort was assigned a unique identification number, which was then applied to each instance of that teacher's data in subsequent years. A careful hand-analysis of the data was undertaken at this point to identify possible name changes over the six years. If there were no indications otherwise, any individual with the same job code, teaching location, year of birth, and first name across two adjoining years was considered to be the same individual if no other similarly named individual existed in the same year. School assignment and public data on state employee pension enrollment was used as a check on this procedure, and discrepancies were compared with the full data sets. Often, missing data in a given year were able to be imputed from other years; for example, missing year 3 data could be added if reliable year 2 and year 4 data were present. Employment data from other sources (e.g. LinkedIn profiles) were only used if triangulated by another reliable public source, such as school board meeting minutes, union contracts, school district web pages, or state pension data. Alternate route teachers assigned to teach high school science classes but who ultimately did not earn an initial certification in a secondary science field were excluded from the cohort.[4] Teachers who were mislabeled in the state data as first-year teachers because we determined they had been teaching as a certified teacher prior to the 2010-11 school year were similarly excluded. Once this procedure was completed, any remaining teachers in the dataset not identified as a member of the 2010 cohort of first-year NJ science teachers were removed. Given the thorough nature of this process, we are confident that we were able to identify every first-year secondary science teacher in our data set, which ultimately totaled 231 unique individuals who began their first year of teaching in New Jersey during the 2010-11 school year.

In this study we chose to divide the teachers into two broad groups based on the race and ethnicity data. The first group, characterized by the two descriptors of *White and non-Hispanic*, represents over 80% of the teacher workforce in the United States (McFarland et al., 2019). The second group, *non-White and/or Hispanic* included those not identified as White as well as all those who were identified ethnically as Hispanic. While we recognize the problematic nature of these categories (Nguyen & Teranishi, 2020), the purpose of analyzing the data through the lens of race and ethnicity relates to the broader recognition for the need to diversify the teacher workforce in order to better reflect the demographic profile of the U.S. student population

[4] There were a dozen or so instances of alternate route teachers who would go on to earn certification in subject areas other than science being assigned to teach science courses. The most straightforward explanation of this phenomenon was the likely administrative use of the provisional status of individuals in alternate route programs for short term coverage of science teacher vacancies.

(Carver-Thomas, 2018). Creating a category of teachers that included teachers of color (i.e. did not identify solely as White) as well as those who identify as Hispanic appeared to be the best choice available to us for highlighting the characteristics of this non-majority population given the available data. Though we hope that the individual teachers themselves were consulted for these data, there is no guarantee that this was the case.

Further manipulation of the spreadsheet data for the years 2011-2016 permitted for identification of individual movement between schools and districts, departure and return after a break in service of one or multiple years, and possible cases of attrition. For each of the latter, an Internet search was conducted to gather evidence to determine if teacher attrition had indeed taken place. This included searching school district websites and school board agendas, LinkedIn for work history information, and other public information sources. The complete de-identified data set and analysis is available as a spreadsheet in the online supplemental section of the journal website.

The starting year for measurement in this study was the 2010-11 school year, or $t_{initial}=2010$. In order to calculate a 5-year retention rate, data from the 2015-16 school year, or $t_{final}=2015$, were required.[5] However, in the process of this analysis, we determined that a number of the first-year hires did not start at the beginning of the school year, so rather than claim that they had been retained for 5 years, we could at minimum state that they had been with the employer for at least 4 out of the 5 years. Further, we found a substantial number of teachers who began their careers as long-term substitute positions during the first year, then were hired in a second district where they stayed. In these cases, the ability of a teacher to be retained in the

[5] In NJ, these data are collected every October, so to be certain that a teacher was retained the full year, the following year's data are needed.

district may have been outside the control of both the teacher and employer. The implications of this finding will be discussed in the final section.

Therefore, for each of the 231 New Jersey science teachers in the 2010 cohort, we examined six years of employment data to determine if they had been retained by one of the following three definitions:

- *Retained-by-employer 4 of 5 years in first district.* This measure indicates whether teachers completed at least 4 of their first 5 years in the district that had initially hired them. This group includes individuals who had a one-year break in service as well as people who left the profession or began a break in service during their 6th year. It does not include anyone who transferred from one district to another during their first 6 years.
- *Retained-by-employer 4 of 5 years in first or second district.* This measure indicates whether teachers completed at least 4 of their first 5 years in either the district that had initially hired them or a district to which they transferred after the first year of teaching. This more inclusive category reframes those who move after 1 year and subsequently stay in the second district as being retained, which other earlier studies may not have done.
- *Retained-in-profession (Active, 5 years).* This measure indicates whether a teacher who was teaching in the beginning of the 2010-11 school year was actively teaching in the beginning of the 2015-16 school year, regardless of district, state, or breaks in service. In reporting this category here, we did not include those teachers in the reserve pool who were *retained in profession* but not actively teaching in 2015-16.

These three definitions of retention were used to present comparisons by preparation pathway, race/ethnicity (White & non-Hispanic compared with non-White and/or Hispanic), year of birth, certification area, and sex (Male/Female) of the teachers in the data set.[6] Additionally, the data were examined to characterize the nature of transfers, breaks in service, and attrition for the teachers in the cohort.

The last stage of the analysis examined the relationship between teacher retention and school contexts, which we separate into salary and school characteristics in the findings section below. Data from first-year salary levels were compared to the three definitions of retention described above in order to identify potential relationships between initial salary and retention.

Findings

Characteristics of the Cohort

The analysis of the demographic makeup of the 2010 cohort of first-year secondary science teachers in NJ is shown in Table 1. There were slightly more female teachers (54%) than male (46%), and only 38 teachers (16%) in the cohort were identified as non-White and/or Hispanic (compared with 48% of NJ public school students in 2010). Almost two-thirds (63%) had completed a traditional teacher education program, with the remaining one-third enrolled in an alternate route program during their first year. The median age of the 231 teachers was 27 years, and the median age of women (26 years, SD=9.4) was slightly lower than that of men (29 years, SD=12), though they had a similar distribution. The median age of the alternate route teachers skewed older (30 years, SD=12) than their traditional route counterparts (26 years, SD=12), which is consistent with the known profile of alternate route teachers nationally

[6] Sex identification data in this data set was presented a binary choice of either male or female.

(Zumwalt & Craig, 2005). There was no difference in the median age by race/ethnicity (27 years) as a whole or between preparation pathways for non-White or Hispanic teachers.

(Insert Table 1 approximately here)

Retention Findings

Overall retention

Overall rates of three types of retention for the cohort are presented in Table 1, and a visual representation of the five-year employment changes for teachers in the 2010 NJ science teacher cohort is shown in Figure 2. Of the 231 first-year NJ science teachers who started the 2010 school year, 150 (65%) were still teaching in a public or private school in the United States after 6 years, and 87 (38%) of them were still teaching in the district in which they were first hired. Ten teachers left New Jersey to teach in other U.S. states, and 7 of these met the criteria for active teaching in year 5.

(Insert Table 2 approximately here)

Table 2 shows the percentage of the total cohort that was teaching over each of the five years. Note that these numbers do not distinguish between teachers who have left teaching with those who are taking a break in service. About 5-6% of the total cohort each year are categorized as having a break in service, as shown in Table 2. Between 2011–2015, 27 teachers (12%; 14 female, 13 male) are recorded as not teaching for a period of 1-3 years. This could represent leaves of absence or time between employment in different districts. Twenty-one of these teachers were still teaching in the 2015-16 school year. It seems likely that there were other individuals beginning a break in service, whose return to service was not identified because it lay beyond the time frame of the data examined in our study. It is noteworthy that 16 of the 27 breaks in service were for a single year, and only 2 resulted in the teacher returning to their prior district.

(Insert Figure 2 approximately here)

Of the original cohort of 231 teachers, 81 (35%) were no longer teaching by the 2015-16 school year. At least 20 (9%) of these individuals had either identifiably left teaching or were working in non-education professions by 2016. There were four Teach for America corps members in the cohort, all of whom left teaching in three years or less: three left to work in medicine or business and the fourth became an educational consultant. It is worth noting that the one-year retention-in-profession rate in our study's population is 87%, a figure that aligns closely with the value of 12.3% of science teachers who were *leavers* in the national sample of science teachers from the 2004-2005 SASS data reported by Ingersoll and May (2012, p. 446).

Age and retention

This study found no statistically significant relationship between age and retention-in-profession rate, by any of the measures used here. To investigate if there were any differences in specific age groups, the cohort was broken into five roughly equal quintiles of age cohorts, as shown in Figure 3. For each quintile, the retention-in-profession rate was between 63–66%, with the exception of the middle cohort of teachers age 26–30, which had a lower retention-in-profession rate of 54%.

(Insert Figure 3 approximately here)

Gender and retention

Slightly more men than women were retained in their first or second districts (52% vs. 47%), though both were retained-in-profession at nearly the same rate (64% and 66% respectively). There was no meaningful difference in the break in service rate between men and women (11% vs. 12%).

Race/ethnicity and retention

For teachers who identified as non-White or Hispanic (38 of the 231), the 5-year retention-in-profession rate was 57%, which was lower than the cohort average. As shown in Table 3, there was a notable difference in retention by preparation route for this group: non-White or Hispanic teachers who attended a traditional teacher preparation program were retained at a rate of 75% (12 out of 16), while those who went through an alternate route program were retained at a rate of 45% (10 out of 22).

(Insert Table 3 approximately here)

Preparation pathway and retention

Teachers from traditional teacher preparation programs were retained in their first or second district at a slightly higher rate (51%) than their alternative route counterparts (46%). However, the 5-year retention-in-profession rate for active teachers was much lower for alternate route (54%) than traditional route (71%) science teachers.

Subject area and retention

Table 4 shows the count of teachers in the cohort by certification area. T-test analyses were performed to examine if there was any identifiable relationship between the subject area and retention. There was no significant difference ($p < .05$) between subject area and retention by each of the three definitions used in the analysis. Nearly half (48%) of all the teachers in the cohort were working with or toward a biological science certification. One quarter (25%) were chemistry teachers, with physics teachers as the next largest group (12%). Earth science and physical science teachers together made up only 5% of the cohort. Unexpectedly, nearly 10% of the cohort was listed as teaching general science, a certification that has not been issued in New Jersey since the early 1990s. Given that all were alternate route teachers, the likeliest explanation for this is that general science—which is still a valid NJ license—was probably selected by administrators as the teachers' initial job code to allow them greater flexibility in scheduling. This hypothesis is supported by the fact that no teacher was listed with the general science certification beyond their third year, after the official certification had been earned.

(Insert Table 4 approximately here)

Salary and retention

The median starting salary across all of the teachers in the cohort was $50,000 (SD=6355). T-test analyses were performed to examine if there was any identifiable relationship between the first-year starting salary and retention. There was no significant difference ($p< .05$) between first-year salary and retention by each of the three definitions used in the analysis.

Interestingly, there was a significant but small effect of sex on initial salary levels at the $p< .05$ level, $t(230) = 2.00$, $p = .024$, with men ($M = 51529$, $SD = 6744$) having slightly higher salaries than women ($M = 49863$, $SD = 5932$). The ratio of women's to men's starting salaries in our sample was 97.8%, a sharp contrast to the broader employment data for the U.S. in the fall of 2010 (U.S. Bureau of Labor Statistics, 2010), where this ratio was 81.3%, and is certainly attributable to the unionize teacher workforce in the state. Given that there was a slight difference in retention by sex in those retained for 4 of 5 years in their first district and retention in 4 of 5 years in first or second district, a secondary level analysis was performed, but there was no significant difference at the $p < .05$ level of the effect of salary on retention in any of the three categories when controlled for sex.

School Characteristics and Retention

An analysis of retention by district factor grouping, which serves as a proxy measure for socioeconomic status (SES), displays a bi-modal distribution in regard to hiring, as shown in Table 5. Specifically, the wealthiest and the poorest districts hired most of the new science teachers in 2010. When charter and county schools are included as separate groups, charter schools in NJ had by far the lowest levels of new teacher 5-year retention-by-employer (13%) over the 6-year period. This lower rate of teacher retention-by-employer among the charter schools is consistent with existing findings in the teacher retention literature (e.g. Miron & Applegate, 2007). There was not a clear retention-by-employer pattern emerging from the other districts by district factor group.

(Insert Table 5 approximately here)

There were 94 total transfers by 74 unique members of the cohort from a NJ public school district to another teaching location during the six years examined in this study. One finding was that it was slightly more common in this group for teachers in higher SES districts to move to lower SES districts (31 transfers) than from lower SES districts to higher SES districts (26 transfers). A total of 17 transfers were lateral, to a school of the same DFG or county/charter status. It was three times more common for a teacher to transfer away from a charter, county (i.e. special services), or vocational school than it was for someone to transfer to those types of schools.

Summary of Findings

By focusing on a single cohort of science teachers in a specific state, one goal of this study was to better understand some of the dynamics of teacher retention that were less visible from larger studies that used a sampling methodology. Highlights of the above findings include:

- After five years, 38% of NJ science teachers in the 2010 cohort were still employed in the district where they were first hired.
- An additional 24% of science teachers changed districts during or immediately after their first year, and ended up being retained in their second districts for four or more years.
- Only 5% of the science teachers appeared to have attritted from teaching after the first year. An additional 5% attritted annually for each of the next three years. An equal number of teachers appeared to have taken a break in service and eventually returned.
- The largest group of science teachers by subject were those with a biological science certification. With the exception of a small number of teachers certified in physical science, this group also had the lowest retention rate of any certification area.
- Only 16% of the science teachers in the cohort identified as non-White or Hispanic, compared with 48% of all NJ students in the same year. Controlling for preparation pathway, these teachers were retained at similar rates to their White/non-Hispanic counterparts.
- Alternate route preparation programs attracted many more secondary science teachers who identified as non-White or Hispanic, but teachers from these

programs had a far lower 5-year retained-in-profession rate (45%) than non-White or Hispanic traditional route teachers (75%).

- It was more common for science teachers in higher SES districts to move to lower SES districts than the reverse. The position turnover rate for science teachers was slightly lower in higher SES districts.
- As a category, charter schools had the lowest 5-year science teacher retention rate (13%).
- There was no identifiable relationship between the starting salary of science teachers and the measures of retention used in this study.

Discussion

The questions asked by this study ultimately required a reconceptualization of key descriptors related to retention, including the concept of retention itself. In this section we discuss each question separately, before exploring some related issues raised by this research.

Retention Descriptors

Our first research question asked: How should descriptors of secondary science teacher retention, mobility, and attrition be conceptualized so that knowledge can be generated and accumulated across studies? Our overall solution to the problem of description arose out of the challenges in characterizing the year-to-year career progress of the 2010 NJ Secondary Science teacher cohort because of the imprecise conceptualization of retention terminology common in the field. The person-position framework introduced here addresses this issue by recognizing two perspectives on retention, that of the employer and that of the employee, and thus distinguishes retention-in-position from retention-in-profession.

A second key feature of our framework was the inclusion of the number of years in any retention measure, as a way to ensure appropriate comparisons. While such an approach remains important, particularly if comparisons are to be made across different studies, we also found that determining the number of years a person was in a teaching position was not always straightforward, particularly in cases where the hire did not occur at the beginning of the school year. There was also a considerable amount of volatility in the first year, as well as when a teacher worked in a district for one year and then transferred to a district where they then remained. Perhaps more important to our purposes here, the interpretation of the position turnover was often conflated with an individual's retention, when in fact many teachers were actually able to be retained in their subsequent district. This finding led us to adopt the *Retained-by-employer 4 of 5 years in first or second district* measure, which holds greater face validity as a measure of retention, particularly from the perspective of the teacher. This approach allowed for an additional 12% of teachers to be counted as retained in our overall sample. One implication of this finding is that instability in one's first year of teaching need not be disruptive to longer-term retention, however defined. Certainly it is not difficult to speculate on the reasons why so many science teachers might transfer schools or districts during or immediately after their first year. One possibility is that some positions may only be temporary, and a transfer may reflect a desire for more stability. Another reason may be related to issues of fit between the individual and the position itself, either in terms of the school/LEA or the community (Holtom et al., 2006; Mitchell et al., 2001).

The person-position framework raises a number of challenges from the perspective of data collection and maintenance, but most can be addressed with a thoughtful approach to the design of data systems. We conducted this research with the state-level data that was available to us, but there is no reason why a more robust data system could not collect, tabulate, and report information about retention-in-position, retention-by-employer, and retention-in-profession. Such a system could also monitor and report transfers and breaks in service, potentially alerting educational leaders and policymakers with indicators of problematic trends, particularly if the reporting was disaggregated by certification areas and demographic groups.

Secondary science teachers can be made visible in this framework in two specific ways, through teaching assignment and certification area. In this study, these two designations were collapsed into a single category because the "job code" data label in the New Jersey staffing data could refer to either. New Jersey is not alone in requiring reporting on the teaching assignment rather than the teaching certification, and in some cases, this resulted in ambiguity about whether an individual was certified to teach in multiple content areas, or whether they were teaching out of their certification. A certified physics teacher who teaches 3 sections of high school physics and 2 sections of chemistry in a given year would simply be listed as a full time teacher in the district, and might have that teaching assignment change from year to year even when retained-in-position. Had the data included certification and teaching assignment as separate fields, it would have been possible to more closely examine the relationship between out-of-field teaching and retention of secondary science teachers.

Finally, we note the issue of the blurred boundary between the reserve pool and attritted teachers, which may in fact be an epistemological distinction that cannot be resolved until a specified amount of time has passed. Ingersoll and Perda (2010) suggested that the perceived science and mathematics teacher "shortage" is in part an issue of a smaller reserve pool for these subject areas. Indeed, in this study we show that after 5 years, the size of the reserve pool plus attrition is about one-third of the total cohort, and it is genuinely not possible to determine what proportion of that group will someday return to teaching secondary science. And yet, the very fact of this reserve pool's existence has implications for efforts to recruit teachers back into the workforce. A previous finding from the literature that this study also reinforces is that some science teachers who take a position in a new district are often able to be retained, a fact that could give hope to novice science teachers who leave in discouragement from their initial district of hire.

Retention Characteristics

Our second research question asked: Using these descriptors, what are the retention characteristics of a state-level cohort of first-year secondary science teachers over a six-year period? In many ways, the findings of our study confirmed some of the larger findings from teacher retention research in the United States, such as the overall one-year and five-year teacher retention rates for our sample. Yet by limiting our analysis to a cohort of novice New Jersey secondary science teachers, we were also able to reveal nuanced aspects of this particular population that might have been overlooked in other studies.

From this analysis we note that biology teachers are retained at a lower rate than other subject areas, providing support for the notion that the pull of alternate career pathways (e.g. medical school or other health-related careers) remains strong in the first years of teaching for these individuals. We can also see that the salaries of first year science teachers—at least in a highly professionalized and unionized state context environment—are likely not an appreciable factor in pushing science teachers back to prospective higher-paying jobs in industry.

Even though science teachers of color remain underrepresented in the teacher population (at least in this one state), the fact that their retention rates are comparable to the larger population of science teachers suggests that their experiences as novices may be distinct enough from their non-science teaching peers to warrant further investigation. Certainly, the impact of racism, workplace microaggressions, and systemic barriers to achievement that impact people of color in STEM are present in the broader teaching profession as well (McGee, 2021). Our finding could simply be a result from the small sample size of teachers of color in this study, itself an artifact of proportional under-representation of science teachers of color in the wider workforce. Yet, the comparable retention of science teachers of color shown in this study, particularly those prepared in traditional teacher preparation programs, is a result worthy of further research.

Perhaps the most compelling finding is the fact that only about a third of all secondary science teachers in our sample were actually retained for four years in the district where they were first hired, and another third left the profession. While this may be “normal” —in the words of Smith and Ingersoll (2004)—perhaps it is not in fact “inevitable,” particularly given the comparatively lower rates of teacher attrition outside of the United States (OECD, 2021).

It appears that some caution must be taken in drawing conclusions from the salary reported in the state-level data for two reasons. First, the reported salary is simply the base-level salary, and does not include other opportunities that a school or district might offer to supplement this with paid extra-curricular opportunities (such as coaching, club advisement, etc.). It is also reasonable to assume that the presence of such additional compensation, as well as the professional impact of such opportunities, could factor strongly in teacher retention. Secondly, New Jersey is a highly unionized state with teacher salaries set by negotiated contracts (with the notable exception of many but not all charter schools), and has made significant effort and progress toward equitable school funding (Baker, 2018). Therefore, though the median starting salary was $50,000 for the first-year teachers in this study, the data do not tell us why there was such a wide variability (SD = 6355) in starting salaries across the cohort. The slight difference in men's and women's starting salaries in the cohort may suggest that some individuals were offered higher initial salaries for prior experience than others.

Framing science teacher retention

Our third question asked: How do different ways of framing teacher retention impact the conclusions that may be drawn from teacher retention data? One of the clear findings of the present study is how different retention statistics appear depending on the time frame measured, and whether retention is characterized by profession, state, employer, or position. A rather obvious point worth emphasizing here is that a one-year retention rate is always going to be equal to or higher than a five-year retention rate. For example, in this study the retention-in-profession 1-year active rate was 88%, as compared with a 65% 5-year rate. A very different point could be made from the same data arguing that only 38% of novice science teachers in New Jersey are still working for the same employer after five years. In short, findings on teacher mobility reported in the literature must be viewed with caution if the exact time frames and descriptors are not provided.

We also see in this analysis that even though some districts were able to attract and hire more science teachers of color into the profession through alternate route pathways, they were far less successful in retaining those teachers over the long term. Being able to identify a finding such as this depends on having data on preparation, race/ethnicity, and year-to-year retention. However it also raises a question of framing in terms of "experience." Perhaps a more correct framing is to compare attrition rates from the profession between teacher candidates in the final year of a traditional program (who might be expected to engage in a full-time clinical experience) and a first year alternate-route teacher, if we expect to compare attrition between two comparable groups in their first full-time teaching experience. Such data may not exist or be very difficult to come by in the United States. In other national education systems where teacher education programs and school systems are more tightly linked, such comparison may not be possible or even nonsensical if entry into the profession is much more competitive.

The findings from our analysis of retention through the lens of the New Jersey district factor grouping, to which we added county and charter categorizations, run somewhat counter to the conventional wisdom that teachers leave low-SES schools for better conditions elsewhere. One unexpected discovery is that the largest group of transferring teachers is from high-SES districts to lower-SES districts, an outcome that we have not seen reported elsewhere for science teachers or teachers more generally. We can only speculate on the reasons for this finding, but it is possible that one part of the answer is that the size of the reserve pool of teachers, particularly for shortage areas like science, is larger for high-SES schools. If high-SES schools are seen as more desirable places to work for the majority of potential teachers, then perhaps the downsides for the employer of non-renewal of a teacher's contract are not as great as they might be in a school where positions are much harder to staff. It may also be the case that high-SES schools challenge novice teachers in very different ways from low-SES schools. For example, the immediate demand for advanced knowledge of subject matter—which research shows is still developing for science teachers (Abell, 2007; Davis et al., 2006)—or unexpected pressures of home communication (e.g. Fantilli & McDougall, 2009) may place an unsustainable burden of stress on the novice science teacher, precipitating a move. Clearly further research is needed, both to determine the specific causes of district transfer as well as to ascertain whether this is a phenomenon particularly relevant to science teachers.

Conclusion

This study confirms that many of the findings from larger and more comprehensive empirical research studies on teacher retention (Goldring et al., 2014; Ingersoll & May, 2011, 2012; Lindqvist et al., 2014; McFarland et al., 2019; Papay et al., 2017) also apply to secondary science teachers, while offering a more fine-grained view on the findings from the wider body of teacher retention research. We have learned that the common axiom that half of all science teachers leave the classroom by their 5th year was not quite true, at least in New Jersey. Rather, we found that after 5 years in the classroom, nearly two-thirds (65%) were retained in the profession and were still active as science educators.

Undertaking this analysis of 6 years of staffing data for the 2010 cohort of New Jersey secondary science teachers led us to critique the specific measures, descriptions, and terminology that have been the hallmark of the teacher retention literature. Additionally, we have challenged the prevalence within the literature of defining retention solely from the perspective of employers. The person-position framework that serves as both an outcome and analytical tool of this study marks an advance in our field's thinking about the careers of not only science teachers, but teachers more broadly as well. This framework permits for future research on teacher retention to build on shared understandings and definitions in order to more productively address the challenges of teacher retention.

Limitations

One limitation of this study is that the population of science teachers examined here represents a single cohort from a single state, and that subsequent analyses from other states where the policy environments are quite different might show very different patterns of retention. For example, in states with very large school districts and no tenure policy, teacher mobility may be much more common both within and between districts. Similarly, states that have less restrictive science certification policies than New Jersey might find different patterns in teacher retention. Another limitation is that the patterns from this particular 2010 cohort of secondary science teachers might look quite different if we studied a different cohort—such as the novice science teachers beginning their careers in the fall of 2020 amid the disruptions of the COVID-19 pandemic. A final limitation relates to the reliability of the data. The wide variability of data completeness and validity across districts remained a concern for us as a research team throughout this project, as were the lack of unique teacher identifiers in the state data set. It remains possible that teachers were either misidentified or overlooked entirely in our analysis.

Implications and Future Research

The push at the federal level for better designed state data systems that was part of the Race to the Top grant competition focused primarily on student data and educational effectiveness, yet the larger movement over the past decade to improve these systems also presents an opportunity to better support the needs of the teacher workforce (Workforce Data Quality Campaign, 2016). The data analyzed here were from one specific publicly available database that was separately maintained from other data (e.g. certification, teacher quality, and teacher preparation data were all located in other non-linked databases). Logically, a well-designed database tool that interfaced with clean and well-ordered state level data across multiple databases with adequate privacy protections could produce retention reports for any given group of districts, schools, or teachers for any specified time frame. Automated annual reports from such a database could provide a much clearer picture of vacancies, shortage areas, and knowledge of sites with high position turnover, and subsequently provide policymakers and educational stakeholders with data to inform courses of action. Such data could have important implications for our field in terms of equity in science education. In school finance litigation, adequacy arguments have been successful precisely because data have raised the curtain on inequities (National Research Council, 1999). From a broad policy perspective, regular reporting on salary differentials across science teachers in different district settings could raise questions about why science teachers with equivalent credentials are compensated differently in different settings.

The future of empirical teacher retention research will certainly need to strike a balance between three key aims: detailing the specific career patterns of individual teachers over time, the public's entitlement to information about its public school employees, and attending to the very real privacy concerns of individual school employees. A public, unique identifier seems a prerequisite in order to adequately track teacher employment from year to year. This study also shows that including teacher certification area in such data could lead to important insights. Where state policy does not require subject matter specialization (National Council on Teacher Quality, 2010), tracking by course assignment may serve the same ends.

In recent years, the issue of supporting new teacher learning in their first years of teaching has drawn greater attention (Bartlett & Johnson, 2010; Bastian & Marks, 2017; Desimone et al., 2014), and the professional needs and challenges of science teachers specifically during these induction years are well-documented in the literature (Davis et al., 2006). The early career model of teacher retention presented here will support further research on questions such as the impact of mentoring and induction programs (Ingersoll & Strong, 2011), understanding the consequences of obligations for service on STEM teacher education scholarship recipients (e.g. Olitsky et al., 2020; Podolsky & Kini, 2016), and the recruitment and retention of teachers from immigrant populations into the workforce (e.g. Ennerberg & Economou, 2021; Ross, 2003).

There is little doubt that teacher retention research, and science teacher retention research in particular, will continue to focus on both the pressing need to ensure that every student who needs a teacher has one, and that the profession remains focused on increasing the quality of these teachers over time. Yet, it is far too easy for such research to lose sight of the individual teachers whose personal and professional lives are reflected in retention statistics. We hope that future empirical research on teacher retention will be informed by the guidance offered here and will differentiate between the types and time frames of retention being reported. We also encourage those working to improve data quality efforts in education to remain in conversation with researchers who use these data. With a better understanding of teacher retention—in terms of subject area, grade level, teacher preparation, demographic characteristics, workplace and community context, salary, and professional support—it becomes possible to make better policy decisions that ultimately serve to improve the education of all students.

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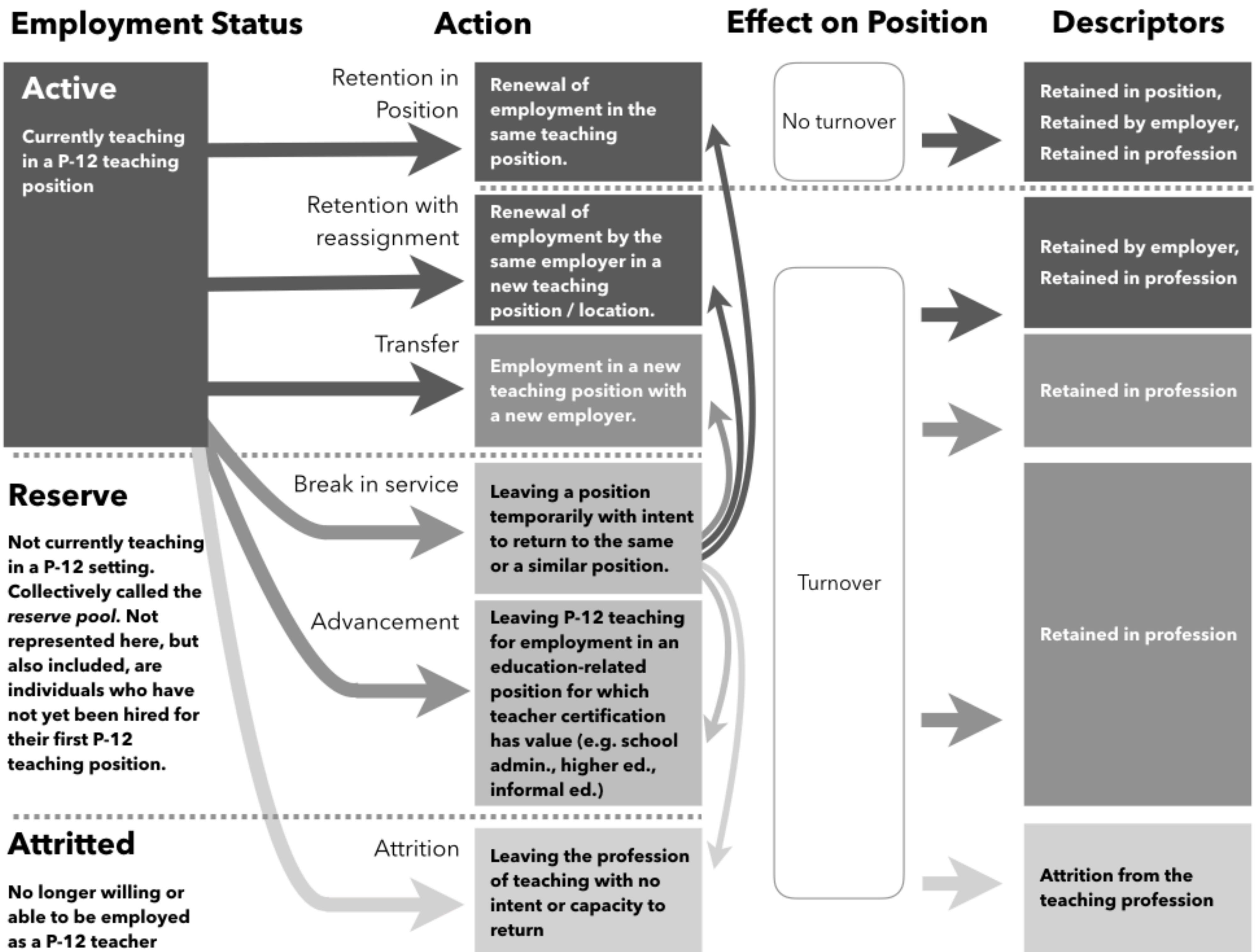
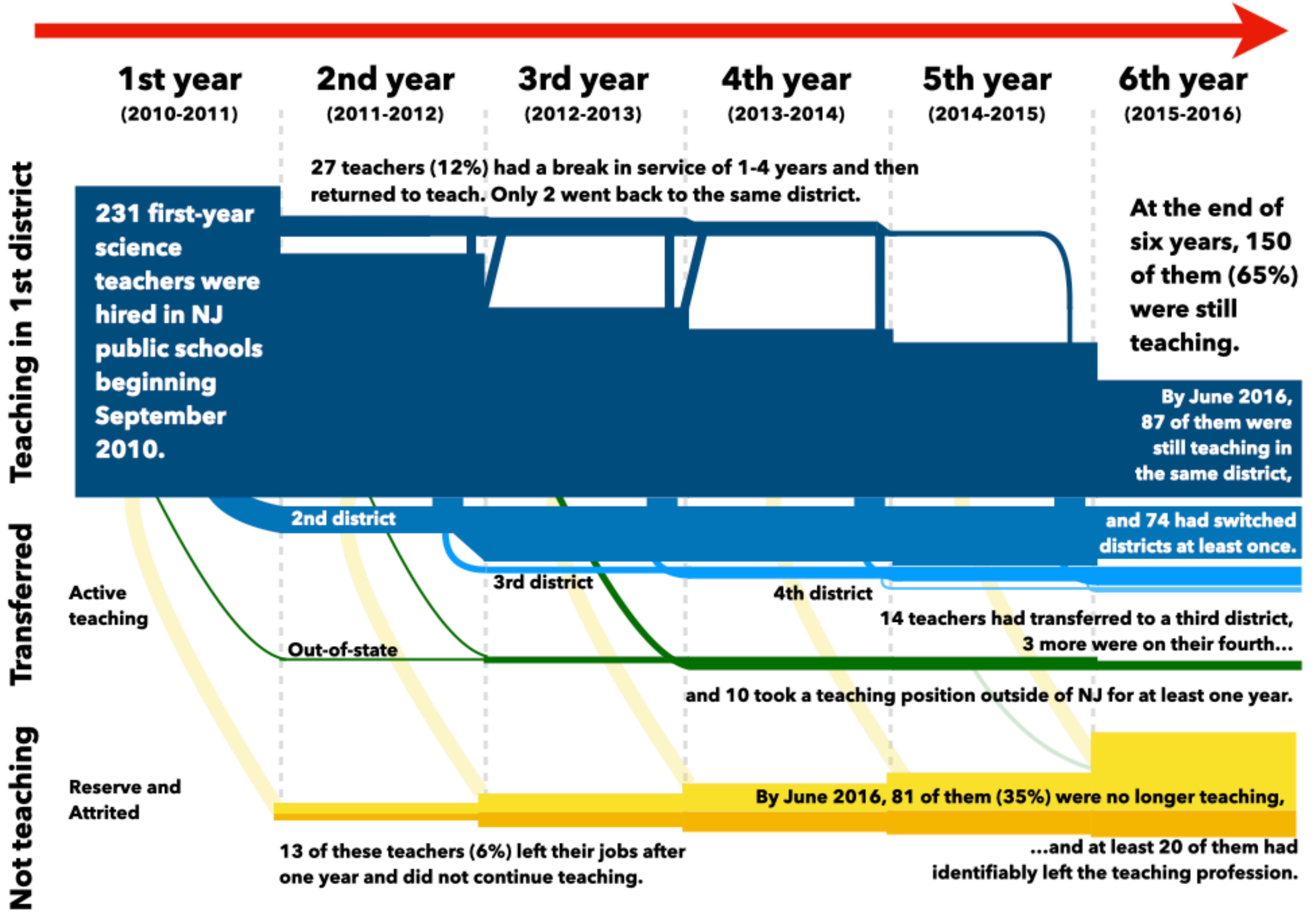

Employment Status
Action
Effect on Position
Descriptors
Active
Currently teaching in a P-12 teaching position
Retention in Position
Renewal of employment in the same teaching position.
No turnover
Retained in position, Retained by employer, Retained in profession
Retention with reassignment
Renewal of employment by the same employer in a new teaching position / location.
Retained by employer, Retained in profession
Transfer
Employment in a new teaching position with a new employer.
Retained in profession
Reserve
Not currently teaching in a P-12 setting. Collectively called the *reserve pool*. Not represented here, but also included, are individuals who have not yet been hired for their first P-12 teaching position.
Break in service
Leaving a position temporarily with intent to return to the same or a similar position.
Advancement
Leaving P-12 teaching for employment in an education-related position for which teacher certification has value (e.g. school admin., higher ed., informal ed.)
Turnover
Retained in profession
Attritted
No longer willing or able to be employed as a P-12 teacher
Attrition
Leaving the profession of teaching with no intent or capacity to return
Attrition from the teaching profession



The height of each pixel represents a single, identifiable NJ secondary science teacher.

Primary source data: NJDOE Certificated Staff reports 2010-2016
Additional data from individual school district websites and LinkedIn

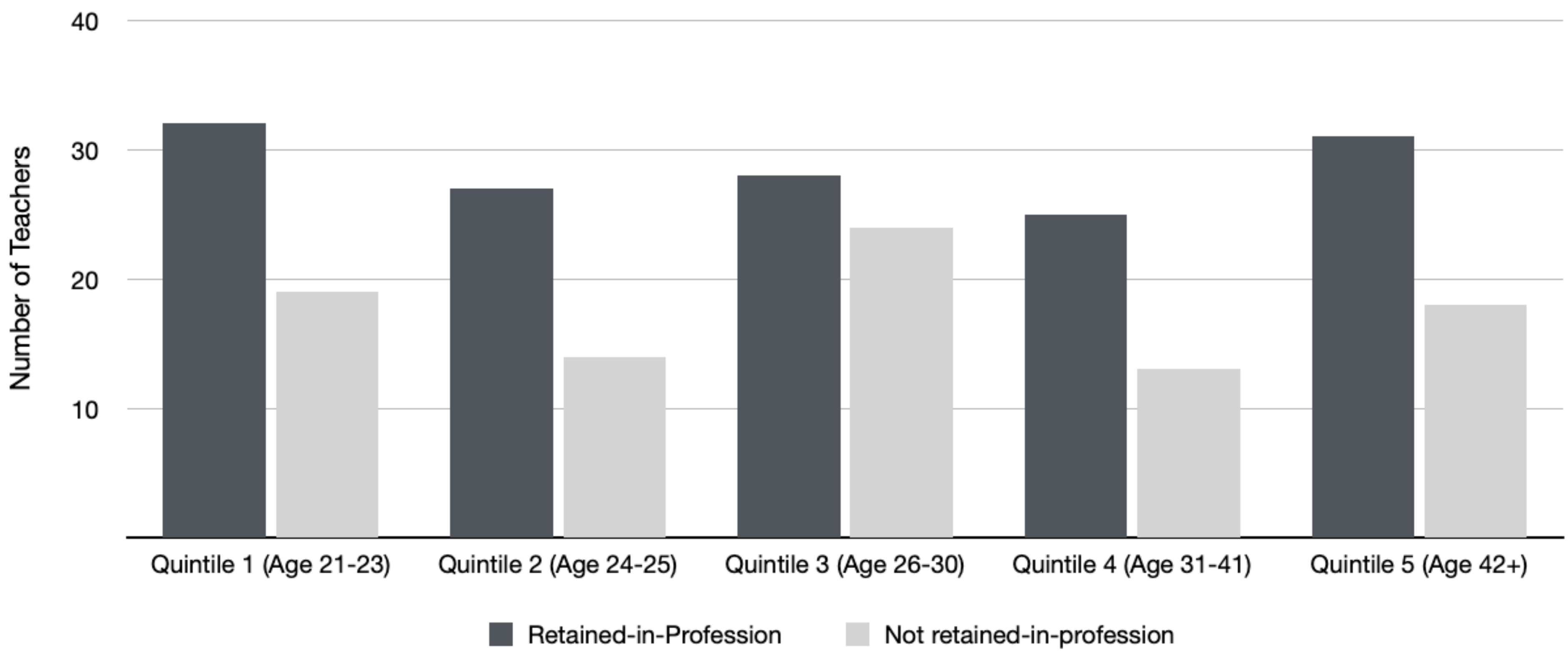

Number of Teachers
40
30
20
10
Quintile 1 (Age 21-23)
Quintile 2 (Age 24-25)
Quintile 3 (Age 26-30)
Quintile 4 (Age 31-41)
Quintile 5 (Age 42+)
Retained-in-Profession
Not retained-in-profession

Table 1. Characteristics and retention of the 2010 NJ Secondary Science Teacher cohort (n=231)

		Total	% of cohort	Retained 4 of 5 years in first district	Retained 4 of 5 years in first or second district	Retained-in-Profession—(Active, 5 years)
Total	All teachers	231	100%	85 (37%)	114 (49%)	150 (65%)
Teacher Preparation	Alternate Route	85	37%	28 (33%)	39 (46%)	46 (54%)
	Traditional	146	63%	57 (39%)	75 (51%)	104 (71%)
Race/ Ethnicity	Non-White or Hispanic	38	16%	13 (35%)	18 (49%)	22 (58%)
	White and non-Hispanic	193	84%	72 (37%)	96 (49%)	128 (66%)
Sex	Male	106	46%	41 (39%)	55 (52%)	68 (64%)
	Female	125	54%	44 (35%)	59 (47%)	82 (66%)

Table 2. Five-year employment status of individuals from the 2010 cohort of first-year secondary science teachers in New Jersey

	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
Employed in a New Jersey public school	**231 (100%)**	**201 (87%)**	**187 (81%)**	**175 (76%)**	**171 (74%)**	**143 (62%)**
Employed in district in which they were first hired	231 (100%)	181 (78%)	141 (61%)	125 (54%)	115 (49%)	87 (38%)
Left New Jersey to teach at least one year	0 (0%)	2 (1%)	5 (2%)	9 (4%)	10 (4%)	10 (4%)
Total Reserve pool + Attrition:	**0 (0%)**	**28 (12%)**	**39 (17%)**	**47 (21%)**	**50 (21%)**	**78 (34%)**
Reserve pool (non-Break in Service) + Attrition:	0 (0%)	13 (6%)	25 (11%)	36 (16%)	46 (20%)	78 (34%)
Reserve pool: Identified Break in Service	—	15 (6%)	14 (6%)	11 (5%)	4 (2%)	—
Left for 1 year absence	—	*11*	*4*	*1*	*0*	—
Left for 2 year absence	—	*1*	*3*	*1*	—	—
Left for 3 year absence	—	*3*	*3*	—	—	—
Left for 4 year absence	—	*0*	—	—	—	—
Transfer total	**0**	**20**	**34**	**11**	**16**	**13**
Transfer to 2nd district	—	20	29	7	12	6
Transfer to 3rd district	—	—	5	4	3	5
Transfer to 4th district	—	—	—	0	1	2

Table 3. Retention-in-profession (5 years) by Teacher Preparation, Race/Ethnicity, and Sex

Preparation Route Ethnicity Sex	Total category count in 2010	Retained-in-profession (5 years)	% of total in category Retained-in-profession (5 years)
Alternate Route	85	46	54%
Non-White or Hisp.	22	10	45%
Female	14	6	43%
Male	8	4	50%
White and non-Hisp.	63	36	57%
Female	30	19	63%
Male	33	17	52%
Traditional	146	104	71%
Non-White or Hisp.	16	12	75%
Female	9	7	78%
Male	7	5	71%
White and non-Hisp.	130	92	71%
Female	72	50	69%
Male	58	42	72%
Total	231	150	65%

Table 4. Retention by certification area of the 2010 NJ Secondary Science Teacher cohort (n=231)

	Total starting in 2010	% of cohort	Retained 4 of 5 years in first district	Retained 4 of 5 years in first or second district	Retained in Profession—(Active, 5 years)
Total	**231**	**100%**	**85 (37%)**	**114 (49%)**	**150 (65%)**
Biological Science	111	48%	42 (38%)	60 (54%)	69 (62%)
Chemistry	57	25%	18 (32%)	23 (40%)	36 (63%)
Physics	27	12%	9 (33%)	10 (37%)	19 (70%)
General Science	24	10%	11 (46%)	14 (58%)	17 (71%)
Earth Science	7	3%	4 (57%)	5 (71%)	6 (86%)
Physical Science	5	2%	1 (20%)	2 (40%)	3 (60%)

Table 5. Five-year retention outcome of 2010 cohort of First-year Science Teachers in New Jersey by district factor group (n=231)

	District Factor Group (A= lowest SES, I= highest SES)									
	A	**B**	**CD**	**DE**	**FG**	**GH**	**I**	**County & voca-tional**	**Charter Schools**	**total**
Total hired in 2010	40	16	17	25	22	35	48	12	16	231
Retained-by-employer (5 years)	13 (33%)	5 (31%)	5 (29%)	9 (36%)	12 (55%)	16 (46%)	19 (40%)	6 (50%)	2 (13%)	87
Transferred but retained-in-profession (5 years)	8 (20%)	3 (19%)	4 (24%)	7 (28%)	7 (32%)	8 (23%)	10 (21%)	4 (33%)	5 (31%)	56
Not retained-in-profession (5 years)	19 (48%)	8 (50%)	8 (47%)	9 (36%)	3 (14%)	11 (31%)	19 (40%)	2 (17%)	9 (56%)	88
District factor group 5-year position “turnover” rate (transfer + attrition)	68%	69%	71%	64%	45%	54%	60%	50%	88%	62%