Early Childhood Education for Children with Autism:
How Teacher and Classroom Characteristics Influence Student Learning

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Dedication

This paper is dedicated to my son Gabriel, who introduced me to a completely new world, and whose joy and vivacity is an inspiration to everyone around him.

Abstract

This paper estimates the relationship between changes in academic performance for pre-school age children with Autism Spectrum Disorder and teacher education and classroom staffing using data from the Pre-Elementary Education Longitudinal Study (PEELS). Strong positive relationships between changes in children's standard scores on selected standardized math and reading tests are found when their teachers have bachelor's or master's degrees in special education, or bachelor's degrees in general education. There is also evidence of relationships between classroom structure and change in student standard scores on standardized reading and math tests for children with ASD.

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Introduction

The Center for Disease Control and Prevention (CDC) has deemed the rapid increase in the prevalence of Autism Spectrum Disorders (ASD) a public health crisis (CDC, 2009). The number of children in the United States being diagnosed with and treated for ASD has risen dramatically since the early 1990s. The CDC announced in March 2012 that an estimated 1 in 88 children have been diagnosed with ASD in the United States (CDC, 2012). In 2006, a widely cited cost estimate put the societal price tag in the US at $35 billion per year in treatment costs, special education spending, lost productivity, and other expenses (Ganz, 2007; Moldin & Rubenstein, 2006). More recently, Autism Speaks (an advocacy organization for people with ASD) funded a study that found that the estimated costs have increased to $126 billion (Mandell, 2012). These numbers likely underestimate expenses for families of people with autism because other factors such as emotional stress and productivity losses are either unquantifiable or too difficult to measure (Ganz, 2007).

One of the largest expenses for families of children with autism is payment for therapy. Several types of behavioral treatments have been shown to increase language and social skills, and reduce unwanted behaviors across settings for people with ASD (Bitterman, Daley, Misra, Carlson, & Markowitz, 2008; Kamps et al., 1992; Lovaas, 1987; Rogers & Ozonoff, 2006). Applied behavioral analysis (ABA) therapy is typically administered in treatment facilities by licensed clinicians, although there is a growing trend toward offering behavior therapy in schools, homes, and other locations. Multiple

studies have explored the effectiveness of treatment delivered in school and home based settings, on different age groups, and provided by different individuals such as parents, aides, speech pathologists, and special education teachers (Cohen, Amerine-Dickens, & Smith, 2006; Morrier, Hess, & Heflin, 2011; Panerai et al., 2009; Rogers & Ozonoff, 2006; Ryan et al., 2011).

Behavior therapy is expensive, and can cost up to $40,000 per child per year or more (Ganz, 2006). These treatment costs can limit access to services for many families. Even those with medical insurance may be denied coverage for the necessary mental health treatment for their children as many companies deny benefits for the treatment of ASDs. States have begun to take an interest in insurance benefits for behavioral therapy for individuals with autism, with 29 states having passed legislation requiring insurance companies to cover behavioral therapy and other necessary treatments for children with Autism Spectrum Disorders (Autism Speaks, 2012). Even families whose insurance companies do cover treatment may still struggle to pay for deductibles, copays, and other related expenses (Sharpe & Baker, 2007). The burden of financing behavioral therapy may then be shifted to states in the form of medical assistance and special education programs.

As the role of education systems in the early identification of and treatment for ASD, it is increasingly important for schools to be able to provide effective interventions for students with ASD. Although spending on special education has increased faster than spending on general education, schools are still faced with limited resources to serve

growing numbers of children who need special education services (Hanushek, Kain, & Steven, 2002). The costs associated with increased prevalence are compounded by the fact that children with ASD have a set of characteristics that make programming effective interventions in schools especially difficult (Scheuermann, Webber, Boutot, & Goodwin, 2003).

There is limited information available on the influence of teacher and classroom characteristics on outcomes for children with ASD. This paper uses data from the Pre-Elementary Education Longitudinal Study (PEELS) to answer the following questions:

1) What is the relationship between teacher education and mathematics and reading achievement for students with Autism Spectrum Disorders in the education system?

2) How is classroom staffing and classroom structure related to these same measures?

The answers to these questions can potentially help schools decide how to utilize their available resources to help students with ASD reach their full potential.

Section I is the literature review, which will focus on different aspects of ASD and will be parsed into several sections, each addressing a specific aspect of educating students with ASD. Section II discusses the data from PEELS and the utilization of the value-added econometric model used in this paper, and provides rationale for the models used in this paper. Section III reports the results of the analyses. Section IV discusses the results and implications. Section V concludes.

Section I. Review of the Literature

First, the definition of ASDs will be examined, including information on identification of autism and related disorders and the evolution of the definition in the fields of psychology and education. Second, psychological and educational treatments for people with ASD will be reviewed. Third, issues with access to treatment will be discussed. Fourth, a review of educational factors, including teacher and school/classroom characteristics will be explored. The importance of teacher education and certification and the current literature on how teacher characteristics such as training and experience are related to student outcomes in special education will be addressed. The final section of the literature review will discuss models of the effectiveness of special education programs in terms of their impact on student achievement.

Definition of Autism Spectrum Disorders

Early estimates of the prevalence of ASD were very low, around one in 10,000 (Kanner, 1943; Wolff, 2004). The most recent estimates of the prevalence of ASD are much larger; in March, the CDC announced than an estimated 1 in 88 U.S. children have been diagnosed with autism (CDC, 2012). The increased prevalence of ASD is at least partially due to expansion of the definition of ASD and increased awareness, however there are also theories suggesting that environmental contaminants have increased the prevalence (Simpson, 2008).

The first two versions of the American Psychiatric Association's (APA) Diagnostic and Statistical Manual of Mental Disorders (DSM-I and DSM-II) included autism as a

form of infantile schizophrenia. It was first introduced as an independent mental health disorder in the DSM-III in 1980, but was restricted to individuals with very severe autistic symptoms and significant cognitive impairment (Volkmar, 2007; Wolff, 2004). The definition and criteria were revised and expanded in 1992 with the release of the DSM-IV under Pervasive Developmental Disorders (PDDs). There are five subtypes of PDDs, each with its own specific diagnostic criteria: Autistic Disorder (also referred to as Classic Autism), Rett's Disorder, Childhood Disintegrative Disorder (CDD), Asperger's Disorder, and Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS). As presented in the DSM-IV-TR (a text revised version of the DSM-IV released in 2000), a clinical diagnosis of a PDD requires that an individual exhibit a number of symptoms (the number and type may vary by disorder) in at least two of the following areas, as evaluated by a certified professional: social skills impairment, language impairment, and/or repetitive and restrictive behaviors. These symptoms must inhibit ability to function across multiple settings (school, home, etc.), and must have been present since the individual was 30 months old or younger.

The first area is social skill impairments, including lack of eye contact, lack of spontaneous initiation of interpersonal interaction, and problems recognizing and interpreting various aspects of nonverbal communication such as reading facial expressions or body language. Problems with empathy or social reciprocity, and lack of appropriate social interactions are also symptoms. Degree and presentation of social skill impairment vary widely among people with ASD. The second area is language and

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communicative impairments, which can range from being non-verbal to stiff and awkward use of language. Echolalia, or use of repetitive and stereotypical language with no intent to communicate, is also common. For example, a person with ASD may repeat lines from a movie out of context, or imitate sirens or other non-verbal sounds for no reason that is apparent to an observer. Communication impairments can also manifest as lack of imaginative play, or inability to understand non-literal communication such as metaphoric or sarcastic speech or the use of humor. The third area is related to restricted or repetitive behaviors. These behaviors include patterns of unusual, restricted, or obsessive interests. Insistence on strict adherence to routines or rituals is also common, and tantrums or strong reactions may result from deviations to expected or desired routines. Repetitive movements such as rocking, hand wringing, twisting, or other movements may also be present.

PDD diagnoses are given in one of the five subtypes, and the criteria differ by subtype. The diagnostic criteria for Autistic Disorder require a combination of at least two social interaction impairments, one communication or language impairment, and one repetitive, obsessive, or stereotyped behavior. People diagnosed with Asperger's Disorder tend to have normal or near-normal intelligence, and may even have above-average intelligence. Language development must be normal for a diagnosis of Asperger's Disorder, and many people with this disorder develop extensive vocabularies although speech patterns may be rigid (Lord & Spence, 2006). Diagnosis of Asperger's Disorder requires deficits in social skills and repetitive or restrictive behaviors.

PDD-NOS, also called atypical autism, is the final form of PDD in the DSM that will be discussed in this paper. PDD-NOS is usually diagnosed in people who have a significant impairment in at least two of the three diagnostic areas, but do not fully meet the qualifications for any of the other diagnoses. Argument exists as to what the distinction should be between PDD-NOS and other PDDs. This diagnosis may be used for individuals who have symptoms that are more moderate or who do not meet the diagnostic criteria in one of the areas evaluated (Volkmar, 2007).

As Gillber (2007) explains, the evolving definition of autism has resulted in the concepts of "high-functioning" and "low-functioning" forms of autism. These are not formally acknowledged diagnoses, and the term "high-functioning autism" has no specific definition, but the term generally refers to those with normal, near-normal, or elevated IQs and moderate or mild symptoms. In Gillber's words:

"The term 'high-functioning' is inappropriate because it suggests that the affected individual is 'well-functioning,' which is almost never the case in an individual with a clinically diagnosed Autism Spectrum Disorder. The individual with this 'diagnosis' is usually relatively high functioning as regards overall IQ, but in respect of the autism symptomatology, functional disability is often major." (p. 43)

Varying diagnoses of different PDD subtypes are the source of some confusion and controversy, and there are differences in how the diagnostic criteria are interpreted and applied (Volkmar, 2007). The APA has proposed major changes to the current structure

of PDDs in the DSM-V to be released in 2013. The proposed changes include merging

the subtypes (with the exception of Rett's Disorder) under Autism Spectrum Disorders

(APA, 2012).

Reaching a consensus on the definition of ASDs among clinicians is important

because a clinical diagnosis of autism is usually required in order to receive treatment or

government services. Educational institutions use separate criteria to determine whether a

student qualifies for special education services under the autism category. The

Individuals with Disabilities Education Act (IDEA) 2004 reauthorization characterizes

autism by impairments in social skills, nonverbal communication, and verbal

communication.

Although the educational definition[1] of autism has similar themes to those in the

DSM, it differs in several ways. The IDEA definition emphasizes impairment in

educational functioning, whereas the DSM definition addresses impairment in multiple

settings. This means that a high-functioning student with a clinical diagnosis of ASD may

not receive services at school if the disorder is not significantly detrimental to their

academic performance (MacFarlane & Kanaya, 2009). The IDEA definition also differs

in that it mentions that students with autism may have repetitive and restrictive behaviors,

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[1] Educational institutions do not diagnose autism or any other mental health disorder, but rather service students under different disability categories. In the public school system, autism is a disability group under which students receive special education services. This is distinct from a clinical diagnosis of a PDD. Here the term "educational definition" refers to the criteria that a student must meet to qualify for special education services under the category of autism, which is set by the state in which they live.

but they are included as associated characteristics rather than as part of the criteria for receiving services. In addition to these differences, there is also variation in criteria across states, as each state is able to set its own disability definitions as long as they comply with the minimum requirements outlined in the Code of Federal Regulations (CFR).

MacFarlane and Kanaya's (2009) examination of the variation in eligibility for special education services revealed considerable differences between states. The definition of autism used by the authors in this study was similar to Autistic Disorder in the DSM. In the study, Asperger's Disorder and PDD-NOS were referred to as Autism Spectrum Disorders. The authors evaluated statutes regarding the eligibility criteria for educational services for autism for all 50 states and Washington D.C. by reviewing state statutes and coded them on four themes: CFR theme, DSM theme, ASD theme, and Evaluation theme. CFR usage was determined by whether the state used only the CFR's minimum requirements (17 states and D.C.) or whether they had some sort of expansion on the definition. States were determined to use a DSM theme if they adopted some or all of the DSM diagnostic criteria for autism in their criteria for children to receive special education services for autism (17 states did). The ASD theme indicated whether Asperger's Disorder and/or PDD-NOS were explicitly included in the state definition (20 states did).

The Evaluation theme was slightly more complicated. This theme was divided into additional four categories. First was a requirement of a pediatrician or clinician on the

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evaluation team (eight states). Second was a diagnosis of Autistic Disorder by a clinician (one state). Third was a diagnosis of Autistic Disorder or ASD by a clinician (two states). Forty states did not require a formal diagnosis or a doctor or psychologist on the evaluation team.

MacFarlane and Kanaya (2009) also evaluated differences in prevalence rates of autism in public schools between states based on the differences in eligibility criteria, and found a significantly higher percentage of children receiving special education services for autism in states where ASDs were included in the eligibility criteria. They did not find significantly different rates between states based on the other criteria. Based on U.S. Census Bureau and CDC data, the authors estimated that roughly 30% of children with a clinical diagnosis of autism were not receiving special education services for ASD in 2006. They added, however, that students with ASD might have received services under other special education categories such as for Emotional Disturbance or Other Health Impairment. Identification and placement of children with ASD within special education is important because it has a number of policy implications and may affect the services a child receives (Iovannone, Dunlap, Huber, & Kincaid, 2003; MacFarlane & Kanaya, 2009).

Psychological and Educational Treatments for ASD

Commensurate with No Child Left Behind (NCLB) mandates, IDEA requires schools to use research-based interventions in educating students with disabilities. Autism is a spectrum disorder; there is a broad range of type and severity of symptoms

and responsiveness to various treatments for children with ASD (Iovannone et al., 2003; Scheuermann et al., 2003). Treatments for people with ASD need to be specialized to the individual and administered correctly by professionals trained in the treatment program being used (Ryan et al., 2011; Simpson, 2008; Simpson et al., 2005).

In addition to legal and compliance concerns, the identification and implementation of appropriate treatments is extremely important. As Simpson et al. (2005) pointed out ASD has been highly susceptible to questionable, unproven, and controversial treatments. Although outcomes are improving as early identification and more effective treatment practices are identified, ASD is generally regarded as a permanent disability. A number of suspect practices claiming rapid improvement and in some cases, complete recovery, have been developed. Families of people with ASD may be attracted to these suspect treatments despite a lack of empirical research backing their efficacy. Furthermore, engaging in ineffectual practices is often at the exclusion of other, potentially beneficial treatments (Simpson, 2005).

In their analysis of a range of services available for individuals (mainly children) with ASD, Simpson et al. identified and reviewed 37 different types of therapy and treatments providing a description of each program, and summaries of studies of the effectiveness of each type of treatment (or lack of adequate information where applicable). Results were reported both in a book (Simpson et al., 2005) and a peer-reviewed journal article (Simpson, 2005). Although Simpson (2005) admits that there may be unintentional bias in reporting, many of the general results received similar

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ratings from other sources (Heflin & Alaima, 2007; Ryan, Hughes, Katsiyannis, McDaniel, & Sprinkle, 2011; Volkmar, 2007).

Simpson et al. (2005) categorized treatments for ASD into five broad categories: Interpersonal Relationship Interventions (IRI), skill based, cognitive, physiological, biological, or neurological based (excluding pharmacological treatments), and "other". The interventions were then judged based on evidence of effectiveness from studies, consistency of results, and amount of research available. Interventions that had sufficient and robust evidence of positive outcomes when appropriately executed were deemed "scientifically based practices". Interventions were "promising practices" if they had evidence of positive outcomes but needed further research to verify their effectiveness. "Practices with limited supporting information" had potentially positive outcomes, but lacked sufficient amounts of evidence supporting their effectiveness. Interventions that were "not recommended" lacked credible information demonstrating their effectiveness and had potential for harmful outcomes.

Behavioral or "skill based" interventions are the most commonly used interventions. These include applied behavioral analysis (ABA), discrete trial teaching (DTT), and pivotal response training, among others. The basic concept behind these interventions is teaching and reinforcing the development of specific skills and behaviors. A child receiving ABA therapy may need to learn basic components of reciprocal communication. A specific sub-skill such as responding appropriately when someone says hello is practiced repeatedly. The therapist will greet the child, and the child will

receive positive reinforcement when they give the desired response. This is repeated a

number of times, first consecutively, and then interspersed with other skills. Progress is

monitored by the percentage of times the child gives the desired response in a given

period until the skill is mastered, and then another specific skill is targeted. Goals and

target behaviors typically change and increase in difficulty and complexity as the

individual gains proficiency in different skills. The basic components of this therapy may

also be incorporated into other parts of the day and/or in contexts that are more natural.

Lovaas (1987) was the first to study ABA therapy as a treatment for ASD. The

study collected information on 59 children diagnosed with Autistic Disorder over several

years. Nineteen of the children received intensive ABA therapy of 30 to 50 hours per

week by trained practitioners, while the control group received no therapy through the

study. Lovaas reported that 47% of those who received ABA therapy achieved a level of

functioning that allowed them to participate in a general education classroom. Nearly all

children in the treatment group had some gains in speech, social skills, and cognitive

functioning. Only 2% of those in the control group were able to participate in a general

education classroom (Lovaas, 1987).

Cognitive strategies are relatively new, with most research having occurred in the

last decade, but generally have shown positive results. Cognitive strategies involve

teaching individuals with autism to monitor their own behavior and shift from an external

to an internal locus of control. Social stories and other similar strategies are designed to

help people with behavioral problems or social skill deficits anticipate and learn

appropriate responses to specific situations (Eikeseth, Smith, Jahr, & Eldevik, 2002; Simpson, 2008; Simpson et al., 2005). One cognitive strategy known as Facilitated Communication was found to be a potentially harmful practice (Simpson et al., 2005). Facilitated communication is based on the concept that nonverbal people may simply be limited by physical disabilities, and a practitioner properly trained in Facilitated Communication can allow the individual with the disability to communicate by guided writing. Facilitated communication became popular in the 1990s, despite a lack of evidence of efficacy and accounts of abuse related to suspect practices (Simpson et al., 2005).

Another category of treatments for ASD referenced by Simpson et al. (2005), Interpersonal Relationship Interventions (IRIs), were largely influenced by early theories on the causes of ASD. Early researchers in the field of ASD hypothesized that parents, through a lack of warmth and affection, caused their children to withdraw emotionally as a self-defense mechanism (Simpson et al., 2005; Wolff, 2004). Although this theory has been thoroughly discredited by a large number of studies, a number of treatments have arisen based on this concept (Ryan et al., 2011; Simpson et al., 2005; Wolff, 2004).

IRIs focus on strengthening relationships or improving emotional functioning in children with ASD. One form of IRI known as play-oriented strategies, in which children with ASD engage in directed play with adults and non-disabled peers, may increase overall functioning (Rogers & Ozonoff, 2006; Simpson, 2008). This is the only IRI that Simpson et al. (2005) determined was a promising practice. A number of other IRI

approaches, mostly based on psychotherapy approaches, have only limited information

available regarding their effectiveness and/or conflicting evidence regarding their

efficacy. One other strategy known as Holding Therapy, in which a child is physically

held by a caregiver and physically forced to make eye contact despite any attempts to

struggle or vocalizations of protest, was determined to be potentially harmful (Simpson et

al., 2005). Another IRI known as Gentle Teaching focuses on replacing maladaptive

behaviors of people with limited communication with desired behaviors through

caregiver bonding and respect for the person receiving treatment. This method insists on

ignoring the undesired behaviors (or interrupting violent ones), thereby giving no

reinforcement of the behavior, while redirecting the person toward an acceptable

alternative behavior. After the person has been redirected to the alternative behaviors,

they are rewarded with intangible social rewards. Gentle Teaching also emphasizes the

importance of adapting the environment to suit the individual receiving treatment (e.g.

removing objects that upset them or facilitate the maladaptive behavior). This method has

mixed evidence of efficacy (Jones, 1992; Simpson et al., 2005).

Physiological, biological, and neurological based interventions attempt to manage

symptoms of ASD through a number of biologically based interventions. Among these

interventions, Simpson et al. (2005) list sensory integration, which attempts to manage

hyper- or hypo- sensitivity to sensory input through exposure to different types of sensory

stimuli, as a promising practice. One of the better-known dietary interventions known as

the Feingold diet attempts to control hyperactivity, attention, and mood problems by

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removing artificial dyes, flavors, preservatives, and perfumes from a child's diet. There is

limited evidence of efficacy of various vitamin, supplement, and dietary interventions

(Simpson et al., 2005).

Important Considerations in Selecting Treatments

A crucial consideration and recurring theme in the literature on effective practices

is the importance of a competent and knowledgeable team of people selecting and

implementing an individualized treatment plan for each person with ASD. Choosing

which treatments to administer to people with ASD is challenging. Simpson (2005)

suggested three questions for those who work with children with autism to consider when

selecting and implementing treatments for individuals with ASD.

The first question relates to the alignment of the prospective treatment with the

individual's specific needs. Not only should treatments be research-based, they should

also be appropriate for the individual with ASD's specific needs and developmental level

(Simpson, 2005). The treatments also need to be shown effective for individuals with

symptoms and levels of functioning similar to the individual who will be receiving

treatment. In addition, it is important that those implementing the therapy are properly

trained so that it can be applied correctly (Hess, Morrier, Heflin, & Ivey, 2008;

Scheuermann et al., 2003; Simpson, 2005).

The second question relates to potential negative outcomes from therapies and

treatments considered. Simpson et al. (2005) only listed two therapies as potentially

harmful to the individuals who receive them (holding therapy and facilitated

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communication), however in his later article, Simpson (2005) also mentioned other potential concerns. He recommended considering the impacts on the families and caretakers of the people with ASD who receive treatments. In addition, time and financial constraints are major concerns as many treatments are intensive and expensive. Another concern is that selecting one method of treatment may preclude the use of certain others, making it difficult to determine the most effective treatment for an individual with ASD (Sharpe & Baker, 2007; Simpson, 2005; Simpson, Mundschenk, & Heflin, 2011; Sutera et al., 2007).

The third question Simpson (2005) recommended considering beforehand was how best to measure the effects of implemented treatments. This planning can assist in making informed decisions about whether to continue current treatments and the implementation of possible future treatments.

Issues with Access to Treatment for ASD

One major factor in the timing and quality of treatment for people with ASD is access to knowledge and resources. Identification and measurement of the needs of individuals with disabilities and assessment of what resources they have available can be difficult. Dymond, Gilson, and Myran (2007) examined the availability of services for children with ASD. They surveyed 783 parents whose children attended public elementary schools, had a medical diagnosis of an ASD, and were receiving educational

services for the disorder[2] to determine the availability of the services for children with

ASD in the state. They argued that parents or primary caregivers were in the best position

to determine what services are needed as they have the responsibility of locating and

coordinating care. They discovered several recurring themes. Parents expressed needs for

(1) improvement in the quantity, quality, accessibility, and availability of services, (2)

education and training of individuals who work with children with ASD, (3) increase in

funding for services, staff development, and research related to ASD, and (4) creation of

appropriate school placements and educational programs for students with ASD

(Dymond et al., 2007).

Dymond et al. (2007) reported that about 20% of parents in their sample wanted

services to be more accessible. Parent's concerns with accessibility of services included

lack of treatment centers near their communities to supplement services received through

special education, lack of transportation to treatment locations outside of school, and

barriers to getting diagnoses and treatment within the medical community. Barriers

within the medical community reported by parents of children with ASD included

delayed referrals to specialists by their primary physicians because of lack of knowledge

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[2] MacFarlane and Kanaya (2009) report that the state of Virginia does not explicitly
include disorders other than Autistic Disorder in their state definition, however the state
does not require a medical diagnosis of Autistic Disorder in order to qualify for
educational services for autism. Children may still qualify for special education services
for autism if they meet the educational definition in Virginia, which does not include any
additional criteria beyond those outlined in the CFR. Children may also be served under
another disability category.

about autism or general reluctance to refer or diagnose young children. Once referrals were made, parents also expressed frustration with the time it took to get formal diagnoses, and once diagnoses were received, they reported long waiting lists for treatment and excessive amounts of paperwork before their children could receive services.

Reinforcement of the need for improvement in the accessibility and availability of services for children with ASD is also recurrent in a study by MacFarlane and Kanaya (2009), who reported significant difficulty in locating and interpreting state statutes on qualification for special education services for ASD in 19 of 50 states. They also cited a 2006 study that reported that less than 10% of Parent's Rights documents provided by state education departments were written at an appropriate reading level.

In addition to concerns about accessibility, there is also evidence of lack of quality and preparation of teachers and school staff within the special education system. Half of the parents in the Dymond et al. (2007) study expressed concern over the training and education of their children's teachers and services providers in the schools. Applied Behavioral Analysis (ABA) is perhaps the most well-known, heavily researched, and generally accepted form of behavioral therapy for children with autism (Simpson, 2008), yet an internet survey of 234 special education teachers in Georgia who worked with children with ASD found that the most frequent teaching strategy used was an IRI strategy known as Gentle Teaching (Hess et al., 2008) that has only limited supporting information of effectiveness (Simpson et al., 2005). None of the teachers in the Hess et

al. (2008) study indicated using ABA therapy as their primary strategy, and only 10% of the teachers in the study reported using strategies that were scientifically based practices as indicated by Simpson et al. (2005) as their primary teaching strategy, and only 21% used strategies rated by Simpson et al. (2005) as "promising practices". Roughly 25% reported primary strategies had only limited support of efficacy, and about 5% reported using Holding Therapy or Facilitated Communication, which are not recommended because they have no evidence of effectiveness and are potentially damaging to individuals with ASD (Hess et al., 2008; Simpson et al., 2005). About one-third of respondents reported using strategies that were not rated by Simpson et al. (2005), and as Hess et al. (2008) pointed out, this may be indicative of a willingness to implement newer and experimental strategies that do not have sufficient evidence of effectiveness in improving outcomes for children with ASD.

A potential limitation of the Dymond et al. (2008) study is that the study only contains information reported by respondents, and due to the nature of the survey, there is no information on whether the reported treatments were implemented correctly. Their study did not report levels of teacher training, but scarcity and high turnover in special education staff has led many states to adopt expedited credentialing processes for teachers (Scheuermann et al., 2003).

The third theme identified by Dymond et al. (2007) was the need for increased funding. Parents surveyed felt that more funding was needed for developing and training teachers and staff to work with children with ASD, to increase the availability of

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community services. The fourth theme identified by Dymond et al. (2007) relates to awareness and identification of effective, evidence-based interventions for children with ASD. Design of educational programs and placement of students in the most beneficial environment relies heavily on the ability of teachers, parents, and other professionals who work with children with autism to identify treatments that will be effective for the individual children (Dymond, Gilson, & Myran, 2007; Hess et al., 2008; Simpson, 2005).

The issue of limited accessibility is further compounded for poor and minority students with ASD. Liptak, Benzoni, Mruzek, Nolan, Thingvoll, Wade, and Fryer (2008) used the CDC's National Survey of Children's Health to estimate the prevalence of ASD diagnoses by race and poverty status. They found that despite similar rates of diagnosis of ASD overall, children with ASD who were from poor households (less than 100% of the federal poverty line) had lower reported rates of diagnosis for children under age 6. In addition, parents from households below the poverty line more frequently reported their children's symptoms as severe than those who were not poor (Liptak et al., 2008). Liptak et al. (2008) also reported on the receipt of medical care for children with autism. They found children with ASD from poor or near-poor families (between 100 and 200% of the federal poverty line) were significantly more likely to have difficulty getting care from a specialist, getting acute care in a timely fashion, and getting phone advice when needed. They also found that children from poor households were less likely to have a personal doctor or nurse, to have visited a doctor or nurse for preventative care, and were less likely to have used prescription medication in the past year. Beyond moral

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implications, demographic disparities in access to treatment can be important when modeling achievement gains related to teacher and school efficacy as discussed in the next section.

Educational Factors and Student Achievement in Education

Studies that estimated the returns to teacher education in general education settings have not typically found significant improvement in student achievement for teachers with graduate degrees in comparison to those with only bachelor's degrees (Rivkin, Hanushek, & Kain, 2005; Rockoff, 2004). Rivkin et al. (2005) examined data from the Texas UTD schools project on more than 600,000 students in the Texas school system from 4th to 7th grade to estimate the effects of various teacher variables on improvement in students' standardized test scores associated with different public school teachers. They found that teacher quality had significant effects on student achievement, but that teachers with graduate degrees were not necessarily more effective than teachers who had only obtained bachelor's degrees. Another finding was that teacher quality was strongly correlated with years of teaching experience, particularly in the first two to five years of teaching (Rivkin et al., 2005).

Rockoff (2004) used data obtained from New Jersey school districts on students and teachers across years (exact numbers were not reported due to privacy concerns) to analyze the relationship between general education teacher quality and student achievement as measured by changes in standardized test scores. His findings were similar to those of Rivkin et al. (2005). He found that teacher quality was significantly

related to student achievement, but that teachers with graduate degrees were not necessarily more effective than those with bachelor's degrees. He also found that experience gained in the first few years of teaching affected teacher quality more than subsequent years (Rockoff, 2004).

Rivkin et al. (2005) did not find a link between graduate education for general education teachers and student achievement, but they noted that this is not necessarily applicable to special education. Sass and Feng (2012) compared different types of special education teacher preparation programs using data from Florida public schools. They evaluated the impact of teacher education and in-services teacher preparation programs using data from the Florida Education Data Warehouse (FLEDW), which contained detailed data on roughly 400,000 students who were receiving special education services. They found significant differences in student achievement related to teacher preparation.

Sass and Feng (2012) found that training teachers received in special education programs prior to beginning their classroom teaching significantly improved teacher ability to increase reading scores for students in special education programs (see the next section for a full description of their data and methods). They found that increasing hours of course work in special education, undergraduate degrees in special education, and special education certification programs all had significant, positive correlations with standardized test scores for children receiving special education services. Another important finding was that students of teachers with dual general education and special

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education licenses had the largest improvements in mathematics test scores (Sass & Feng, 2012).

Based on the results from Sass and Feng (2012) and the generalization of the role of special education teachers, Brownell, Sindelar, Kiely, and Danielson (2010) recommend several changes to special education teacher training, licensing, and compensation strategies. In their opinion, states would ideally require dual special and general education certification for all beginning teachers, however they also recognize the implausibility of that requirement. One recommendation they made was that states implement "career ladders" for special education teachers, meaning that they would begin as general education teachers to acquire foundational teaching knowledge and experience, and then become licensed as special education teachers. They also advocate wage premiums for general education teachers who obtain some training in special education (Brownell, Sindelar, Kiely, & Danielson, 2010).

In addition to the difference in subsequent impacts on improvement in reading and math test scores presented by Sass and Feng (2012), there is also evidence that special education teacher program can result in better classroom practices for beginning special education teachers. Nougaret, Scruggs, and Mastropieri (2005) examined the classroom practices of 40 first-year teachers, 20 of who had completed traditional special education teacher programs, and 20 of whom had non-education related bachelor's degrees but had been granted provisional licenses due to shortages in special education teachers. These first-year teachers were observed in their classrooms during their second semester of

teaching, and they were scored in four areas: planning and preparation, classroom environment, and instructional practices. Nougaret et al. (2005) found that teachers who had completed traditional special education teacher licensing programs were rated higher than those with provisional licenses in all of the areas in which they were evaluated. There were several limitations to this study, however. The sample was small, only 40 teachers, and there was no mention of recruitment methods, the number of volunteers for the study, or selection criteria measured (Nougaret et al., 2005). The methodology in this survey raises concern for a number of reasons, specifically regarding selection bias and limited background and placement information as addressed in the next section.

Studies of Special Education Effectiveness

Hanushek et al. (2002) examined the effectiveness of special education programs using data from the University of Texas – Dallas (UTD) Schools Project. The UTD Schools Project tracked students from 4th to 7th grade, collecting detailed data on students, schools, and teachers. Hanushek et al. (2002) evaluated annual data on 767,763 students receiving special education services. They evaluated data on students in all disability categories were, including those receiving services for autism, but focused especially on students who were learning-disabled, emotionally disturbed, or had speech-impairments. The results showed that student participation in special education programs was associated with improvements in their performance on standardized testing (Hanushek, Kain, & Steven, 2002).

Hanushek, et al. (2002) examined the relationship between student participation in special education programs and changes in student scores on standardized math and reading tests between time periods. They used a fixed effects model to determine whether special education programs led to improvements in student performance on standardized tests in math and reading for children with disabilities. To control for student background characteristics, they used a vector of demographic and family characteristics including race, gender, whether the student switched schools between time periods, and whether the student received free or reduced lunch. School characteristics included proportions of Black and Hispanic students and of students eligible for free or reduced lunch.

The data were divided in two parts based on whether a child entered or exited a special education program during a given year. Children who entered special education and remained there for at least two years had the highest increases in test scores. Results showed that children with learning disabilities and emotional problems did benefit from the services received in special education, but those with speech impairments did not. This may have a direct implication for children with autism as language impairments play a large role in the disorder, and development of communicative speech before age 6 is strongly associated with improved outcomes later in life (Howlin, Goode, Hutton, & Rutter, 2004).

Hanushek et al. (2002) also tested whether the relationship between inclusive classrooms and subsequent standardized test score improvement using a binary variable to indicate whether the child was in an inclusive classroom. They also examined the

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impact of inclusive classrooms on the test scores of students in general education. There were no significant differences between the test scores of children receiving special education services in integrated classrooms and those receiving services in segregated special education classrooms. Their research did show slightly elevated scores for regular education students in integrated classrooms, however the difference was not significant.

One limitation of the Hanushek et al. (2002) analysis of the impact of integrated classrooms did not distinguish between different levels of "mainstreaming" for students receiving special education services. Further, the level of student participation in general education classes is likely to be related to the development of the student (Brownell, Sindelar, Kiely, & Danielson, 2010; Hanushek, Kain, & Steven, 2002). Students that are more able may generally be more likely to be placed in an integrated classroom and therefore the actual effect of performance based on placement in an inclusive classroom cannot be evaluated in this way (Hanushek, Kain, & Steven, 2002).

Another limitation of the study was that a significant number of students in special education were exempt from standardized testing because their IEPs indicated that standardized tests would not give an accurate measure of their learning and ability. Only 5.5% of 4th grade students with autism had valid test scores, however the percentage of students with ASD with valid scores increased slightly to 12.6% by the time those students reached 7th grade.

The focus of the Hanushek et al. (2002) study was whether participation in a special education program improved achievement for students receiving special

education services. There was no explicit measure of how differing characteristics between programs affected student learning. They found that participation in a special education program significantly raised test scores for students receiving special education services, especially those with learning disabilities or emotional disturbance. Students receiving services for ASD accounted for a very small portion of the students, roughly 0.5% of all special education students in the sample.

Sass and Feng (2012) employed a similar model in their analysis of teacher training and the achievement of students receiving special education services. They also used first-differenced data on test scores for students receiving special education services over a period of five years. They emphasized the importance in controlling for heterogeneity among special education students in terms of initial ability, severity of needs, and other characteristics. They also noted that selection bias is a potential problem as students with greater needs may be placed with better-trained and/or more experienced teachers, and there is a strong association between severity of impairment and later outcomes that is unrelated to teacher quality, training, or ability (Sass & Feng, 2012). This selection bias could potentially mask the impact of teacher characteristics on student achievement.

To control for student heterogeneity and selection bias, Sass and Feng (2012) included a rich set of student level controls including the students' decile rankings from tests in the previous year and information on the disability categories under which students were being served. This issue of selection bias was addressed by including the

percent of peers in the students' primary classrooms that were also receiving services for special education.

Conclusion

The definition of Autism Spectrum Disorder has changed substantially since Kanner's first publication on the disorder in 1943. Psychiatric diagnostic criteria and criteria for receiving educational services for ASD differ in several important ways, and there is substantial variation in educational criteria across states, but common themes in the definitions include deficits in social skills, deficits in language and communication skills, and restrictive, repetitive, and stereotypical behaviors.

Behavioral therapy and other treatments have also changed substantially both in the variety of services available and the location and providers of the services. Several types of behavioral and cognitive therapies have proven to be very effective at improving outcomes for people with ASD. There are a number of other types of therapy that show promise in being effective, but need more research to confirm their effectiveness. Some types of treatment have the potential for harmful effects.

The role of special education in improving outcomes for children with ASD is increasing due to the increasing prevalence, and the number and type of treatments available, resulting in the need for more teachers with adequate knowledge of effective educational interventions for people with ASD. There is some evidence of a lack of requisite knowledge of how to identify and implement appropriate treatments in the

current system, and alternative certification systems for special education teachers may not provide the needed training for effective education of students with ASD.

Several studies have modeled the effectiveness of special education programs in raising student achievement. Hanushek et al. (2002) and Sass and Feng (2012) used fixed effects models to analyze first-differenced data on special education programs that linked student achievement to teacher data and were able to demonstrate improved student outcomes associated with participation in special education programs and additional education for special education teachers, respectively. Both studies emphasized the importance of controlling for selection bias and student heterogeneity when constructing models.

Section II. Methods and Data

This paper differs from previous studies in that it uses a nationally representative sample, and specifically examines the relationship between teacher education and classroom characteristics on gains in academic skills for children with ASD. The children examined in this study are also much younger than the children in the UTD Schools Project and the FLEDW, ranging from ages three to five and in pre-school during the initial assessments.

Econometric Model

The value-added model[3] uses differences in performance over time to measure the impact of different factors on children's academic development. The model assumes that children's gains in standardized test scores from the initial testing period (t_0) and the following year's testing period (t_1) were caused by academic circumstances observed during t_0 when controlling for other factors.

The model takes the basic form:

$$\Delta A_{it} = A_{it_1} - A_{it_0} = \beta_0 + \beta_1 K_{it_0} + \beta_2 D_{it_0} + \beta_3 L_{it_0} + \beta_4 T_{it_0} + \beta_5 C_{it_0} + \varepsilon_{it}$$

where ΔA_{it} is the change in child i's age-normed standard score on the test between the initial and follow-up testing sessions.

Child Test Scores

Children's scores were from two subtests of the Woodcock-Johnson III Tests of Achievement (WJ-III). The two subtests used were the Applied Problems (AP) subtest, which measures math achievement, and Letter-Word Identification (LWID) subtest, which measures early reading skills. Both tests were normed on a nationally representative sample of over 8,800 individuals ages 2 to 90, and use a standard score of 100 with a standard deviation of 15. By regressing on the change in the child's standard

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[3] This model differs slightly from the traditional value-added model in that it includes interaction terms between teacher education and classroom characteristic variables and children's initial standard scores on the subtest as explanatory variables. The inclusion of the initial scores in the model changes the interpretation of the intercept.

score, this provides a measure of child i's child's improvement in the measured skill

relative to the reference group of his or her non-disabled peers.

Child Academic Characteristics

K_{it} is a vector of child i's academic characteristics during the initial time period;

specifically child's initial standard score on the test that measures the skill being

examined and whether the child has an aide assigned to them in the classroom. Whether a

child has an assigned classroom aide is distinguished from the general number of aides

available to all students in the classroom. In addition to profound cognitive disabilities,

aides may be assigned because of a child's behavioral problems or for other reasons that

would impede learning, but not necessarily reflect the child's intellectual functioning.

The child's initial standard score and whether the child has an assigned classroom aide

serve as proxies for the severity of the child's disability. I also estimate models using

initial language ability in both the reading and math models to serve as a proxy for the

severity of a child's disability.

Child, Family, and Local Education Agency Characteristics

D_{it} is a vector of demographic variables for child i and child i's family including

race and ethnicity, and poverty status during the initial exam. These demographic

variables are added as controls for family background characteristics that typically

influence student learning and achievement.

L_{jt} is a vector of variables controlling for the characteristics and resources of the

local education agency (LEA) or school district in which the child attends school. The

school district variables used in the models include racial and ethnic distributions, the district wealth category, the metropolitan code (whether the school district was in an urban, suburban, or rural area), the percentage of households in the district that speak a language other than English in the home, and region of residence. The variables measuring the racial, ethnic, and home language characteristics of children's school districts serve to control for cultural and other related factors that might influence student learning. The district wealth category serves as a proxy for district's resource availability since wealthier districts are more likely to have more resources available to serve students both with and without disabilities. The metropolitan code serves as a control for general community resource availability, as urban and suburban areas are more likely to have outside resources available to serve children with ASD and other disabilities.

Teacher and Classroom Characteristics

The two sets of independent variables of primary interest in the model are the vectors T_{it0} and C_{it0}, which are the teacher characteristics and classroom characteristics during the initial period, respectively. Teacher characteristics examined include years of teaching experience as a quadratic term, degrees earned, and degree fields. The sample was restricted to teachers who had a bachelor's degree but who did not have a doctoral degree, hence the only degree levels in the sample were bachelor's degrees and master's degrees. This restriction was imposed to specifically examine the difference between master's degrees and bachelor's degrees without the implications of doctorate level education. A series of binary variables was used to designate the field(s) of each type of

degree. Degree fields considered in these analyses were special education, general education, and dual special and general education degrees at both the bachelor's degree and the master's degree levels. Each teacher had a bachelor's degree and some combination of the following: a bachelor's degree in special education, a bachelor's degree in general education, a bachelor's degree in another field, a master's degree in special education, a master's degree in general education, and/or a master's degree in another field. Because of the overlap in degree types and the inclusion of the interaction term for dual degrees in special and general education, each binary variable serves as a comparison to teachers who did not have that specific degree type.

Classroom characteristics analyzed included the percent of students in the classroom who had IEPs, which helps to mitigate the problem of selection bias in the placement of children with disabilities. If children with disabilities are more likely to be placed with more effective teachers, then this may obscure the effect that the teachers have on student academic progress. The total number of students in the classroom is also included. If interaction with other children encourages language development in children with disabilities, then we could expect a positive relationship between the number of students in the classroom and changes in language scores over time. Conversely, if larger class size lead to less individualized attention, this could result in lower scores. To control for this, the number of students per teacher and the number of students per classroom aide are also included in the models. These factors enable the model to tease

out the effects of more interaction with other students through larger classes and more individualized attention through lower student-to-staff ratios.

Interaction Terms

As noted above, selection bias is an important factor to consider at the student level. Feng and Sass (2012) used a quartile range for the students' initial test scores and detailed disability categories to control for this bias in classroom placement, as children with more profound disabilities may be more likely to be placed with teachers who have more education and experience. Initial student ability is a major concern as the severity of a child with ASD's disability is a strong predictor of later outcome, particularly early development of language skills (Howlin, 2004). The two student academic controls (initial test scores in both the subject of interest and language ability, and whether the child has an assigned classroom aide) serve as a baseline for the severity of the child's disability. However, experience, teacher, and classroom variables are all interacted with initial test scores in the subject of interest both to examine the relationship between characteristics of the teachers and classroom and changes in student test scores and how these effects change at different levels of student ability.

The analyses use the SAS procedure SURVEY REG to estimate GLS models. The models were also weighted using the child-parent-teacher longitudinal weight for waves one through three of data collection, which were provided by PEELS. These weights control for sample attrition during the first three waves of data collection. Approximately 87% of the children in the sample had valid child assessments, parent

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interviews, and teacher interviews. The weight used in these analyses was designed to correct for bias due to sample attrition, and make the resulting estimates nationally representative.

The Pre-Elementary Education Longitudinal Study (PEELS)

The Pre-Elementary Education Longitudinal Study tracked approximately 3,000 young children with disabilities through their early school years. The study began tracking the children when they were between ages three and five, and includes detailed information on the children, their parents or caregivers, and their teachers and schools. The data set includes observations on children from all 50 states, and uses weights to make the data nationally representative. The data set is small in comparison to the data sets used by Hanushek et al. (2002) and Sass and Feng (2012), however the children sampled in the study were much younger than those in the Texas UTD Schools Project and the FLEDW, making it possible to study the effects of early educational experiences on gains in test scores. In addition, because the sample includes observations from all 50 states and are weighted, estimates are nationally representative.

PEELS collected data in five waves between 2003-04 and 2008-09 school years. This study uses child, parent, and teacher data from waves one through three, and test score data from waves one through four. Each child in the data set used in these analyses had test scores from at least two consecutive years. Several children had test scores from more than two years, and so had multiple test score change observations. The data were clustered by child, resulting in 70 test score change observations for 50 individual

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children (the standard errors were adjusted accordingly)[4]. The 50 children in these

analyses had autism listed as their primary disability at the time they entered the study[5].

whose primary disability was autism. Summary data are compared to approximately

1,580 observations on children who had any other primary disability category.

Child Demographic Characteristics

Data on the children in the study were collected from parent and teacher surveys

and interviews. Demographic characteristics include disability category, gender, race and

ethnicity, and receipt of food stamps or WIC to serve as a proxy for poverty status.

Traditionally studies on educational outcomes use eligibility for free or reduced-price

lunch as a proxy for poverty status, however the younger cohorts of children in the

PEELS sample made this impractical as many of the children were in pre-elementary

programs that did not serve school lunch. Instead, receipt of WIC or food stamps was

used to specify household poverty status because of similar income eligibility

requirements.

Disability data were reported from teachers, or if that information was not

available, from parents. There were 17 disability categories used in the PEELS survey,

including autism. The percentage of students whose primary disability was autism

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[4] Numbers are rounded due to IES data reporting restrictions.
[5] As discussed earlier, ambiguity and inter-state differences in criteria for receiving special education services for ASD differ by state. For the remainder of the paper, the terms "children with autism" and "children with ASD" will be used interchangeably and refer to children whose primary disability category, as reported in PEELS, is autism.

increased with each wave from a low of approximately 7% in the first wave, and

increasing to over 10% in the fourth wave, however because test score data were missing

at a high rate for children with ASD, roughly 60% of the children with ASD were

excluded the analysis. PEELS data were weighted to account for sample attrition and

missing child assessment, teacher interview, and parent interview data, but there were

some missing data even among children who had valid assessment scores and interview

data (i.e. a question was skipped or a test was omitted). Mean test scores and

demographic variables did not differ significantly between children with missing data and

children with all information available.

There were several differences in the demographic characteristics of the

observations on children with ASD versus those with other primary disabilities. Table 1

shows the weighted demographic characteristics of the subsamples.

The first notable demographic difference was between the gender ratios of

children in each disability category. The proportion of female students in the subsample

of students with autism was much smaller than that of children with other primary

disability categories. This is consistent with expectations as males are much more likely

than females to be diagnosed with ASD (CDC, 2012).

Table 1. Child demographic characteristics by disability group

Primary disability:	Autism (N =70)	Other (N =1,580)		
Variable	% of Subsample	% of Subsample	Diff.	p-value
Female	20%	33%	-13%	0.01
Ethnicity*				
White	84%	88%	-4%	0.17
Black	5%	12%	-7%	0.04
Hispanic/Latino	23%	18%	5%	0.14
Asian/PI	7%	3%	5%	0.01
Native American	7%	4%	2%	0.16
Receives WIC or food stamps	17%	24%	-7%	0.10

*Respondents were able to choose more than one racial/ethnic category, percentages do not sum to 100%.
Sample sizes rounded per IES data privacy rules.

The racial and ethnic distributions of children also differed slightly between subsamples. Children were categorized as Black, White, Hispanic/Latino, Asian/Pacific Islander (PI), or American Indian/Alaska Native (Native American). There was considerable overlap between race/ethnic groups as individuals were allowed to select multiple categories. No changes were made to the racial/ethnic categories reported by respondents. Children with ASD were less likely to be Black, and more likely to be Asian. Other racial/ethnic differences were not statistically significant. Another notable difference was the poverty status. Children with ASD were less likely to receive nutritional assistance from Women, Infants, and Children (WIC) or food stamps than children with other primary disabilities, which suggests lower poverty rates.

Teacher Education and Experience

In waves 1 through 3, early childhood teachers were asked about their educational backgrounds[6], including types of degrees and professional licenses received and the fields in which they received their degrees. Individuals were able to specify up to five major fields per degree type. Degree types included high school diplomas, associate's degrees, bachelor's degrees, master's degrees, and doctoral degrees. All of the teachers who responded to the survey had at least a high school diploma.

For the purposes of this analysis, educational field was divided into three areas based on the major field specified: general education, special education, and other field. Individuals who specified that they had a degree in elementary/secondary education or early childhood education were classified as having a degree in general education. Individuals who specified that they had a degree in special education or early childhood special education were classified as having a special education degree. All other fields were classified as other. Table 2 shows the comparison of teacher degree types and fields between observations of children with ASD and those with other primary disability categories.

Overall, teachers of children whose primary disability was ASD were approximately 13% more likely to have a degree in special education at the bachelor's degree level. Seven percent more teachers of children whose primary disability was

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[6] Surveys were also collected from Kindergarten and elementary teachers, however they did not include data on teacher education or experience.

autism had a master's degree in special education than teachers of children with other primary disabilities, however the difference was marginally insignificant. Teachers of children with ASD were 8% less likely to have a master's degree in any field other than education. Overall, this suggests that teachers of children whose primary disability was autism had more education specifically related to special education.

Table 2. Teacher degrees, degree types, and professional license types by disability group

Primary disability:	Autism (N =70)	Other (N =1,580)		
Variable	% of Subsample		Diff.	p-value
Bachelor's degree	100%*		---	---
Special education	49%	36%	13%	0.01
General education	47%	49%	-3%	0.33
Other field	28%	33%	-4%	0.22
Master's degree	62%	59%	3%	0.28
Special education	38%	32%	7%	0.12
General education	18%	14%	4%	0.18
Other field	11%	19%	-8%	0.04
Professional licenses	100%		---	---
Special education	73%	59%	14%	0.01
General education	48%	47%	2%	0.39
Other field	16%	31%	-15%	0.00

*Teachers who did not have a bachelor's degree or who had a doctoral degree were excluded from the analyses.
Sample sizes rounded per IES data privacy rules.

There were also differences in the professional licenses held by teachers between subsamples. Teachers of children whose primary disability was autism were 14% more likely to have a professional license in special education than teachers of children with other primary disabilities. They were also 15% less likely to have a professional license in an area other than education.

Many of the teachers in the sample had degrees in both general and special education, and many also had dual general and special education licenses. Table 3 shows the percentages of teachers with dual general education and special education degrees and licenses by subsample. Teachers of children whose primary disability was autism were more likely to have dual degrees at the bachelor's degree and master's degree levels, and were substantially more likely to have dual licensure. Nearly all of the teachers of children with autism had dual licenses.

Table 3. Dual general and special education degrees and licenses by subsample

Primary disability:	Autism	Other		
	(N =70)	*(N =1,580)*		
Variable	% of Subsample		Diff.	p-value
Bachelor's degree	50%	20%	30%	0.00
Master's degree	10%	5%	5%	0.03
Professional license	90%	39%	51%	0.00

Sample sizes rounded per IES data privacy rules.

Teaching experience is the final teacher-specific measure used in the analyses. Teacher experience was measured as years of experience teaching children ages 3 to 5 with disabilities, however experience teaching all children ages 3 to 5 and experience teaching children with disabilities at all age groups were also reported. Table 4 shows the summary statistics on years of teaching experience for teachers of children whose primary disability was autism.

Table 4. Years of teaching experience by subsample

Variable	Median	Mean	Max.
Primary disability is Autism (N=70)			
Children ages 3 to 5	8	9.8	30
Children with disabilities	10	12.7	31
Children ages 3 to 5 with disabilities	7	9.4	30
Other primary disability (N=1,580)			
Children ages 3 to 5	8	10.4	41
Children with disabilities	10	11.7	51
Children ages 3 to 5 with disabilities	7	8.9	41

Sample sizes rounded per IES data privacy rules.

Years of teaching experience ranged from 1 to 31 years for teachers of children with autism and 0 to 41 years for teachers of children with other primary disability categories. The median years of experience were identical across experience and disability types, but mean years differed slightly. Teachers of children whose primary disability was autism had slightly higher mean years of experience teaching children with disabilities in both age categories, but teachers of children with other primary disabilities had slightly more experience teaching children ages 3 to 5 at the mean.

Classroom Characteristics

Data on classroom characteristics were collected via teacher interview surveys. Variables used in the analyses were total number of students in the classroom, percent of students in the class who had Individual Education Plans (IEPs)[7], number of students per teacher, and number of classroom aides per teacher.

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[7] An IEP is an education plan developed by a team of educators and parents of a child with disabilities.

The total number of students in the child's classroom was derived by adding the number of students in the class who had IEPs (including the child for whom the survey was being completed) and the number of students with IEPs in the class who did not have IEPs. The percent of students in the class with IEPs was simply the number of students in the class who had IEPs divided by the total number of students in the class. Each state has specific regulations regarding the format and content of the IEP, but generally it contains information on the child's disability, academic progress, and the child's needs, and identifies goals and development areas that the child's educators will focus on over the next school year. A child must qualify under a specific disability category in order to obtain an IEP, making it the ideal way to identify the number of children in a child's classroom who have a disability, although the specific disabilities of other children in the classroom were not included in the PEELs data set.

The number of teachers in the classroom was the sum of special education and general education teachers usually present in the child's classroom setting. Similarly, the number of classroom aides was the sum of special education and general education aides generally present in the child's classroom setting. The number of students per teacher was calculated by dividing the number of teachers by the total number of students, and the number of students per classroom aide was similarly derived.

Table 5 shows the summary statistics on classroom characteristics for children with autism contrasted with classroom characteristics for children with other primary disabilities. Class sizes for children with ASD ranged from six to 26 students with a mean

class size of 15 children. The spread of class sizes was larger for children with primary

disabilities other than autism, ranging from two to 57, but the mean class size was also 15

children.

Table 5. Comparison of classroom characteristics between subsamples

Primary disability:	Autism *(N = 70)*	Other *(N = 1,400)*
	Mean of subsample	
Total students in the classroom	15	15
% of students in the classroom who have IEPs	28%	36%
Number of students per teacher	13	13
Number of students per classroom aide	10	12

Sample sizes rounded per IES data privacy rules.

The mean number of students per teacher was also very similar between

disability categories, as was the mean number of students per classroom aide, although

the ranges were also smaller for in the sample of children with autism in both categories

than were the ranges in the sample of children with other disability categories. The mean

number of students per teacher was 13 for both children with autism and students with

other primary disabilities. The number of students per teacher ranged from five to 22 in

the sample of children with ASD and from one to 41 in the sample of children with other

primary disabilities. The number of students per classroom aide ranged from two to 22 in

the sample of children with ASD and from one to 42 in the sample of children with other

primary disabilities.

Local Education Agency Characteristics

There were also significant differences in the demographic characteristics of the

local education agencies (LEA) – i.e. the school districts – that the children in the study

attended. Table 6 summarizes the ethnic, racial, wealth, language, and location

characteristics of the LEA where children in the study attended school by disability

category.

Children in the sample with ASD attended LEAs that had 12% fewer White

students than did children with other primary disabilities (p<0.001). On average, there

were 11% more Hispanic/Latino students in LEAs attended by the children in the sample

with ASD than in the LEAs attended by children with other primary disabilities

(p<0.001).

There were also considerable differences in the percentages of children who were

English Language Learners (ELL) in LEAs attended by children with ASD in comparison

to children with other primary disability categories. Children with ASD were 13% less

likely to live in LEAs in which 0 to 10% of children were ELLs (p<0.01), and 6% less

likely to live in LEAs in which 11 to 25% of children were ELLs (p<0.10). Children with

ASD were 25% more likely to live in LEAs in which 26 to 50% of children were ELLs

than children with other primary disabilities (p<0.001).

There was no significant difference between children with ASD and children with

other primary disability categories in terms of the percentage who lived in very low or

low poverty LEAs (p = 0.44 and p = 0.19, respectively). However among the children

who lived in less affluent areas, children with ASD were about 20% more likely to attend

high poverty LEAs (p<0.00), while children with other types of primary disabilities were

approximately 10% more likely to attend medium poverty LEAs (p<0.05).

Table 6. Summary of Local Education Agency demographics

Primary disability:	Autism (N =70)	Other (N =1,580)		
	% of Subsample		Difference	p-value
Ethnic/Racial Distributions				
% White	56%	69%	-12%	0.00
% Black	14%	14%	0%	0.26
% Hispanic/Latino	25%	14%	11%	0.00
% Asian**	-	-	-	-
% Native American**	-	-	-	-
% of students who are ELL				
0 to 10	60%	73%	-13%	0.01
11 to 25	9%	15%	-6%	0.07
25 to 50	31%	5%	25%	0.00
District wealth category (% below poverty line)				
Very low poverty (0 to 25)	27%	26%	1%	0.44
Low poverty (26 to 50)	37%	42%	-5%	0.19
Medium poverty (51 to 75)	10%	18%	-8%	0.04
High poverty (76 to 100)	27%	8%	19%	0.00
Metropolitan QED code				
Urban	70%	28%	41%	0.00
Suburban	22%	52%	-30%	0.00
Rural	9%	20%	-11%	0.01
Census region				
Northeast	22%	17%	5%	0.12
Southeast	29%	26%	3%	0.31
Central	21%	31%	-10%	0.04
West/Southwest	28%	27%	2%	0.36

*Numbers may not add to 100% due to rounding error.
**Suppressed per IES data privacy rules.
Sample sizes rounded per IES data privacy rules.

The physical locations of the LEAs attended by children with ASD also differed

significantly from those attended by children with other primary disabilities. Children

with ASD were over 40% more likely to attend LEAs located in urban areas (p<0.001),

about 30% less likely to attend LEAs in suburban areas (p<0.001), and about 10% less

likely to attend LEAs located in rural areas (p<0.01). There was some variation in the regions the LEAs attended by children with ASD were located in; children with ASD were approximately 10% less likely to attend LEAs located in the Central census region than children with other primary disabilities.

Child Test Scores

Differenced standard scores were used to measure children's academic progress between periods, and was the dependent variable in the models. Children's scores were from two subtests of the Woodcock-Johnson III Tests of Achievement (WJ-III). The two subtests used were the Applied Problems (AP) subtest, which measures math achievement, and Letter-Word Identification (LWID) subtest, which measures early reading skills. These tests were chosen for the analyses because they measure math and reading ability, and were administered to all age groups in the sample.

The WJ-III AP (math) subtest is an oral test of math calculation using word problems. Children are given problems that require relatively simple calculations and are asked to give a response. Children are scored based on the number of correct responses they give. This particular test of math achievement may be problematic as it incorporates word problems, and this may have affected the results for children with language problems. However, this was the only mathematics subtest administered to children from all age groups and gives math achievement information on the most children. Two specifications were run for this test, one of which incorporated the child's score on the Peabody Picture Vocabulary Test (PPVT), which measures child vocabulary and can

serve as a rough proxy for language ability, in order to control for this potential bias. Figure 1 shows the weighted distribution of the children's initial scores by disability type.

Changes in math subtest standard score for children with primary disabilities other than autism followed a fairly smooth and even distribution, roughly centered at zero with even tails. Changes in standard scores for children whose primary disability was autism had a more erratic distribution, with clustering in several areas, particularly near -10 and +15. Despite differences in the shapes of the distributions, weighted mean standard scores and standard score changes were strikingly similar. Table 7 shows the summary statistics of the score distributions on the WJ-III AP subtest.

There were no significant differences in the initial scores, follow-up scores, or changes in the scores between subgroups, and both followed roughly normal distributions, but the ranges of scores did vary significantly between the two groups. Because the scores are age normed, the change in scores can be interpreted as a child's growth relative to his or her peers without disabilities. A change of zero indicates that the

Figure 1. Weighted distributions of changes in child test scores on the WJ-III Applied Problems (math) subtest by primary disability category
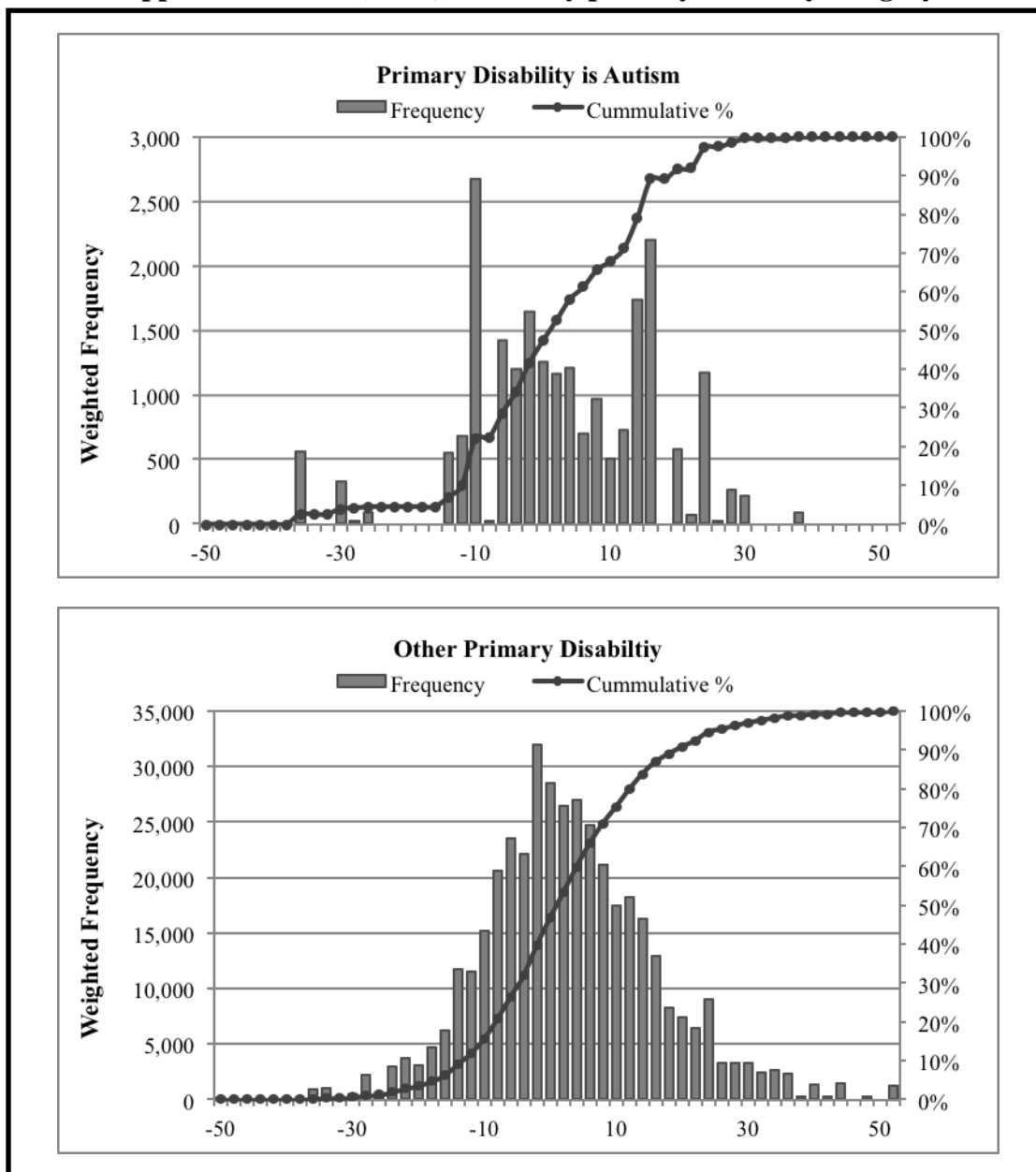
child is developing at the same rate as non-disabled peers in their age group; a negative

change indicates that the child is growing at a slower rate; and a positive change indicates

that the child is growing at a faster rate than his or her non-disabled peers. Children with

ASD had a somewhat smaller spread of age-normed scores. The child with the largest

negative change fell about two standard deviations behind their initial placement among

peers, while the child with the largest positive change gained two standard deviations

relative to his or her peers. The weighted mean scores of the children in the sample

(initial and follow-up scores) were consistently below that of the children's non-disabled

peers.

Table 7. Initial and follow-up scores on WJ-III Applied Problems subtest

Variable	Mean	Std. Dev.	Min.	Max.
Primary disability is Autism (N=70)				
Initial score	87	19	31	134
Follow-up score	88	20	12	130
Change	**1**	**15**	**-37**	**36**
Other primary disability (N=1,580)				
Initial score	89	18	15	142
Follow-up score	90	17	15	152
Change	**2**	**15**	**-61**	**67**

Sample sizes rounded per IES data privacy rules.

The WJ-III LWID (reading) subtest involves reading letters and words aloud

when presented with the word or letter written in large print. The letters and words

become increasingly difficult as the child progresses, and children's scores depend on the

number of correct responses. This test is a measure of letter and word recognition, which

is a good measure of early reading ability.

Table 8 shows the summary statistics on initial and follow-up scores on the

reading subtest by disability category. The mean initial and follow-up scores are

significantly higher for children with autism for both the initial and follow-up

assessments. The mean scores of the children with autism decreased by 5 points, while

the mean score for children with other primary disabilities increased by 2 points. Additionally, this test measures word and letter recognition rather than language comprehension or general language skills.

Table 8. Initial and follow-up scores on WJ-III Letter-Word Identification subtest

Variable	Mean	Std. Dev.	Min.	Max.
Primary disability is Autism (N=70)				
Initial score	114	21	60	192
Follow-up score	109	20	60	166
Change	**-5**	**16**	**-51**	**75**
Other primary disability (N=1,580)				
Initial score	96	17	48	195
Follow-up score	99	16	29	192
Change	**2**	**15**	**-63**	**69**

Figure 2 shows the distributions of the changes in reading scores by primary disability category. Once again, there appears to be clustering in the score changes among children with autism, most notably around -10 and +10. The changes in scores among children with other primary disabilities appears to be somewhat smoother, although there are clusters of score changes around +5 and +10, and it also appears to be slightly right-skewed.

The Peabody Picture Vocabulary Test (PPVT), which was used to control for language ability on the model measuring math achievement, measures receptive language skills. Children were presented with cards that had four pictures. The evaluator spoke a word and asked the child to point to the picture that corresponded with the word. This test was also normed on individuals age 2 to 90, and both standard and raw scores are

Figure 2. Weighted distributions of changes in child test scores on the WJ-III Letter-Word Identification (reading) subtest by disability category
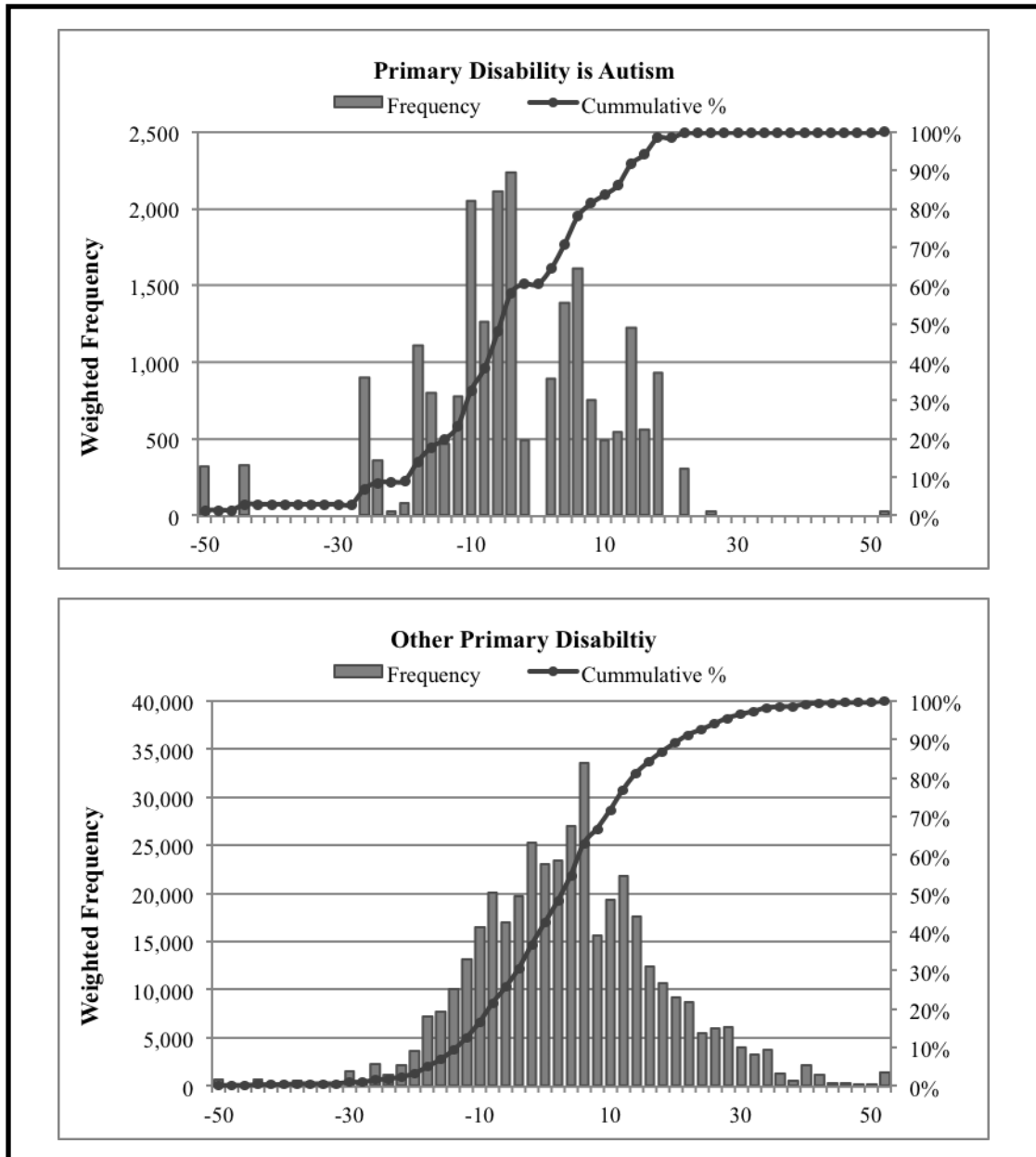
analyzed. Figure 3 shows the distributions of the PPVT score changes by disability category.

Table 9 shows the summary of initial and follow-up scores on the PPVT by disability group, not controlling for student, teacher or classroom characteristics. Changes in scores on the PPVT showed a much larger spread than those in the AP and LWID subtests. Mean scores in the initial and follow-up periods were the same for children whose primary disability was autism and those with other primary disabilities, and gains between periods were slightly positive and not statistically significant.

Table 9. Summary of child scores on the Peabody Picture Vocabulary Test by disability group

Variable	Mean	Std. Dev.	Min.	Max.
Primary disability is Autism (N=70)				
Initial score	91	18	0	139
Follow-up score	93	18	0	120
Change	**4**	**18**	**-101**	**86**
Other primary disability (N=1,580)				
Initial score	89	18	0	140
Follow-up score	95	18	0	144
Change	**6**	**19**	**-111**	**131**

Sample sizes rounded per IES data privacy rules.

Missing Data and Scores

Missing scores were problematic, and differed substantially by subgroup. Approximately 60% of children whose primary disability was autism did not have valid scores across periods, and 30% of children with other primary disabilities were missing scores. However, there were no significant demographic differences between children

Figure 3. Weighted distribution of changes in child standard scores on the Peabody Picture Vocabulary Test by primary disability category
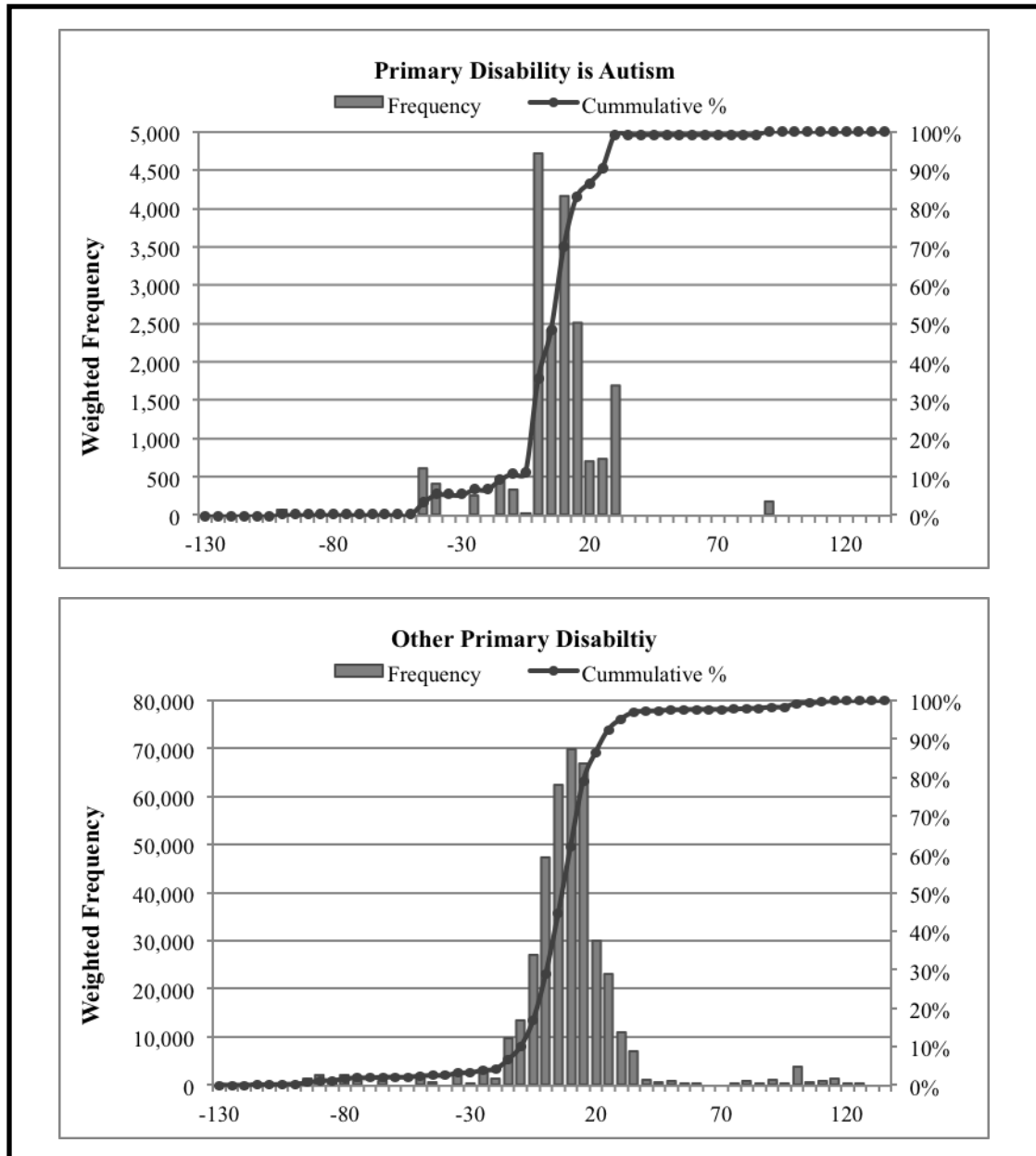
with and without missing scores among children with ASD, and PEELS provides weights

to deal with the problem of missing information. As previously mentioned, the weights

used control for sample attrition and missing survey data; they weight observations in waves one through three to make observations with valid child assessment, parent interview, and teacher interviews nationally representative, and they adjust for bias in estimates.

The summary statistics discussed in this section reveal significant differences in child demographics and academic characteristics between children with autism and children with other primary disabilities. There are also significant differences in LEA attended by children with autism and there are some differences in teachers and classroom structures.

Section III. Results

The purpose of this analysis is to explore the relationship between teacher education, classroom staff, and classroom structure on academic performance for children with Autism Spectrum Disorders, and whether and how those relationships change with differing levels of child ability.

The General Model

Table 10 presents the results of the models that estimated the relationships of child, classroom, and teacher variables with changes in standard scores on the WJ-III Applied Problems (AP) (math) and Letter-Word Identification (LWID) (reading) subtests between initial and follow-up testing sessions. These models do not use interaction terms, and control for the severity of a child's disability through the variable indicating whether a child has an assigned classroom aide, their initial score on the math or reading subtest,

and their follow-up score on the PPVT. The reference category for the teacher education field in both models is a bachelor's degree in general education. A negative change in a child's score between periods indicates that the child's development in the skill being measured by the test was slower than that of their non-disabled peers, and positive changes indicate that the child's development in the skill being measured was higher relative to their non-disabled peers.

Teacher Education

Overall, there did not appear to be much difference between degree types at the bachelor's degree level in the math or reading models. Children with ASD whose teachers had bachelor's degrees in special education or dual special and general education did appear to have slightly higher increases in their math and reading standard scores between testing sessions compared to children whose teachers only had bachelor's degrees in general education, however the differences were not statistically significant. Interestingly, the math model estimated that a child whose teacher had a bachelor's degree in a non-education field gained approximately 4 more standard points on the math exam between testing sessions than children whose teachers had bachelor's degrees in general education, and this estimate was significant at the 10% level.

Teacher education at the master's degree level had more varied results. The math model estimated that a child with ASD whose teacher had a master's degree in special education gained approximately 9 additional standard points on the math subtest between testing sessions than a child whose teacher had a bachelor's degree in general education,

Table 10. Estimated relationships between teacher education and classroom characteristics and changes in math and reading standard scores (general model, no interaction terms)

	Math		Reading	
	Estimate	Std Error	Estimate	Std Error
Child academic characteristics				
Initial standard score	-0.579 ***	0.097	-0.143 *	0.087
Child has an assigned classroom aide	-10.062 **	4.414	-2.264	4.345
PPVT standard score at t1	0.385 ***	0.142	-0.036	0.127
Teacher's experience educating children ages 3 to 5 with disabilities				
Years of experience	0.111	0.986	-1.119	0.895
Years of experience²	-0.008	0.037	0.043	0.036
Teacher education				
Bachelor's degree				
General education		-Reference-		
Special education	4.467	4.874	1.095	3.945
Dual general & special education	1.986	4.884	2.776	4.974
Other field	4.324 *	2.684	-0.543	2.957
Master's degree				
General education	2.382	4.753	4.837	5.842
Special education	9.423 **	4.130	3.303	4.208
Dual general & special education	-4.893	7.973	-15.275	10.244
Other field	14.237 ***	3.853	7.945 **	3.959
Classroom characteristics				
Total students in classroom	-0.681	0.722	0.027	0.794
Percent of children in classroom with IEPs	0.148	0.120	0.002	0.129
Students per teacher	-1.074 **	0.536	-0.834	0.526
Students per classroom aide	0.260	0.428	1.445 ***	0.339
Number of Observations	70		70	
Number of Clusters	50		50	
Adjusted-R²	0.414		0.278	
Root MSE	6.572		7.527	

*** Significant at the 1% level

** Significant at the 5% level

* Significant at the 10% level

Sample sizes rounded per IES data privacy requirements

Note: Additional control variables (not shown) include child, family, and school district demographic characteristics as discussed in Section 3

and this estimate was statistically significant. At the master's degree level, having a

teacher with a master's degree in a non-education field was also associated with larger

gains in standard math scores. Children whose teachers had a master's degrees in a non-

education fields gained an estimated 14 additional standard points on the math subtest

between testing sessions compared to children whose teachers had only a bachelor's degree in general education. The model also estimated a positive and significant relationship between standard score gains on the reading subtest and having a teacher with a master's degree in a non-education field. A child whose teacher had a master's degree in a non-education field gained an estimated 8 additional standard points on the reading subtest between testing sessions compared to children whose teachers had only bachelor's degrees in general education. The models did not estimate significant relationships between teacher education and changes in child standard scores for other types of master's degrees.

Classroom Characteristics

The models shown in Table 10 estimated that for children with ASD, each additional student in a child's classroom was associated with a 0.7-point decrease in the child's gain in their standard math score between testing sessions, however the result was not significant in either model. The estimated relationship between class size and changes in child standard scores was near zero and not significant, as was the estimated relationship between the percent of students in a child's classroom and changes in their standard score between testing sessions. Both models estimated negative associations between the number of students per teacher in a child's classroom and changes in the child's standard score on both the math and reading subtests, however the estimate was only significant in the math model. In the math model, each additional student per teacher in a child's classroom was associated with a one-point decrease in the child's standard

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score on the math subtest. In the reading model, each additional student per teacher in a child's classroom was associated with a 0.8-point decrease in the child's standard score on the math subtest, however this estimate was not significant.

Estimates of the association between increases in the number of students per classroom aide and changes in child standard scores were positive in both the math and reading models; however the result was only significant in the reading model. This result is somewhat counterintuitive. In the reading model, each additional student per classroom aid was associated with a 1.5-point larger gain in the child's standard reading score.

Models with Interaction Terms

Table 11 presents the results of the models that include interaction terms between student initial standard scores and both teacher education and classroom characteristic variables. As with the previous models the reference category for the teacher education variables is children whose teachers have bachelor's degrees in general education. Table 12 presents estimated effect sizes[8] at several levels of initial ability, as measured by children's initial standard scores on the two subtests. The purpose of this presentation of the results is to show the estimated effects across a range of initial achievement levels. In the both models, the estimates are calculated at initial standard scores of 70, 85, and 100. These scores were chosen to illustrate the differences in estimated effects for a range of

[8] Estimated effect sizes were calculated using the estimated coefficients from the regression results. For each variable and interaction term, the formula is:

$$Estimated\ Effect\ Size = \beta_{degree} + \beta_{interaction} \times Initial\ Standard\ Score$$

Table 11. Estimated relationships between teacher education and classroom characteristics and changes in math and reading standard scores (with interaction terms)

	Math		Reading	
	Estimate	Std Error	Estimate	Std Error
Child academic characteristics				
Initial standard score	-0.826 **	0.358	0.123	0.120
Child has an assigned classroom aide	-14.705 ***	3.530	-6.103	5.050
PPVT standard score at t1	0.362 ***	0.094	-0.118	0.117
Teacher's experience educating children ages 3 to 5 with disabilities				
Years of experience	1.383	0.935	4.119 ***	1.367
Years of experience²	-0.074 *	0.038	-0.152 ***	0.053
Teacher education				
Bachelor's degree				
General education		-Reference-		
Special education	17.927	17.101	54.816 ***	19.639
× *Initial standard score*	*-0.139*	*0.182*	*-0.456 ****	*0.170*
Dual general & special education	29.734 *	16.285	-63.558 ***	20.034
× *Initial standard score*	*-0.186*	*0.161*	*0.516 ****	*0.178*
Other field	-49.836 **	23.618	14.052	29.961
× *Initial standard score*	*0.617 ***	*0.252*	*-0.134*	*0.239*
Master's degree				
General education	29.134 **	11.986	43.455 **	19.708
× *Initial standard score*	*-0.307 ****	*0.104*	*-0.422 ***	*0.182*
Special education	142.173 ***	28.323	42.051	28.019
× *Initial standard score*	*-1.491 ****	*0.325*	*-0.367*	*0.236*
Dual general & special education	-189.979 ***	47.489	12.201	61.997
× *Initial standard score*	*2.160 ****	*0.499*	*-0.080*	*0.438*
Other field	2.000	24.969	82.913 ***	18.111
× *Initial standard score*	*0.011*	*0.277*	*-0.679 ****	*0.174*
Classroom characteristics				
Total students in classroom	4.817 *	2.814	9.028 *	5.174
× *Initial standard score*	*-0.058 ***	*0.029*	*-0.082 **	*0.042*
Percent of children in classroom with IEPs	194.671 ***	37.053	-18.482	57.916
× *Initial standard score*	*-1.986 ****	*0.401*	*0.256*	*0.487*
Students per teacher	-14.713 ***	3.971	-14.775 ***	4.082
× *Initial standard score*	*0.144 ****	*0.041*	*0.119 ****	*0.036*
Students per classroom aide	1.787	3.118	4.003	2.513
× *Initial standard score*	-0.013	0.035	-0.019	0.023
Number of Observations	70		70	
Number of Clusters	50		50	
Adjusted-R²	0.699		0.473	
Root MSE	4.136		5.649	

*** Significant at the 1% level
** Significant at the 5% level
* Significant at the 10% level

Sample sizes rounded per IES data privacy requirements

Note: Additional control variables (not shown) include child, family, and school district demographic characteristics as discussed in Section 3

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below average to average performing students and represent the 50th percentile score (100), one standard deviation below the 50th percentile (85), and two standard deviations below (70).

Teacher Education

Math Subtest

In the math model, changes in children's standard scores between testing sessions were not significantly different for children whose teachers had bachelor's degrees in special education compared to children whose teachers had bachelor's degrees in general education. For children with ASD, having a teacher with bachelor's degrees in both general and special education was associated with significantly larger changes in their standard math scores compared to children whose teachers had bachelor's degrees only in general education. However, the negative coefficient on the interaction term suggests that the magnitude of the relationship declined as children's initial standard score increased. For a child with ASD whose initial standard score was 70, having a teacher with dual bachelor's degrees in general and special education was associated with an estimated 17-point larger increase in their standard score between testing sessions compared to children whose teachers had a bachelor's degree only in general education. For a child with an initial standard score of 85, the estimated magnitude of the increase dropped to 14-points, and for a child whose initial standard score was 100, the estimated magnitude dropped to approximately 11-points.

Table 12. Estimated effect sizes of teacher education fields on changes in math and reading standard scores for children with ASD between testing sessions

	Math				Reading			
Initial Standard Score:		70	85	100		70	85	100
Bachelor's degree								
General education		-Reference-				-Reference-		
Special education	17.93	8.23	6.15	4.07	54.82 ***	22.92	16.08	9.25
× *Initial standard score*	*-0.14*				*-0.46 ****			
Dual general & special ed.	29.73 *	16.68	13.89	11.09	-63.56 ***	-27.43	-19.69	-11.95
× *Initial standard score*	*-0.19*				*0.52 ****			
Other field	-49.84 **	-6.64	2.62	11.88	14.05	4.70	2.70	0.70
× *Initial standard score*	*0.62 ***				*-0.13*			
Master's degree								
General education	29.13 **	7.68	3.08	-1.52	43.45 **	13.90	7.57	1.23
× *Initial standard score*	*-0.31 ****				*-0.42 ***			
Special education	142.17 ***	37.82	15.46	-6.90	42.05	16.39	10.90	5.40
× *Initial standard score*	*-1.49 ***				*-0.37*			
Dual general & special ed.	-198.98 ***	-47.08	-14.53	18.02	12.20	6.62	5.42	4.22
× *Initial standard score*	*2.17 ***				*-0.08*			
Net effect of dual degree		-1.59	4.00	9.59		36.91	23.88	10.86
Other field	2.00	2.79	2.96	3.13	82.91 ***	35.37	25.18	14.99
× *Initial standard score*	*0.01*				*-0.68 ***			

*** Significant at the 1% level
** Significant at the 5% level
* Significant at the 10% level

The math model also estimated a significant relationship between a child's teacher having a bachelor's degree in a non-education field and changes in the child's standard math score between testing sessions compared to children whose teachers had bachelor's degrees in general education. For a child with ASD, having a teacher with a bachelor's degree in a non-education field was associated with an overall decrease in the gains in a child's standard score between testing sessions compared to children whose teachers had bachelor's degrees in general education, however the estimated effect changed fairly rapidly as children's initial standard math scores changed. For a child with

ASD whose initial standard math score was 70, having a teacher with a bachelor's degree in a non-education field was gained approximately 7 fewer standard points on the math subtest than children whose teachers had bachelor's degrees in general education. However, for a child whose initial standard score was 85, this changed to a 3 standard point *increase* in a child's gain in his or her standard score, and a child with an initial standard score of 100 gained approximately 12 more standard points on the math subtest when his or her teacher had a bachelor's degree in a non-education field.

The math model also estimated significant relationships between teacher education at the master's degree level and changes in children's standard math scores. For a child with ASD, having a teacher with a master's degree in general education had a positive association with changes in children's standard math scores between testing sessions compared to children whose teachers had only bachelor's degrees in general education, and the negative coefficient on the interaction term indicated a decrease in the gains as initial ability level increased. For a child with ASD whose initial standard score was 70, the model estimated that the child would gain approximately 8 additional standard points on the math subtest when his or her teacher had a master's degree in general education, compared to children whose teachers had bachelor's degrees in general education. For a child whose initial standard score was 85, the gain decreased to approximately 3 additional standard points, and for a child whose standard score was 100, the model estimated that the child would gain approximately 2 fewer standard points between testing sessions.

At the master's level, the model estimated a positive and significant relationship between having a teacher with a degree in special education and changes in a child's standard math scores between testing sessions. For a child with ASD whose initial standard score was 70, having a teacher with a master's degree in special education was associated with a 38-point larger increase in the child's standard score compared to children whose teachers had only bachelor's degrees in general education. The estimated effect changed to a 15-point larger gain for a child whose initial standard score was 85, and to a 7-point *smaller* gain in standard score for a child whose initial standard math score was 100.

The estimated relationship between a child's teacher having dual master's degrees in general and special education and changes in the child's standard math score was significant as well. For a child with ASD whose initial standard score was 70, having a teacher with a master's degree in special education was associated with a 47-point decrease in the child's gains in his or her standard math score compared to children whose teachers had only bachelor's degrees in general education. The estimated effect decrease to a 15-point smaller gain for a child whose initial standard score was 85, and to a 18-point *increase* in the child's gain in his or her standard score between testing sessions. The negative relationship between gains in a child's standard math score between testing sessions and having a teacher with dual master's degrees in general and special education may be the result of selection bias in children's placement if this is not adequately controlled for in the model. If children with ASD with more severe disabilities

are usually placed with teachers who have more education and the model does not adequately control for this, then this could explain the negative relationship. This result could also be caused by non-linearity in the relationship the interaction term and the estimated variable.

Reading Subtest

In the reading model, children with ASD whose teachers had bachelor's degrees in special education, or dual degrees in general and special education had significant differences in the changes in their standard scores between testing sessions. For a child with ASD whose initial standard score on the math subtest was 70, having a teacher with a bachelor's degree in special education was associated with a gain of approximately 23 additional standard points on the reading subtest between testing sessions compared to children whose teachers had bachelor's degrees only in general education. A child with an initial standard score of 85 gained an estimated 16 additional standard points on the reading subtest, and a child with ASD whose initial standard score was 100 gained approximately 9 additional standard points on the reading subtest. The estimated relationship between a child's teacher having dual bachelor's degrees in general and special education degrees and changes in the child's standard reading score between testing sessions was negative and significant. For a child with ASD whose initial standard score was 70, having a teacher with dual bachelor's degrees in general and special education was associated with a 27-point smaller increase in the child's standard reading score between testing sessions compared to children whose teachers only had bachelor's

degrees in general education, and the estimated relationship changed to a 20-point smaller gain in standard score for children with an initial standard reading scores of 85, and to a 12-point smaller gain in standard score for children whose initial standard reading scores were 100.

The results of the reading model estimated that for children with ASD, having a teacher with any type of master's degree was associated with larger increases in their standard scores on the reading subtest compared to children whose teachers only had bachelor's degrees in general education, however the result was only significant for children whose teachers had master's degrees in general education and/or a non-education field. For a child with ASD whose initial standard score was 70, having a teacher with a master's degree in general education was associated with a 14-point larger increase in the child's standard score between testing sessions compared to children whose teachers only had bachelor's degrees in general education, and the estimated relationship changed to a 8-point larger gain in standard score for children with initial standard reading scores of 85, and to a one-point larger gain in standard score for children whose initial standard reading scores were 100. The size of the estimated relationship between children with ASD having teachers with master's degrees in special education compared to children whose teachers had only bachelor's degrees in general education was very similar between the two models, however the results were not significant for the latter degree type. The estimated relationship between a child's teacher having dual general and special education degrees at the master's level and the child's gains in

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standard reading score between testing sessions compared to children whose teachers had bachelor's degrees in general education was not significant.

The reading model estimated that children with ASD whose teachers had master's degrees in non-education fields had significantly larger gains in their standard reading scores compared to children whose teachers had only bachelor's degrees in general education. For a child with ASD whose initial standard score was 70, having a teacher with a master's degree a non-education field was associated with a 35-point larger increase in the child's standard score between testing sessions compared to children whose teachers only had bachelor's degrees in general education, and the estimated relationship changed to a 25-point larger gain in standard score for children with an initial standard reading scores of 85, and to a 15-point larger gain in standard score for children whose initial standard reading scores were 100.

Non-Education Degree Reference Category

In order to directly examine the relationships between the performance of children with ASD and whether their teachers have degrees in any education field, I have also included an analysis of the model using interaction terms with children whose teachers have bachelor's degrees in non-education fields as the base category. Table 13 presents the estimated effects of the variables in the same manner as table 12 presented those of the previous model (see p. 59).

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Math Subtest

The math model estimates that children whose teachers have bachelor's degrees in general education and children whose teachers have bachelor's degrees in special education both have significantly larger gains in their standard scores between testing sessions compared to children whose teachers have bachelor's degrees in non-education fields, and that the magnitude of these relationships vary by initial child achievement level.

The math model estimated that children with ASD whose teachers had bachelor's degrees in general education had significantly larger gains in their standard math scores compared to children whose teachers had bachelor's degrees in non-education fields. A child with ASD whose initial standard score was 70 and whose teacher had a bachelor's degree in general education gained an estimated 16 additional points in his or her standard math score between testing sessions than a child whose teacher had a bachelor's degree in a non-education field. Once again, the estimated coefficient on the interaction term indicated a change in the relationship as child initial standard scores increased. A child with an initial standard math score of 85 gained only 4 additional standard points, and a child with an initial standard score of 100 gained approximately 21 fewer standard points on the math subtest. The size of the estimated gains in standard math scores for children whose teachers had bachelor's degrees in special education was similar in both direction and magnitude. A child with ASD with an initial standard score of 70 and whose teacher had a bachelor's degree in special education gained an estimated 23

additional standard points on the math subtest compared to children whose teachers had bachelor's degrees in non-education fields, and this changed to an estimated 11 additional standard points for a child whose initial standard score was 85, and to 12 fewer standard points for a child whose initial standard score was 100.

Table 13. Estimated effect sizes of teacher education field compared to teachers with bachelor's degrees in non-education fields

		Math				Reading		
Initial Standard Score:		70	80	100		70	80	100
Bachelor's degree	Estimate				Estimate			
General education	102.96***	16.44	4.08	-20.64	34.95	16.10	13.41	8.02
× Initial standard score	-1.24***				-0.27			
Special education	103.93***	22.78	11.19	-12.00	64.76***	29.30	24.23	14.10
× Initial standard score	-1.16***				-0.51***			
Dual general & special ed.	-83.47**	-5.31	5.86	28.19	-94.83***	-40.25	-32.45	-16.86
× Initial standard score	1.12**				0.78***			
Net effect of dual degree		**33.91**	**21.13**	**-4.45**		**5.15**	**5.19**	**5.27**
Master's degree								
General education	16.11*	0.56	-1.66	-6.10	20.35	5.79	3.71	-0.45
× Initial standard score	-0.22***				-0.21			
Special education	171.48***	44.98	26.90	-9.24	45.07	20.26	16.72	9.63
× Initial standard score	-1.81***				-0.35			
Dual general & special ed.	-196.40***	-41.41	-19.26	25.02	-20.58	-12.84	-11.73	-9.52
× Initial standard score	2.21***				0.11			
Net effect of dual degree		**4.13**	**5.98**	**9.68**		**13.22**	**8.70**	**-0.34**

*** Significant at the 1% level
** Significant at the 5% level
* Significant at the 10% level

The estimated net effect of the dual degree is the sum of the estimated effect of the general education, special education, and dual degrees. For children whose teachers had dual bachelor's degrees in special and general education, the model estimated significant differences in the changes in their test scores between testing sessions compared to children whose teachers had bachelor's degrees in non-education fields. For a child with ASD, having a teacher with bachelor's degrees in both general and special

education was associated with a gain of 35 more standard points between testing sessions compared to children whose teachers had bachelor's degrees in non-education fields when the child's initial standard math score was 70, 20 more standard points when the child's initial standard score was 85, and 5 fewer standard points when the child's initial standard score was 100.

The model estimated that young children with ASD gained more standard points on the subtests between testing sessions when their teachers had a master's degree in any field, however the size of the estimated gains varied with initial child achievement as measured by the math subtest. For a child with ASD whose initial standard score was 70, having a teacher with a master's degree in general education had no estimated impact compared to children whose teachers had bachelor's degrees in general education. The estimated effect size was negative for children with higher initial achievement levels, however the estimated effects were small. A child with ASD whose initial standard score on the math subtest was 70 and whose teachers had a master's degree in special education gained approximately 45 more standard points on the math subtest than a child whose teacher had only a bachelor's degree in a non-education field. The estimated gain was approximately 27 additional standard points for a child with an initial standard score of 85, and a child with an initial standard score of 100 gained approximately 10 fewer standard points between testing sessions. The net estimated effect for children with ASD of having a teacher with master's degrees in both general and special education compared to having a teacher with a bachelor's degree in a non-education field was a gain of 4

additional standard points for a child with an initial standard score of 70, 6 additional

standard points for a child with an initial standard score of 85, and 10 additional standard

points for a child with an initial standard score of 100.

Reading Subtest

The results of the reading model followed a similar pattern to those of math

model, however the size and significance of the estimates varied. The reading model

estimated that children with ASD whose teachers had bachelor's degrees in general

education did have higher estimated gains in their standard reading scores compared to

children whose teachers had bachelor's degrees in non-education fields, however the

results were not significant. For a child with ASD whose initial standard score was 70,

having a teacher with a bachelor's degree in general education was associated with a gain

of 16 additional points in the child's standard reading score between testing sessions

compared to children whose teachers only had bachelor's degrees non-education fields.

The relationship changed as children's initial standard scores increased so that a child

with ASD whose initial standard score was 85 gained approximately 13 more standard

points on the math subtest between testing sessions, and a child whose initial standard

score was 100 gained 8 more standard points. The estimated standard reading score gains

for children whose teachers had bachelor's degrees in special education compared to

children whose teachers had bachelor's degrees in non-education fields were larger and

they were statistically significant. The model estimated that a child with ASD whose

initial standard score was 70 and whose teacher had a bachelor's degree in special

education gained 29 additional points in his or her standard reading score between testing sessions compared to children whose teachers only had bachelor's degrees non-education fields. The estimated relationship changed to 24 additional standard points for a child with initial standard reading scores of 85, and to 14 additional standard points for a child whose initial standard reading score was 100. The net effect of having a teacher with dual general and special education bachelor's degrees was also significant. For a child with ASD, having a teacher with bachelor's degrees in both general and special education was associated with a 5-point larger gain in his or her standard reading score between testing sessions, and this result was relatively consistent across initial reading achievement levels.

At the master's degree level, the model estimated significant relationships between teacher education and changes in student standard reading scores between testing sessions, and again the estimated effects varied by initial child ability level. For a child with ASD whose initial standard score was 70, having a teacher with a master's degree in general education was associated with a gain of 6 additional points in the child's standard reading score between testing sessions compared to children whose teachers had bachelor's degrees in non-education fields; the estimated relationships decreased as children's initial scores on the reading subtest increased. For a child with ASD and an initial standard score of 70, having a teacher with a master's degree in special education was associated with a gain of 20 additional standard points on the math subtest between testing sessions compared to children whose teachers had bachelor's

degrees in non-education fields. The estimated gain in standard score was 17 additional

standard points for a child with an initial standard score of 85, and 10 additional standard

points for a child with an initial standard score of 100. The net estimated effect for

children with ASD of having a teacher with master's degrees in both general and special

education compared to having a teacher with a bachelor's degree in a non-education field

was a gain of 13 additional standard points a child with an initial standard score of 70, 9

additional standard points for a child with an initial standard score of 85, and no

difference in estimated gain in standard score for a child with an initial standard score of

100.

Classroom Characteristics

Both the math and reading models estimated significant relationships between

classroom characteristics and changes in child standard scores between testing sessions.

In the math model, the total number of students in a child's classroom, the percentage of

children in the classroom with IEPs, and the number of students per teacher in a child's

classroom all had significant estimated relationships with changes in standard scores for

children with ASD across testing sessions. In the reading model, the total number of

students in a child's classroom and the number of students per teacher both had

significant estimated relationships with changes in standard scores. Table 14 presents the

estimated effect sizes of the classroom characteristics in the same manner as table 12 and

13 presented the estimated effect sizes for the teacher education variables (see p. 59)

Math Subtest

The math model estimated that several of the classroom characteristics had significant relationships with changes in child standard scores between testing sessions, and that the size of the estimates varied with initial child ability level. The estimated relationship between the change in a child's standard score on the math subtest and the number of students in the classroom was positive for children with a mean initial score of 70, increasing by approximately one point for each additional child in the classroom however the opposite was true for children with initial standard math scores of 100. For a child with ASD whose initial score on the math subtest was 70, the estimated gain in a child's standard score increased by approximately 0.5 standard points for each additional percent of children with IEPs in the child's classroom. The estimated gain was decreased to approximately 0.25 for a child with an initial standard score of 85, and to zero for a child with with an initial standard score of 100.

Higher student-to-teacher ratios were associated with negative estimated changes in children with ASD's standard scores on the math subtest between testing periods. For a child with ASD whose initial score on the math subtest was 70, the model estimated a 5-point decrease in the child's gains in their standard score on the subtest for each additional student per teacher in their classroom. The estimated losses in gains in standard score were somewhat smaller for children with higher initial ability levels. Children whose standard scores were 85 had an estimated 3-point decrease in the gain in their standard scores associated with each additional student per teacher in the child's

classroom. The size of the relationship decreased to near zero for children whose initial

score was 100.

Table 14. Estimated effect sizes of classroom characteristics on changes in math and reading standard scores for children with ASD between testing sessions

	Math	70	85	100	Reading	70	85	100
Initial Standard Score:		70	85	100		70	85	100
Total students in classroom	4.82*	0.74	-0.14	-1.01	9.03*	3.31	2.09	0.86
× Initial standard score	-0.06**				-0.08*			
% of children with IEPs	1.95***	0.56	0.26	-0.04	-0.18	-0.01	0.03	0.07
× Initial standard score	-0.02***				0.00			
Students per teacher	-14.71***	-4.65	-2.49	-0.33	-14.78***	-6.48	-4.70	-2.92
× Initial standard score	0.14***				0.12***			
Students per classroom aide	1.79	0.90	0.71	0.53	4.00	2.65	2.36	2.07
× Initial standard score	-0.01				-0.02			

*** Significant at the 1% level
** Significant at the 5% level
* Significant at the 10% level

Reading Subtest

The estimated relationship between the change in a child's standard score on the

reading subtest and the total number of students in the child's classroom was positive, but

declined as the child's initial math achievement as measured by the subtest increased.

The estimated model estimated that a child with an initial standard score of 70 gained 3

additional standard points on the reading subtest for each additional student in the child's

classroom, but the gain decreased to 2 points for a child with an initial standard score of

85, and one point for a child with an initial standard score of 100. In the reading model,

estimated relationship between the percentage of students in a child's classroom who had

IEPs and changes in the child's standard score on the reading subtest was small and was

not significant.

Higher student-to-teacher ratios were associated with negative changes in standard scores on the reading subtest between testing periods for children with ASD. For a child with ASD whose initial standard score on the reading subtest was 70, the model estimated a the child would gain 6 fewer standard points on the subtest for each additional student per teacher in their classroom. The estimated loss was somewhat smaller for children with higher initial ability levels. Children whose standard scores were 85 gained approximately 5 fewer standard points on the math subtest for each additional student per teacher in the child's classroom, and children whose initial standard reading scores were 100 gained approximately 3 fewer standard points for each additional student per teacher in the child's classroom.

Section IV. Discussion

The results from Section III suggest strong relationships between teacher training and classroom structure and student achievement in math and reading. Children with ASD whose teachers had degrees in special education appeared achieve larger gains in their standard scores on the WJ-III Applied Problems (AP) subtest measuring math skills and Letter-Word Identification (LWID) subtest measuring reading skills. There was also evidence that students received benefits in terms of gains in their standard scores when their teachers held general education degrees at the undergraduate level. The results of these analyses are consistent with Sass and Feng's (2012) findings that pre-service teacher training at the graduate level was positively associated with gains in student achievement.

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For both math and reading achievement, classroom structure and student-to-teacher ratio was an important indicator of changes in child standard scores. The results varied by child initial ability level as measured by the subtests, and across subject areas.

Math Achievement

The results suggest a strong, positive relationship between both the level and field of teacher education and math achievement for young children with ASD, particularly for children with lower initial math achievement as measured by the math subtest. In addition, classroom composition and student-to-teacher ratios also appeared to be strong predictors of gains in student achievement relative to peers. There was also a significant relationship between the estimated test score gain children with ASD received from different factors in the analyses and their initial math achievement level. Students with lower initial ability levels appeared to gain the most from having teachers with degrees in special education at both the bachelor's and master's degree levels.

Children with ASD also varied in the benefit they received from different classroom composition variables based on initial math achievement. There was some evidence of a positive relationship between the percent of students in a child's classroom and changes in their standard scores between testing sessions, which may suggest that, on average, children with ASD fare better in specialized classrooms with respect to their math achievement. Student-to-teacher ratios had a strong, negative relationship with changes in student math scores relative to non-disabled peers, as was expected.

Reading Achievement

Teacher education appeared to be less relevant regarding gains in reading achievement for young children with ASD as measured by the reading subtest, however there was evidence that students received some benefit in terms of reading achievement from having a teacher with a degree in special education at both the bachelor's and master's degree levels. In the reading model, there was much higher variability in comparison to the size of the estimates, and it would be interesting to study the effects of different curricula in teacher education programs and how they relate to student outcomes.

With respect to classroom structure, student to teacher ratio had the largest impact on reading achievement for young children with ASD. Higher student-to-teacher ratios had a significant, negative association with changes in student standard scores on the reading subtest between testing periods. The percent of children with IEPs in the child's classroom had a positive, significant association with student standard scores on the reading subtest. These results seem to suggest that young children with ASD may do better in smaller classrooms with more specialized instruction.

Teachers and Classroom Aides

Based on the data available, the education of teachers was associated with a clearer impact on student achievement in math and reading than classroom aides. Higher levels of teacher education were positively correlated with gains in children's test standard scores between initial and follow-up tests. There was no evidence in these

analyses that the student to classroom aide ratio influenced changes in student standard scores. The lack of significance may be misleading, however, as there was no detailed information on the education, training, or background of the aides in the children's classrooms, or their expected roles in their classrooms. Education and training of classroom staff is an important area for consideration in future research. If properly trained classroom aides can help students achieve better outcomes, this may be a cost-effective way for schools with limited financial resources to better serve students with disabilities.

Model Limitations

While this data set is valuable due to the ages of the children in the study, and because the estimates are nationally representative, the small sample size is problematic and may result in imprecise estimates, or mask the significance of the estimates. The weights provided by PEELS for use in the analyses mitigated some of the risk of bias due to sample attrition and other factors, however this data set contained observations on approximately 50 children, while the data used by Hanushek, et al. (2002) and Sass and Feng (2012) contained information on thousands of children. The small sample size limited the ability to use different model specifications, such as the fixed effects model implemented in Hanushek, et al. (2002) analysis. Another concern resulting from the small sample size is the possibility of the results being driven by an outlying observation or by the functional form assumption. Despite these controls for child, teacher, and school characteristic variables, possible bias remains a concern.

Section V. Conclusion

The education and training of special education teachers is clearly an important factor in fostering math and reading skills in young children with ASD, however there is also a clear need for more study on effectiveness of specific training programs and types of teacher preparation. The rapidly increasing number of children in the United States being diagnosed with ASD necessitates that action be taken now to help children and families affected by the disorder to attain the highest degree of independence, and the best possible outcomes. In order to achieve this, it will be important to educate teachers and other educators in best practices and the ability to recognize and implement effective treatments for children with ASD in the special education system.

In addition to training and information for teachers, more data is needed on how to train classroom aides, paraprofessionals, and other classroom staff to effectively teach children with ASD. Thorough analysis of the relationship between education and training programs for special education classroom staff and student learning will require the use of larger, nationally representative samples of young children with disabilities, and reviews of the programs that train teachers and other classroom staff. The inconsistency in results regarding general education emphasizes the need for comprehensive teacher education that would assist teachers and other education professionals in developing and implementing effective education programs to provide the greatest possible benefit to children with ASD in all academic areas.

Important questions for consideration in future research include:

- What type of coursework or training enables teachers to provide effective education for children with ASD?

- Is there a connection between the type of training classroom aides and paraprofessionals receive and student outcomes?

- How do these findings transfer or relate to the social and emotional development of children with ASD?

- How do teacher education and classroom structure relate to the academic development of children with ASD in elementary and secondary special education programs?

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