A Penny and a Half and a Pool

Lead Poisoning and its Impact on Academic Achievement

by

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ABSTRACT

Lead is a neurotoxin that has been shown to have a long and lasting impact on the brains, bodies, and behaviors of those who are poisoned. It also has a greater presence in communities with high levels of poverty and minority populations. Compounded over time, the effects of lead poisoning, even at low levels of exposure, impact a child's readiness and ability to learn. To investigate the relationship between the risk of lead poisoning, school level academic achievement, and community demographics, three sets of data were combined. The Lead Poisoning Risk Index (LPRI), used to quantify the risk in each census tract of being poisoned by lead, standardized state assessment data for third grade reading and eighth grade math, and census 2000 demographic data were combined to provide information for all Arizona schools and census tracts. When achievement was analyzed at the school level using descriptive, bivariate correlation, and multivariate regression analyses, lead's impact practically disappeared, exposing the powerful effect of poverty and race on achievement. At a school in Arizona, the higher the percentage of students who are poor or Hispanic, African American or Native American, these analyses' predictive models suggest there will be a greater percentage of students who fail the third grade AIMS reading and eighth grade AIMS math tests. If better achievement results are to be realized, work must be done to mitigate the effects of poverty on the lives of students. In order to improve schools, there needs to be an accounting for the context within which schools operate and a focus on improving the neighborhoods and the quality of life for the families of students.

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Introduction

Since the 1982 release of *A Nation at Risk,* policymakers have turned their attention to educational reform by implementing systems of school accountability. The current model of school accountability, the No Child Left Behind Act of 2001 (NCLB) is a quota based accountability system involving rigorous standards measured at key benchmark years by high stakes assessments in an attempt to realize constant progress with special attention being paid to traditionally underserved or vulnerable subpopulations of students. Lack of measurable progress results in severe consequences for states, districts, schools, staffs, and students. The pressure applied by accountability should "increase educational output: Educators will try harder; schools will adopt more effective methods; and students will learn more" (Vasquez Heilig & Darling-Hammond, 2008, p. 75). Schools face the threat of closing schools, the replacement of superintendents, principals or teaching staffs, loss or redirection of financial support, conversion to a charter school, and public labeling of school progress. This should in theory push schools to perfect what they do. The longer consequences are applied, the more severe, disruptive, and destructive they tend to be to school campuses and school communities (Groves, 2002).

Research has critically reviewed the effects of No Child Left Behind (NCLB), questioning whether the policy and its accountability is producing what it set out to do. Though varying opinions abound, NCLB does not appear to produce the results it intended (Mathis, 2009; Lee & Wong, 2004, Mintrop &

Sunderman, 2009). The policy and accountability system touted to leave no child behind leaves poor, minority students behind to a much greater degree than before the system was implemented (Owens & Sunderman, 2006; Amrein & Berliner, 2002). A slate of unintended negative consequences have been identified as school systems work to meet the accountability requirements. One issue is validation of results and the inability of researchers to validate student achievement gains on state assessments by way of comparing them to national assessment data (Amrein & Berliner, 2002). A second unintended consequence is the tendency for districts and schools to "game" the system to improve scores. This "gaming" consists of manipulating the testing pool by excluding potentially low scoring students from testing (Vazquez-Heilig & Darling-Hammond, 2008), retaining students in grades prior to important testing windows (Allington & McGill-Franzen, 1992; Allensworth, 2005), and either identifying more students for special education or leaving them in special education longer (Haney, 2000; Figlio & Getzler, 2002). Additionally, states that have high stakes testing as an element of accountability see an increase in drop outs and a decrease in graduation rates (Amrein & Berliner, 2002). Even more troubling is that these unintended consequences fall upon students of poverty and color far more frequently(Vazquez-Heilig & Darling-Hammond, 2008; Allington & McGill-Franzen, 1992; Allensworth, 2005; Haney, 2000; Figlio & Getzler, 2002).

In addition to the aforementioned unintended consequences, schools that are identified as needing improvement for repeatedly not showing progress have higher percentages of Black and Latino students compared to better performing schools (Owens & Sunderman, 2006). The same is true for poverty – the schools identified as needing improvement enroll a higher percentage of low income students. So not only do exclusionary practices disproportionately impact low income minority students, but schools that are identified for needing improvement enroll greater percentages of minority and low income students. The brunt of consequences from school accountability most frequently falls on the shoulders of minority, low income students and communities, the very students and communities NCLB was envisioned to help.

Interestingly enough, what is also overwhelmingly present in these very same populations are the deleterious effects of out of school factors that compromise readiness to and ability to learn while in school. Few researchers or policymakers have addressed the possible impact of out-of-school factors on schools' academic performance. Factors such as food insecurity, inadequate health care, pollutants, family stress, and low birth weight all impact a student's readiness or capability to learn (Berliner, 2009). Schools have little control over these factors. Given the association between some of these factors and poverty (Berliner, 2006) and the high levels of economic segregation in U.S. schools (Saponto & Sohoni, 2007), these out of school factors could have a large and unmeasured impact on schools' academic performance. Should this be the case, then potentially the consequences applied for not making adequate progress may fall unjustly on schools for a context of learning entirely out of the school's control.

One such out of school factor is the prevalence of toxins in the environment, specifically, lead. One of the most significant environmental child health and development issue in the United States is the environmental exposure of lead to children (CDC, 1991). A naturally occurring element that has been used for over 5,000 years, lead is a proven neurotoxin that has deleterious effects on children's cognitive and physical development (Levin et al., 2008; Landrigan et al., 2002). Over the past 40 years, government regulations have been aimed at reducing occupational and environmental exposure to lead, reducing ambient lead levels by 94% from 1982-2002 (EPA, 2006). This drop in ambient lead levels went hand in hand with a corresponding drop in the blood lead levels of children in the United States. In 1976-1980, prior to regulations taking effect, U.S. children between the ages of one and five had a median blood lead level of 15 micrograms per deciliter (µg/dL), whereas in 1999, the median blood lead level for that same group of children was 1.9µg/dL (CDC, 2000). Though a dramatic drop in both measures, lead poisoned children still exist in high numbers. In 1999-2002, an estimated 310,100 (1.6%) U.S. children had blood lead levels greater than or equal to 10µg/dL and 1.4 million children (almost 14%) had blood lead levels in the 5µg/dL to 9µg/dL range (CDC, 2005).

Statement of the Problem

The negative effects of lead exposure on health, development, behavior, IQ and achievement are well documented (Bellinger et al., 1992; Canfield et al., 2003; Lanphear, Kietrich, Auinger & Cox, 2000; Lanphear et al., 2005; Fulton et al., 1987; Jusko et al., 2008; Surkan et al., 2007). Studies have shown that there is a greater likelihood that high levels of lead will be present in communities that have high minority population and high levels of poverty (Bernard & McGeehin, 2003). Given the other factors associated with poverty such as greater prevalence of health issues, crime and educational impacts, communities with high poverty and minority populations that also have a high prevalence of lead may experience an intricate web of compounding difficulties as the impact of lead exposure may be exacerbated by poverty (Vargas, Crall & Schneider, 1998; Berliner, 2009). If this is the case, children living in poverty have a greater likelihood of carrying with them to schools cognitive and behavioral deficits that will impact their academic skills, which may in turn affect schools' academic performance.

Purpose of the study

This study will explore the relationship of lead and school academic performance. Using data measuring these two different variables, this study will explore the risk of being poisoned by lead and its impact on the achievement of Arizona's youth. This study seeks to understand the characteristics of neighborhoods with a high risk of lead exposure. In particular, this study seeks an answer to the question: What is the relationship between the risk of lead poisoning, academic achievement and demographics? This study intends to add to the literature information related to out of school factors and their impact not only on a child's readiness and ability to learn, but also on school level academic achievement and the potential for application of school accountability consequences.

This cross-sectional quantitative study will explore the relationship between the risk of being poisoned by lead, academic achievement, community demographics and location. As a fundamental part of Arizona's targeted blood screening program, the Lead Poisoning Risk Index (LPRI) factors in Arizona demographic, socioeconomic, and housing data to quantify the risk by census tract of being exposed to lead. Arizona's Instrument to Measure Standards (AIMS) assessment, a state-wide standards based test that all public school students complete, will quantify academic achievement in reading, writing, and mathematics at grades three, five, and eight. To assist with understanding the context and characteristics of the neighborhoods in which these children live and these schools reside, 2000 Census socioeconomic and demographic information related to race, poverty, and household composition will be used along with school location coordinates for use with Geographic Information Systems (GIS) technology. Collectively, this study will explore the relationship between the LPRI, AIMS scores, and confounding sociodemographic and geographic variables.

Limitations

One disadvantage of a cross-sectional study is the lack of ability to detect any kind of pattern over a period of time. Trend data, whether positive or negative, cannot be discerned as there is no longitudinal data readily available for comparative purposes. This is particularly limiting in the case of lead poisoning, which due to the compounding nature of lead's physical and educational impacts year after year, a cross-sectional study only shows lead's impact as of that administration of the exam and does not show whether there was an increasing or decreasing impact over time.

Another limitation of this cross sectional study stems from the school level data aggregation. A school level analysis of the relationship between achievement and lead poisoning masks whether or not an individual was actually exposed to lead. The LPRI indicates the likelihood of being poisoned by lead but does not guarantee exposure. Without a measurement of individual lead exposure to verify the presence of lead, there is no way to know for sure whether any student was exposed using the LPRI. Even though the LPRI serves as a measure of potential or likely collective impact of lead on an area, the data aggregation at the school and census tract level masks the more accurate individual level of exposure, giving no indication as to how many of the subjects were exposed and how that contributed to the greater performance.

Delimitations

The cross-sectional nature of this study allows for a vibrant picture of school level achievement across the entire state of Arizona for 2005. It provides a robust data set of academic achievement and demographic characteristics inclusive of every public school in the state of Arizona for an academic school year. The LPRI has been calculated for every census tract in Arizona, giving an indication of the likelihood of being poisoned by lead for the entire state of Arizona. Combining these two inclusive state wide databases allow for an analysis of the relationship between academic achievement and the risk of being poisoned by lead for all of Arizona's schools.

Significance of the Study

The findings of this study will improve the understanding of the relationship between academic performance and an out of school factor like lead poisoning that might influence student learning. Aggregated at the school level, a relationship between the risk of lead poisoning and academic achievement could contribute to the discussion concerning consequences and school accountability programs. Depending on the direction and significance of these relationships, the assumptions and beliefs undergirding and guiding current school accountability programs will be challenged. Additionally questioned will be the appropriateness of applying school level consequences for achievement that is impacted to some possible degree by out of school factors, an irreversible dynamic over which schools have no control. With current Arizona state law and federal Race to the Top regulations mandating portions of teacher evaluation components be directly related to student achievement which can have an impact on incentive play, employment status and placement, the impact of the presence of an out of school factor like lead will be considered as well.

On a grander scale, with the desire for school improvement amidst tight economic times and a conservative legislative political climate, findings may contribute to the discussion related to where to direct resources to best and most efficiently ensure the highest level of school readiness and ability to learn for all of Arizona's children. With this in mind, findings may also contribute to policy discussions about the screening of children for lead exposure as well as the primary versus secondary approaches to attenuating or preventing the effects of lead in communities with high prevalence of lead.

Background

History. Lead is a soft, metallic naturally occurring element that is easily accessible, malleable, has a low melting point, and resists corrosion. From as far back as the third millennium BC, lead has been smelted and used by humans to make tools, jewelry, and other useful implements for a variety of purposes. The ancient Romans used it most commonly for pipes and plumbing needs as they provided their empire with water. As the world advanced technologically and commercially, lead became an integral part of many societies, particularly because of the need for coinage and its connection to the smelting of silver. With the Industrial Revolution and the rise in manufacturing, lead's presence and consequences dramatically increased worldwide (Levin et al., 2008). In the 20th century, lead as an additive to paint and gasoline had the most dramatic effect on environmental exposure.

Sources of Lead. Since 1924, a form of lead, tetraethyllead (TEL), was used as an antiknock additive in gasoline. As scientific data consistently documented lead having a negative impact on human growth and development, efforts began in 1959 to remove TEL from gasoline. As lead consumption via gasoline declined in the 1970's and 1980's, the ambient lead levels in the United States decreased proportionally (CDC, 1991). In 1980, approximately 80% of the air lead emissions in the U.S. was from leaded gasoline, while in 2002, on-road vehicles contributed less than one half of one percent of air lead emissions (EPA, 2006).

Another major source of contamination is lead based paint, currently the most common source of high dose exposure for children in the United States. The CDC estimated in 1991 that there was 3 million metric tons of lead used in the paint on 57 million of the privately owned and occupied housing units built before 1980, which was 74% of the all housing at the time (CDC, 1991). Even worse, there were 14 million unsound housing units where deteriorated conditions increase the exposure of inhabitants to lead via lead paint and dust. Of those 14 million dilapidated units, 3.8 million were homes for children.

Soil contamination is an additional long term source of childhood exposure as lead from the environment accumulates. Undisturbed soil has been shown to be contaminated at a depth of two to five centimeters, while disturbed, turned under urban soil is contaminated to far greater depths (EPA, 1986). Roadside soil, primarily contaminated from leaded gasoline, may have lead levels that are 30 to 2,000 ppm higher than what would occur naturally. Likewise, measures of lead in soil near smelters range as high as 60,000 ppm with lead levels decreasing exponentially with a 5-10 kilometer zone around the smelter complex (EPA, 1986).

Manufacturing and mining not only result in elevated ambient and soil lead contamination levels -- workers and the children of those workers also show elevated blood lead levels. Battery manufacturing, smelters, and solid waste incinerators are all high producers of environmental lead emissions. Baker et al.

(1979), studying two different smelters and a lead chemical plant, reported a clear relationship between the work environment and elevated blood lead levels in workers. Of particular note are the Port Pirie studies from one of Australia's largest smelters (Wigg et al., 1988; Tong et al., 1998) while Tsai, Shih & Sheu (1997) found similar associations in battery manufacturing plants in Taiwan. Not only is the product being smelted toxic, but the process of smelting is toxic as well.

Arizona's sources of lead are partly consistent with the rest of the nation, but there does exist a unique path for exposure due to our geographical and cultural link with Mexico (Arizona Department of Health Services, 2005). Lead based paint in older homes is one of the largest sources of lead. However, specific to our large Hispanic population and our cultural ties to Mexico, ceramic pottery and folk remedies that contain lead are just as big a source as leaded paint. Together, folk remedies, ceramic pottery, and leaded paint account for 44% of the amount of lead, while contaminated soil accounts for an additional 15%.

Ambient Reduction. As regulations were implemented in the late 1970's related to lead in gasoline, there was a dramatic change not only in gasoline's contribution to air borne lead but to overall ambient lead levels as well.[1] In 1980, approximately 80% of the air lead emissions in the U.S. were from leaded gasoline, yet that improved to a point that in 2002, on-road vehicles contributed

[1] In Bangladesh, attempting to discover a baseline effect of lead exposure from gasoline, Kaiser *et al*. (2001) found that across five communities representing a range of socioeconomic levels, almost 90% of children had blood lead levels high enough to affect their development and learning abilities.

less than half of one percent (EPA, 2006). With the decrease in lead from gasoline consumption, manufacturing became the top source of air borne lead. In 2001, industrial emissions accounted for 78% of ambient lead in the United States while fuel consumption accounted for another 10% (Levin et al., 2008). For children, however, lead based paint is the most common high dose source of lead (Levin et al., 2008).

Even though the EPA (2006) documents that from 1983-2002 the U.S. airborne lead emissions decreased 94%, in 1999-2002, an estimated 310,000 U.S. children still had a blood lead level greater than 10 micrograms per deciliter (µg/dL) and 1.4 million had blood lead levels between 5µg/dL and 10µg/dL (CDC, 2005). Even more troubling is that non-Hispanic black children are three times more likely to have a blood lead level greater than 5µg/dL and 13.5 times more likely to have a blood lead level greater than 20µg/dL than non-Hispanic white children (Bernard & McGeehin, 2003). With similar associations seen between blood lead levels and other risk factors like poverty, it is clear that even with a massive reduction in ambient lead levels over the last twenty years of the 20th century, hundreds of thousands of children living in the United States and disproportionally, those in poor, minority neighborhoods, are likely to have elevated blood lead levels.

Toxicity Defined

Official definitions of lead toxicity have changed over time as the negative health effects of lead have become better understood. Tellingly, in the past 40 years, the official definition of lead toxicity has been reduced by 80 percent. Before 1970, lead toxicity had been defined by the Centers for Disease Control (CDC) as the presence of lead in the blood at a rate of greater than 60µg/dL. In 1971, 1977, and 1985, the CDC lowered the official lead toxicity rate to 40µg/dL, 30µg/dL in 1977, and 25µg/dL, respectively (CDC, 1991). Each reduction in the threshold followed research that documented the negative effects of lead below the stated threshold. The current threshold for blood toxicity is 10µg/dL, which the CDC adopted in 1991.

But what does the current threshold of 10µg/dL mean? To make sense of this measurement, I will use the U.S. penny and a typical residential pool. The average U.S. penny weighs 2.5 grams. The common unit of measure for blood lead levels is micrograms, which is one millionth of a gram. If the penny was split into a million equal parts, each part would weigh approximately 2.5 micrograms (µg). This means four of those one million pieces would equal 10 micrograms, the current amount of lead for toxicity. A deciliter (dL) is equal to 3.3 liquid ounces or just under a half a cup. Four of the one millionth size pieces of the penny placed in a half cup measure that is a little over 80% filled is the approximate value of 10 micrograms per deciliter (10µg/dL). Applying it to a human body with the typical 5 liters of blood, it would take 50 of the half cups each with four of the one millionth size pieces of the penny in it to equal the 10µg/dL threshold for a person.

To make this relative dose a bit more tangible, this is where the pool comes in. The average residential pool in Arizona is 10,000 gallons, and in this case will equal the amount of blood in one person's body. Taking one and a half pennies and tossing them into this pool is the approximate ratio of lead to blood contamination to equal 10µg/dL, the current level of lead toxicity.

Treatment

When there is evidence of lead toxicity, there are two main methods for remediating the elevated blood lead levels. One is to work outside the body, the other works inside the body. The first approach is a removal of lead from the environment in which the person lives or works. This can be a variety of activities, such as vacuuming the lead laden dust in the home, removing leaded paint and using lead-free paint instead, changing out leaded pipes and fixtures in the home, and working with employers to minimize occupational exposure to lead. These approaches work to limit future exposure to lead.

To remediate lead exposure and hopefully mitigate the internal damage that could occur in the human body due to elevated blood lead levels, the most common approach is to use chelation therapy. Chelating agents are drugs that attach themselves at a molecular level to heavy metals like lead and mercury. This attachment of the chelating agents to the metals prevents or reverses the attachment of the lead molecules to body tissues, instead causing them to be excreted from the body via feces, urine, or filtration and preventing the damage. Doses are administered usually over a period of five days for a cycle of treatment. Patients are then recalled and retreated a month or two later, depending on the level of toxicity.

Over the years, several chelating agents have been used, each with varying complexities related to ease of administration, side effects and effectiveness

(Porru & Alessio, 1996). Dimercaprol, also know as British Anti Lewisite, or BAL, was used in the 1940's as a lead chelating agent. Though its oral administration was easy, the high frequency of side effects made it an unattractive option. Penicillamine (PCA) was also orally administered and did a good job of removing lead (via urine) in blood and soft tissues. It did not, however, remove lead from red blood cells. Calcium disodium ethylenediamenetetraacetic acid (CaNa2EDTA or EDTA) was the chelating agent of choice since the 1960's. Administered by intravenous injection (IV), or deep intramuscular injection (IM), it is very effective at removing lead with minimal minor side effects.

The newest chelating agent is succimer or DMSA, known clinically as 2,3 – dimercaptosuccinic acid. Primarily causing the lead to be excreted via urine, the orally administered drug is far less toxic than BAL, is rapidly absorbed in the body, and has few, infrequent side effects. Compared to EDTA, succimer seems to be more effective at the removal of lead from blood and brain tissues.

Impact of Lead

Since 1991, the CDC and World Health Organization (WHO) have questioned but not lowered the current 10µg/dL threshold because of unresolved questions about the effects of confounding variables and the precision of analytic and psychometric measurements (WHO, 1995). However, researchers continue to document adverse health and developmental issues associated with lead exposure below the 10µg/dL threshold. Longitudinal and cross-sectional studies have documented negative correlations between low levels of lead exposure (at or below 10µg/dL) and the unsettled behavior or diminished development of a fetus

(Bellinger et al., 1990), the prevalence of dental carries (Moss, Lanphear & Auinger, 1999), a delay in pubertal development of pubic hair and breasts and a delay in the age of menarche (Selevan et al., 2003), the reduction of gray matter in the frontal cortex of the brain (Trope, Lopez-Villegas, Cecil & Lenkinski, 2001), increased risk of ADHD (Nigg et al., 2007), lower height (Factor-Litvak, Wasserman, Kline & Graziano, 1999), as well as a host of others. Add to this the preponderance of research documenting the negative relationship between low levels of exposure to lead and behavior, intelligence, and academic performance, it is no wonder the current threshold is in question.

Intelligence. Lead has devastating effects on individuals. Taken collectively, lead's impact on individuals is extended and exacerbated in communities. Gilbert and Weiss (2006) surmised that with a five point loss of the average IQ of a naturally distributed national population due to lead, there would be a 57% increase in the number of children with extremely low IQ (<70) and a 40% reduction in the number of children scoring in the very superior range (IQ> 130). This would result in a significant loss in the number of our brightest minds and a massive increase in the number of citizens declared mentally disabled. Surkan et al. (2007) took it a step further, combining both academic achievement and full scale IQ scores, showing that even when controlled for IQ, academic performance was still lower than what would be expected. This population shift in IQ and achievement would produce a cadre of students whose collective performance is not only lower overall, but lower than would be expected based on

IQ. Lead's impact on a community could feasibly create an underachieving, lower performing population.

Economic. From an economic perspective, lead toxicity carries with it substantial annual costs. Using data equating schooling, intelligence, and labor market outcomes, Salkever (1995) determined that lead at a level of 1µg/dL and its corresponding loss of .25 IQ points results in approximately $7.56 billion annually in lost wages for a cohort of children. He also posited that the loss of 1 IQ point results in a 2.3% reduction of lifetime earnings. Landrigan et al. (2002) took these amounts of loss and applied his analysis to five year old children who in 1997 had a mean blood lead level of 2.7µg/dL. This resulted in a total annual loss of $43.4 billion of lifetime earnings per cohort of children. Compounded year after year, lead's impact runs into the hundreds of billions of dollars per cohort. From individual health and developmental impacts, losses of future earnings, to an impact on national crime rates, lead is a neurotoxin that has grave impacts at many levels.

Social. A number of studies suggest that lead poisoning has broader social costs. Nevin (1999, 2007) has looked at blood lead levels trends since the 1900s and argued that long-range crime trends are dramatically impacted by lead exposure, mostly from industrial exposure, leaded paint, and leaded gasoline. Comparing consumption of gasoline lead and United States crime rates, Nevin (2000) found significant relationships between lead and rates for murder, rape, robbery and assault. In follow up work using international crime statistics, the same was found to be true in countries throughout the world (Nevin, 2007).

These results were right in line with Stretesky & Lynch's (2004) findings of lead's impact on violent and property crime, even after controlling for a variety of sociological predictors of crime.

On an individual level, lead's social costs can be seen in a variety of ways. As a result of lead's compounding effect on IQ and behavior, children with elevated blood lead levels are more likely to be seen as troubled youth. Adjudicated delinquents were seven times more likely to have an elevated blood lead level (Needleman, 2002). Similarly, a survey of children in the Philadelphia foster care program indicated that almost 90% of children in foster care in the mid 1990s had elevated blood lead levels (Chung, Webb, Clampet-Lundquist & Campbell, 2001). Michael Martin, a research analyst for the Arizona School Board Association, refers to several pieces of research that draw connections between lead poisoning, ADHD, and the propensity of these poisoned, ADHD youth to mitigate the effects of distractibility and impulsivity with drugs and alcohol (Martin, 2002). Though placement in foster care is not a crime, incarceration, drug use, and placement in foster care all draw upon costly social programs, the demand for which seem to be exacerbated by the impact of lead poisoning.

Summary

Lead's well documented physiological and behavioral effects manifest themselves in a variety of broad and costly academic, economic, and social consequences. As children suffer lead's effect and come together in schools, readiness and ability to learn are impacted in ways yet to be fully understood.

This chapter attempts to provide a general overview of the importance of exploring lead's impact on academic achievement. Chapter 2 will lay out in detail what the research says related to the current body of knowledge surrounding lead's impact, exposing a gap in the research this study will attempt to address. Chapter 3 will document the research design, characteristic of the data, the limitations and strengths of this design, and the analyses to be employed to understand and make sense of the data. Chapter 4 will document specifically the results of the statistical analyses while Chapter 5 will synthesize the findings and place them accordingly into the existing body of research.

Chapter 2

Literature Review

Lead carries with it a lengthy catalogue of deleterious health, developmental, and intelligence effects. Though the current threshold established by the Centers for Disease Control (CDC) is 10 micrograms per deciliter (µg/dL), a growing body of evidence is accumulating showing negative effects below this threshold (Bellinger et al., 1992; Canfield et al., 2003; Lanphear, Kietrich, Auniger & Cox, 2000; Lanphear et al., 2005; Fulton et al., 1987; Jusko et al., 2008; Surkan et al., 2007). In the sections below, I review the research on the relationship between lead exposure and its impact on the health, mental development, and academic achievement of children which will provide an important backdrop for my analysis.

Fetal Impact

Considerable work has been done to study the effect of lead on the development of a fetus. At best, data seems to support the conclusion that there is some impact of lead exposure on fetal development but the inconsistencies in results of studies suggest that additional studies are needed. In her review of research on prenatal lead exposure, Erhnhart (1992) noted that the inconsistency of fetal impact results could be attributable to the difficulty of accounting for the many factors that influence children's development, suggesting great opportunity for future research related to low exposure to lead and fetal development.

Fetal development, particularly height, weight, gestational age, and behavior are all areas where the presence of lead has shown to have a significant relationship. Fetal birth weight was negatively associated with umbilical cord blood lead levels (UCBLL) greater than 15µg/dL(Bellinger et al., 1990). Fetuses with blood lead levels greater than 15µg/dL tended to be 80-100 grams smaller than non poisoned fetuses. Compared to fetuses with low levels of lead, fetuses with blood lead levels greater than 15µg/dL were 1.5 – 2.5 times more likely to have lower birth weights than fetuses with blood lead levels below 15µg/dL. This finding of an impact around the 15µg/dL level is consistent with other research of an effect at a threshold of 12-15µg/dL (Bornschein et al., 1989; Gonzalez-Cossio et al., 1997).

There is conflicting evidence about the relationship between lead exposure and gestational age, the conflict possibly being related to the different thresholds of blood lead levels explored in the studies. Bellinger et al.'s (1990) study of low level lead exposure, a study sample that averaged a blood lead level of 7µg/dL, showed a slight increase in gestational age due to lead. This was not supported, however, by Rothenberg et al.'s (1988) higher level lead exposure data which had 70% of its sample with a blood lead level greater than 10µg/dL. In these two studies, with differing levels of lead exposure, the study with the lower exposure showed an impact on gestational age while that effect was not found in the study with the higher level of exposure. Additional research is called for.

Rothenberg et al. (1988) did discover, however, a connection between lead and fetal behavior. When umbilical cord blood lead levels increased from thirty six weeks of gestation to birth, the fetus was less receptive to being consoled by others when upset as well as it had greater difficulty calming itself. This measure of consolability and self regulating behavior of a fetus was seen during the first thirty days of life.

Looking a bit further into the future, some research suggests long term effects of fetal lead exposure on development. For example, Factor-Litvak, Wasserman, Kline & Graziano (1999) found that elevated blood lead levels were not significantly associated with fetal height. However, later in life, children at four years of age showed a 7 cm declination in height for each log unit increase in blood lead level. The height decrease was also found to be prevalent in early teen years as children with higher lead concentrations were associated with decreased height (Selevan et al., 2003). Particularly interesting in the Selevan et al. study is the fact that the decreased height pattern was evident at extremely low levels of exposure, comparing children with 3µg/dL to those with 1µg/dL. The smallest of exposure, at levels 70% to 90% of the CDC's threshold for toxicity, showed an impact.

Physiological Development

As the body develops and matures, lead has been shown to significantly impact the body. One long term physiological effect of lead is its impact on the prevalence of dental caries. In a comparison of urban and rural children with relatively low levels of lead exposure, lead was positively associated with an increase in dental caries with urban children showing a particularly larger penchant for developing dental caries. Drawing from the third National Health and Nutrition Examination Survey (NHANES III), even after controlling for diet, dental care, and sociodemographic characteristics, children with a 5µg/dL increase in blood lead level were 1.8 times more likely to have dental caries (Moss, Lanphear & Auinger, 1999). Though the data implied a similar likelihood for low income children to receive restorative dental care compared to more affluent children, these same low income children were five times more likely to have untreated dental caries. They would seek out care, but would not receive sufficient services to remediate all of their dental needs. Additionally, for children aged six to fourteen and fifteen to eighteen, African American and Mexican American children were twice as likely as their non Hispanic white counterparts to have one or more decayed permanent tooth (Vargas, Crall & Schneider,1998). Similar to Vargas, Crall & Schneider (1998), Moss, Lanphear & Auinger (1999) determined that poverty and its impact on dental caries is at least partially explained by lead.

Turning to life in the early teen years, lead has been shown to have a marked impact on measures of pubertal development, particularly in African American and Mexican American girls. In an analysis of the NHANES III data for 2186 non Hispanic white, African American and Mexican American girls aged eight to eighteen years of age, Selevan et al. (2003) found higher blood lead concentrations associated with delays in all pubertal measures for African American girls and breast and pubic hair development in Mexican American girls. Delays in age of menarche (for African Americans) and breast and pubic hair development (for African American and Mexican Americans) ranged from two to six months in length. As with decreased height, the detected delays in pubertal development came out of comparisons of low level lead exposure, comparing children with blood lead levels of 3μg/dL to those with blood lead levels of 1μg/dL. These findings maintained their significance even after controlling for racial and ethnic group characteristics as well as other confounding variables like socioeconomic status (Selevan et al., 2003). Even at very low levels of lead exposure, pubertal developmental delays were witnessed with a greater prevalence for African American and Mexican American girls.

The Brain

The preponderance of research on lead's impact on children has focused on intelligence, achievement, and behavior, all of which have a direct connection to the brain. As children grow and develop, lead has been shown to have an impact on the size and amount of gray matter in the brain. Trope et al. (2001) looked specifically at the ratio of particular metabolites in the frontal lobe, the area of the brain which involves functions such as attention, executive functions, social-behavioral conduct, and impulse control. Researchers sought the ratio of N-acetylaspartate (NAA), a metabolite associated with neurons, and creatine (Cr), a stable metabolite that is constant following neuron loss. The ratio of NAA levels to Cr has been shown to be lower in neurologically delayed children (Kimura et al., 1995). Compared to control groups, lead exposed subjects exhibited lower NAA/Cr ratios, which was suggestive of neuronal loss in the region examined (Trope et al., 2001).

Additional studies have found strong associations between elevated blood lead levels in children and decreased gray matter volumes, particularly in males (Brubaker, Dietrich, Lanphear & Cecil, 2010; Cecil et al., 2008). Looking at white matter in the brain, Brubaker et al. (2009) reported associations between elevated blood lead levels and altered myelination and axonal integrity. As the white protective sheath (myelin) that surrounds the axons is compromised, the nerve cells can no longer fire correctly. With the sheath diminished, the axon is dangerously exposed, resulting in a diminished or loss of axonal use – a permanent damaging of the brain and its function. Areas of the brain impacted by the loss of white and gray matter, particularly the prefrontal cortex and the anterior cingulated cortex, are responsible for executive function, mood regulation, and decision making. Children with damaged and diminished areas of the brain suffer grave behavioral and intellectual consequences the rest of their lives.

As the volume of the brain is depleted, there will be subsequent diminished performance of executive functions and attention, a pattern of behavior similar to people diagnosed with ADHD. Looking at children ages 8-17 years old, Nigg et al. (2007) explored low level (below 5μg/dL) lead exposure and its impact on ADHD, specifically its connection to the striatal-frontal circuitry. Exposure to lead at levels less than 5μg/dL hindered the striatal-frontal circuitry, negatively effecting response suppression and response variability, executive functions directly linked with ADHD. Though not a causal link, there appears to be a relationship between lead, ADHD, and the striatal-frontal circuitry.

The finding of Nigg et al. that executive function is impacted by low level lead exposure is consistent with the Surkan et al. (2007) finding of executive function deficits due to lead in the 5μg/dL to 10μg/dL range. Focusing on an even lower level of blood lead levels, Braun et al. (2006) reported that children with lead levels at or above 2µg/dL were four times more likely to be diagnosed by a doctor with ADHD. Braun and his colleagues claimed that 290,000 cases of ADHD could be attributed to environmental lead exposure.

Problematic across all of the studies investigating lead's connection to ADHD is the wide variance of blood lead levels between studies, making clear comparisons difficult. However, though the mean blood lead levels varied considerably, with high levels of exposure in Trope (geometric mean 39.93µg/dL) and low levels in Nigg (geometric mean 1.03µg/dL) and Surkan (all less than 10µg/dL), all studies showed brain disrupting impacts, impacts that potentially could result in IQ and behavioral problems long term. Apparently, regardless of the level of lead exposure, the brain was negatively impacted.

Behavior

Given what is known of lead's impact on the brain, it would be expected that there would be impacts on behavior, as well. In a 1992 review of data regarding low level prenatal lead exposure, Ernhart (1992) posited that despite a few studies with positive findings, "there is little consistency in the evidence of behavioral effects of …lead exposure" (p. 37). Whatever small increases in lead's impact that were detected, they took place at ages younger than six months while additional studies were limited by sample size, range of exposure, and study design. Since then, much work as been done to account for the aforementioned limitations, as well as expand the age of subjects being studied.

Defining behavior in a very narrow manner, one possible measure of behavior is physical behavior or control of the body. Applied to infants, the Bayley Scales of Infant Development, and specifically its Psychomotor Development Index (PDI), measures "the degree of control of the body, coordination of the large muscles and finer manipulatory skills of the hands and fingers" (Ernhart, 1992, p.35). Using data from a prospective study in Mexico City, Tellez-Rojo et al. (2006) found dramatic negative impacts of lead on the PDI. An increase in one log unit of 24 month blood lead level was associated with a 5.4 point reduction in PDI. Furthermore, greater impact was seen below 10µg/dL with the steepest decline measured below 5µg/dL. Lead, even at very low levels, has a severe negative impact on a child's control of his body.

Stepping back a bit and taking a more generalized look at behavior, lead is associated with increased behavior problems. Regardless of the age of the children being studied, lead poisoned children have more behavioral issues. Starting with children ages birth to three years of age, a prospective study of children with a wide range of blood lead levels by Wasserman et al. (1997) found clear connections between lead and behavior. Using the Child Behavior Checklist (CBCL), lead was found to be associated with the CBCL subtest scores for Withdrawn and most clearly Destructive. Comments such as "can't concentrate" and "quickly shifts from one thing to the next" are characteristics of the Destructive child. Quantifying this increase, Factor-Litvak, Wasserman, Kline & Graziano (1999) showed that a 10µg/dL increase in blood lead level resulted in an increase ranging from 0.8 points for Sleep Problems to a 2.1 point increase for the

Withdrawn subscale score. There were also small increases in other subscale scores for Sleep, Somatic Problems, Anxious/depressed, and Aggressive behavior.

For children aged two to seven years old, lead continues to have a negative impact on children's behavior as they prepare to enter school. In a prospective observational study, Chen et al. (2007) found that when parents and teachers used the Behavioral Assessment System for Children (BASC) with a teacher rating scale (TRS) and a parent rating scale (PRS), blood lead levels had direct effects on a behavioral symptoms index, externalizing behaviors, and school problems. The PRS showed an association between lead and conduct and problems in school, while the TRS showed lead associated with school problems, externalizing problems, and an index of behavioral symptoms. Even more profound, on a sample of first grade students between the ages of six and a half and seven and a half years old, hair lead measures, an indication of chronic lead exposure, showed a stronger relationship with classroom attention deficit behavior than did other measures such as blood, bone, or dentine (Tuthill, 1996). Additionally, the strongest relationship was between students with high lead level and physician diagnosed ADHD – a narrower, more extreme disorder than the general behaviors Tuthill assessed via the abbreviated Boston Teacher's Rating scale. The most significant relationship was between lead and a doctor verified disorder, as opposed to a measure derived from a battery of broadly tested behaviors that indicated the severity of lead's impact on attention.

Lead's behavioral impact is seen well into the elementary aged years. A retrospective cohort study followed seven year olds for four years, comparing bone lead levels and scores on the Child Behavior Checklist (CBCL). Just like the Wasserman et al. (1999) and Factor-Litvak et al. (1997) studies, lead poisoned children showed a significant association with CBCL cluster scores (Needleman et al., 1996). Additionally, at age eleven, children with high lead levels also had higher scores on self reported acts of delinquency. Needleman et al. (2002) detailed a similar increase in self reports of delinquency in lead exposed adjudicated youth.

In sum, looking at children from birth to eleven years old using a variety of lead exposure measures, lead poisoned children self report and parents and teachers observe significantly more behaviors that are destructive, anti social, and delinquent. Heading into adolescence, lead and behavioral effects continue to interact in negative ways. The destructive, anti-social, and delinquent behaviors seen in children aged seven to eleven eventually can manifest themselves into illegal activities. Not only does lead seem to be a contributor to criminal activity, when individual exhibitions of negative behavior are taken collectively, lead exposure rates and rates for serious crimes are significantly similar. Elevated lead levels are associated with an elevated risk of adjudicated delinquency (Needleman et al., 2002). For adolescents aged twelve to eighteen, adjudicated delinquents were four times more likely to have elevated lead levels. Combine these individuals into patterns of behavior and the lead adjudicated delinquent connection fits nicely with the work of Stretesky and Lynch (2004) whose work correlated ambient air lead levels and rates for property and violent crime. As air lead levels increased (thus increasing exposure to and poisoning by lead), so too did crime rates. Comparing consumption of gasoline lead and United States crime rates, Nevin (2000) found significant relationships between lead rates for murder, rape, robbery and assault. In follow up work using international crime statistics, the same was found to be true in countries throughout the world (Nevin, 2007).

As children grow up with lead in their system, there is an ever increasing amount of problematic behavior. What may start out as an inability of a fetus to console itself, can turn into heightened distractibility, lack of focus and aggressive behavior in the primary school aged years. Eventually, this behavior can result in delinquent, anti-social, and destructive behavior that taken collectively has a significant relationship with crime rates worldwide. Lead is a contributor to negative individual behaviors and seems to be a factor in world wide negative and sometimes criminal behavior.

Intelligence

The most commonly researched area related to lead's deleterious effect is its impact on measured intelligence. Whether longitudinal or cross-sectional, small sample or nationally representative sample, and across a range of mean blood lead levels and socioeconomic levels, lead has a significant inverse relationship on children's IQ (Bellinger, Stiles & Needleman, 1992; Canfield et al., 2003; Lanphear, Kietrich, Auinger & Cox, 2000; Lanphear et al., 2005; Fulton et al., 1987; Jusko et al., 2008; Surkan et al., 2007).

Studies have consistently shown that a 10µg/dL increase in blood lead level results in a loss of IQ points. For example, in a longitudinal study of economically advantaged children, Bellinger, Stiles and Needleman (1992) found that for every 10µg/dL increase in a child's blood lead level, there was a 5.8 point decline in the Wechsler Intelligence Scale for Children-Revised (WISC-R) full scale IQ score. Similarly, in a longitudinal study, Canfield et al. (2003) documented a 4.6 IQ point loss for the same 10µg/dL increase in the child's blood lead level. Using bone lead amounts instead of blood lead levels, Wasserman et al. (2003) documented a 5.5 point loss in full scale IQ points on the WISC-R for each doubling of the bone lead level. For each measured increase in the amount of lead present in a child's body, there is a significant and marked decrease in IQ points.

As powerful and significant as this loss of IQ points from a 10µg/dL increase may sound, the association between lead exposure and IQ seems to be strongest at low levels of lead exposure. Looking more closely at low levels of lead exposure, Schwartz's (1994) meta-analysis of seven studies highlighted a steeper slope of IQ declination in blood lead levels less than 15µg/dL. At even lower levels of exposure, an analysis of the Third National Health and Nutrition Examination Survey (NHANES III) data showed an inverse relationship between blood lead levels below 5µg/dL and IQ (Lanphear, Kietrich, Auinger & Cox, 2000). Fulton et al. (1987) and Schwartz's (1994) reanalysis of Bellinger, Stiles and Needleman's 1992 study indicate there may be no threshold at all for the effect of lead. If that is true, the effects of lead on children have been vastly underestimated.

Current research has taken a hard look at the lead-IQ relationship below the current 10µg/dL CDC threshold for toxicity. As the blood lead level increases from 1µg/dL to 10µg/dL, Lanphear et al. (2005) and Canfield et al. (2003) showed a 6.2 and 7.4 respective IQ point loss. Taking a different look at the low level lead exposure range but still staying below the 10µg/dL threshold, Jusko et al. (2008) compared children with blood lead levels in the 5-10µg/dL range to children in the 1-2µg/dL range, and found that the children in the 5-10µg/dL range exhibited 4.9 fewer points. Similarly, Surkan (2007) found an IQ loss of 5 points which for the children in the 5-10µg/dL range, they were two standard deviations lower than children whose blood lead levels were 1-2µg/dL. This is a large statistical difference, as well as a socially significant, difference. These findings were quite similar to Wasserman et al.'s (2003) result of a 5.5 point loss when bone lead levels double. A consistent IQ point loss has been detected, but when compared to the loss of IQ points of higher levels of lead exposure, the amount of loss of IQ points in the 1µg/dL to 10µg/dL range was shown to be twice the amount of loss from 10-20µg/dL and four times the amount of loss experienced from 20-30µg/dL (Lanphear et al., 2005). In the blood lead level range of 1µg/dL to 10µg/dL, the spectrum of blood lead levels below the official threshold, significantly large losses of IQ points are seen, more so than the loss above the threshold. Apparently, children experience negative effects due to low level exposure to lead, and there seems to be a steeper slope of decline in IQ between 5µg/dL and 10µg/dL.

Achievement

As losses in IQ are realized, so too are there negative impacts on academic achievement. Even with blood lead levels below the CDC threshold of 10µg/dL, there are deficits in intelligence, visual spatial skills, executive function and IQ-adjusted academic achievement (Surkan et al., 2007).

One avenue to measure lead's impact on achievement is to look at special achievement subtests that are a part of most standardized intelligence tests. One such measure of achievement is the Performance IQ subscale score from the Wechsler Intelligence Scale for Children-Third Edition (WISC-III). The Performance IQ score is a measure of visual spatial abilities. Comparing children with blood lead levels ranging 1-2µg/dL to those who measured 5-10µg/dL, Surkan et al. (2007) highlighted a 5.3 point loss on the Performance IQ subscale score for the elevated blood lead level group. Similarly, as bone lead levels doubled, Wasserman et al. (2003) documented a 6.3 point declination in Performance IQ. A comparable performance measure, the Perceptual Performance subscale on the McCarthy Scales of Children's Abilities, was shown to decline by 2.3 points for each log unit increase in blood lead level (Bellinger et al., 1991). Multiple ranges of lead exposure measured a variety of ways using a variety of assessments all showed a loss of achievement due to lead.

Turning to a more content based focus of achievement, data continue to show an inverse relationship between elevated blood lead levels and math and reading scores (Lanphear, Kietrich, Auinger & Cox, 2000; Surkan et al., 2007; Fulton et al., 1987). In a general examination of advantaged, low level lead exposed (less than 7µg/dL) children, a significant inverse relationship was found between lead levels and five subtests on the Wechsler Intelligence Scale for Children - Revised (WISC-R), with arithmetic and spelling most notably being impacted (Bellinger, Stiles & Needleman, 1992). Fulton et al. (1987) showed a 5.1 point loss on the word reading test of the British Ability Scale in a cross sectional study of children aged six to nine years old. Lowering the exposure even more, Lanphear, Kietrich, Auinger and Cox (2000) discovered cognitive deficits below 5µg/dL for a sample of subjects with a mean blood lead level of 1.9µg/dL. Highlighting that arithmetic and reading scores on the Wide Range Achievement Test-Revised (WRAT) were negatively impacted by lead, particularly reading, Lanphear et al. indicated that each 1µg/dL increase in blood lead level resulted in a 0.7 point loss in arithmetic and a 1 point loss on reading.

Even more startling than the consistency of an impact on math and reading scores is that when those results were controlled for the impact of IQ, the loss in reading and math scores became more pronounced. Surkan et al. (2007) showed that children with blood lead levels in the 5-10µg/dL range, when compared to children with blood lead levels in the 1-2µg/dL range, scored 7.9 points and 8.7 points lower on the reading and mathematics subtest on the Wechsler Individual Achievement Test (WIAT). As dramatic as this finding was, when IQ was accounted for, the significance of the lead-reading and arithmetic relationship increased. "This implies that the children's academic achievement was significantly lower than would be expected based on their intelligence (i.e. an aptitude-achievement discrepancy)"(Surkan et al., 2007, p. 1176). This gap between aptitude and achievement is the kind of gap that is traditionally used to determine eligibility for special education services for students. Apparently, lead has a dramatic impact on math and reading achievement and has been shown to create an aptitude-achievement discrepancy, increasing the chance of lead poisoned children qualifying for placement in special education.

In a school setting, lead's inverse relationship with achievement, IQ, and behavior culminates in an unfavorable experience. Research frequently focuses on standardized assessments of intelligence and performance, but lead's impact has also been measured via a variety of school system measures. Using classroom assessments in a study of North Carolina students, Miranda et al. (2007) found that high blood lead levels equal lower scores and higher failure rates on the end of course exams. And like previously mentioned studies (Lanphear, Kietrich, Auinger & Cox, 2000; Surkan et al., 2007; Bellinger et al., 1991), this effect was seen below the 10µg/dL threshold, and possibly even below 5µg/dL. Broadening the scope from the classroom to the school level, lead poisoned students have lower class rank, increased absenteeism, lower vocabulary and grammatical reasoning scores, were almost six times more likely to have a reading disability, and were seven times more likely to drop out of high school (Needleman et al., 1990). And these are low lead level exposed children, described by researchers as having "no outward signs of lead poisoning" or "any overt signs of lead toxicity" (Needleman 1996 and 2000).

Whether a performance subscale IQ, a subscale content score, or an end of course exam, elevated blood lead levels, particularly blood lead levels between 5-

10µg/dL have significant negative impact on academic achievement. Add to this the previously reported lead induced increase in parent, teacher, and self reported destructive and delinquent behaviors, and life as a school aged child is one of failure and difficulty with a significantly increased likelihood of dropping out of school. Considering the economic cost of supporting drop outs and factoring in the loss of life time earnings, lead's impact not only is costly for the school experience of the individual, but it is costly for society as well.

Readiness to Learn

Lead is a proven neurotoxin. Whether measured via blood, bone, tooth, or hair, its presence has negative and lasting effects. From the moment it enters the body of a fetus, a cycle of physiological and neurological deficits are created. Should a child escape exposure in utero only to ingest lead through other avenues postnatal, a similar litany of physiological and neurologically effects are created. As behavior, intellect, and development are impacted, these consequences layer upon each other over time and have harmful academic consequences for the individual. When the numbers of children in high lead environments get older, there are broad social and community level impacts such as delinquency and crime rates that increase (Stretesky & Lynch, 2004; Nevin, 2000, 2007) while potential earnings decrease (Landrigan et al., 2002). And somewhere in the middle, in neighborhoods with high levels of lead, whether it is high ambient lead levels or a plethora of homes older than 50 years old, large cohorts of children grow up suffering from exposure to lead will come together in schools. Common to these lead exposed children is a diminished readiness and capability to learn and a heightened tendency for behavior and attention problems. This being the case, the individual performance, and collectively, the school performance will be negatively impacted as well. Lead has a well documented impact on the individual, and as individuals come together in group settings like schools, the individual impacts are aggregated, compounding and exacerbating the power of the impacts.

There is also a strong chance that with such a small number of children actually screened for blood lead levels, a large number of children with unmeasured lead related cognitive and behavioral deficits are showing up expecting to learn like all the other non poisoned students. When annual assessments are administered carrying with them potential consequences for students, teachers, schools and districts, lead poisoned, brain damaged students are bound to perform lower, a performance that research makes clear, is not their fault. Should a student's or a school's pattern of performance not meet state and federal accountability expectations, consequences follow. If the pattern is consistent, the consequences will become more severe. If the school's performance is related to lead, then lead's impact should be taken into consideration prior to implementing consequences. That is what this research is intended to do. In what follows I explore the relationship between lead and academic achievement.

Summary

Lead is undeniably one of the most significant environmental child health and development issues in the United States (CDC, 1991). With a well documented range of deleterious physiological and intellectual impacts in people from pre-birth through adulthood, exposure to lead, particularly at levels below the CDC's threshold of 10µg/dL, is a costly, debilitating experience. Lead's impact on height, weight, physical development, behavior, intelligence, achievement, and health can result in disorders, increased crimes, decreased performance and severe losses of lifetime earnings. For children entering school with discernable lead levels, however measured, the associated behavioral, intellectual, and achievement deficits compound year after year. This surely compromises a child's readiness and ability to learn. Discernable levels of lead in the students of a school manifests itself in lower than expected performance, a pattern that could carry severe and disruptive consequences for individuals and the schools they attend. This study explores the relationship between lead exposure and academic achievement at the school level.

Chapter 3

Methodology

This chapter will describe the research design, case selection, database, and statistical analyses that will be employed to investigate the relationship between lead and academic achievement for the state of Arizona.

Arizona is a state with 1.08 million students in over 2,100 public schools. Of these students, 49% are white, 36% are Hispanic, 9 % are Native American, 5% are African American, while 2% being Asian (National Center for Educational Statistics). For school aged children aged five to seventeen years of age, 18.9% of them live with families in poverty, which according to the U.S. Census Bureau, the income level for a family of four to be declared at the poverty level is $21, 756 (2006).

Arizona administers as part of its state-wide assessment program two different tests to students in grades two to ten. The purpose is to fulfill state and federal guidelines to measure student progress toward mastery of adopted state curriculum standards. At the high school level, students must take the Arizona Instrument to Measure Standards (AIMS) in reading, writing, mathematics, and science, with a passing score being required on the reading, writing, and mathematics portion in order to graduate. Students in second through ninth grade take the norm referenced Stanford 10 and the standards based AIMS. The Stanford 10 is administered as a stand alone assessment to students in second and ninth grade, while students in grades three through eight have the Stanford 10 embedded in the AIMS exam. All students grades three through eight take the

AIMS reading and math portions. AIMS science is administered to grades four and eight and writing is administered to grades five, six, and seven. All public school students are required to participate in the state-wide assessment program.

The results of these assessments are used for a variety of purposes. On a student level, the scaled scores and their accompanying performance labels give students and families an indication as to how successfully the child mastered the content standards. Students can earn a label of Excelling, Meets, Approaches, and Falls Far Below. Aggregated at a school level, scale scores are incorporated into a complex formula to measure to effectiveness of a school. Should a school not consistently meet predetermined benchmarks for performance as measured by the average scale score for a particular content assessment at a particular grade level, elements of accountability are applied in an attempt to correct the poor performance. Schools also receive labels as a type of grade for the school's performance. The labels for public school performance in the state of Arizona are Excelling, Performing Plus, Performing, Underperforming, and Failing. The components of the statewide assessment program that meet the various requirements of state and federal legislation are coordinated and monitored by the Arizona Department of Education.

Another state department charged with the well-being of Arizona students is the Arizona Department of Health Services (DHS). As one part of its multifaceted services, DHS is the organization that administers the Arizona Childhood Lead Poisoning Targeted Screening Plan, Arizona's blood lead screening program for children. Keeping costs of universal screening in mind, the

Center's for Disease Control recommended that the cost benefits of universal blood lead screening are diminished in circumstances where less than 12% of the children are poisoned and less than 27% of the housing was built before 1950 (CDC, 1997). Arizona, having met these criteria, developed a targeted screening plan that uses the Lead Poisoning Risk Index (LPRI), a formula that calculates the risk of being poisoned by lead in each zip code and census tract. The higher the index score, the higher the chance of being exposed to and poisoned by lead.

Research Design

This cross-sectional quantitative study will use secondary data analysis to explore the relationship between the risk of being poisoned by lead, academic achievement and possible confounding community demographics. The study will incorporate three major data sources, all of which are publicly available sources. No student level data will be used.

The cross-sectional nature of this study allows for a comprehensive picture of school level achievement across the entire state of Arizona for 2005. It provides a robust data set of academic achievement and demographic characteristics inclusive of every public school in the state of Arizona for an academic school year.

One disadvantage of a cross-sectional study is the lack of ability to detect any patterns over a period of time. Trend data, whether positive or negative, cannot be discerned as there is no longitudinal data readily available for comparative purposes. This is particularly limiting in the case of lead poisoning, which due to the compounding nature of lead's physical and educational impacts year after year, a cross-sectional study only shows lead's impact as of that administration of the exam and does not show whether there was an increasing or decreasing impact over time.

Another limitation of this cross sectional study stems from the data being aggregated at the school level. A school level analysis of the relationship between achievement and lead poisoning masks whether or not an individual was actually exposed to lead. The Lead Poisoning Risk Index (LPRI) indicates the likelihood of being poisoned by lead but does not guarantee exposure. Without a measurement of individual lead exposure to verify the presence of lead, there is no way to know for sure whether any student was exposed using the LPRI. Even though the LPRI serves as a measure of potential or likely collective impact of lead on an area, the data aggregation at the school and census tract level masks the more accurate individual level of exposure, giving no indication as to how many of the subjects were exposed and how that contributed to the school's performance.

Sampling/Census

For this study, all public schools in the entire state of Arizona are subjects with minor exceptions. As far as could be determined, only 17 schools out of 2115 were excluded from the study due to an inability to determine necessary location data. This amount equates to less than one percent of all schools, while the student population of the excluded schools, 504 students, represents less than .0005 percent of all students. Schools excluded had small enrollments, all with less than 100 students. Schools not located typically do not exist any longer, either because programs at the undetectable site were moved to other sites thus erasing the original location information, or schools simply closed completely. Due to the linking of the LPRI to census tracts, not being able to locate a physical address or location for a school means it is impossible to determine in which census tract it resides as well as the level of risk of lead poisoning, thus making analyses impossible. After locating as many schools as possible, the total count for this study is 2098 schools.

The Lead Poisoning Risk Index, by virtue of its creation, encompasses the entire state of Arizona. The process followed by the Lead Poisoning Screening Coalition, the body that devised the index, incorporated data pertaining to characteristics of each of Arizona's 1059 census tracts. Originally aggregated by zip code, in 2005 the Lead Poisoning Screening Coalition recalculated the index by census tract, providing a finer tuned measurement of risk for the entire state of Arizona. For the purpose of this study, the all inclusive nature of the LPRI and Arizona's census tracts makes it a useful data set since all census tracts for the state are included.

The 2000 Census provided community and household demographics. Conducted every 10 years and canvassing the entire nation, census data is tabulated and categorized by state and by census tract within each state. The information on the distribution of race, age, and head of household composition is inclusive of the entire state of Arizona, making this, too, a complementary data source for this study.

Data

The data for this study includes information on three different factors involved in the relationship between academic achievement, lead poisoning, and demography. Arizona's Instrument to Measure Standards (AIMS) assessment, a state-wide standards based test that all public school students complete, will quantify academic achievement in reading and mathematics at grades three, five, and eight. As a fundamental part of Arizona's targeted blood screening program, the Lead Poisoning Risk Index (LPRI) factors in Arizona demographic, socioeconomic, and housing data to quantify, by census tract, the risk of being exposed to lead. To assist with understanding the context and characteristics of the neighborhoods in which Arizona's children and the schools for this study reside, 2000 Census socioeconomic and demographic information related to race, age, and household composition will be used. Collectively, this study will combine these data sets to explore the relationship between the LPRI, AIMS scores, and confounding sociodemographic variables. See Table 1.

School Location. Arizona's Business and Education Council (ABEC) compiled data from the Arizona Department of Education and provided school identification and location information. For each of the 2098 included schools, the ABEC data included the school's location within its district, city, county, congressional district and state. It provided school and district name, identification number, and geographic location measured by longitude and latitude. For charter schools, the ABEC data also indicated the charter name, who held the charter, and where the charter school was located.

Table 1

Source and Year of Data by Type of Variable

Variable	Source	Year	Unit of Measurement
School Identification	Arizona Department of Education	2005	school level
Demographic	U.S. Census	2000	census tract
Academic Achievement	Arizona Department of Education	2005	school level
School Demographics	Arizona Department of Education	2005	school level
Lead Poisoning Risk Index	Arizona Department of Health Services	2005	census tract
Free/Reduced Lunch	Arizona Department of Education	2005	school level
Race	Arizona Department of Education	2004	school level

Academic Achievement. Data for academic achievement was provided by the Arizona Department of Education. Academic achievement was measured using the number and percentage of students at each school who achieved a particular performance level on the Arizona's Instrument to Measure Standards (AIMS) test at grade three in reading and grade eight in math. Students' performance on AIMS is categorized into four levels: Falls Far Below, Approaches, Meets, and Exceeds the standard (FAME). Students who Meet or Exceed on the AIMS test will be combined into a variable for reading and mathematics called "Pass". Students who scored in the Falls Far Below and

Approaches category will be combined into a variable for reading and mathematics called “Not Pass”.

After careful consideration of annual sets of testing data, 2005 was selected as it offers the most complete contemporary set of data along with the most thorough listing of public school identification codes. For each school, the number and percentage of students in 12 special education categories and the four AIMS performance levels was provided.

For the purpose of this study, analysis of student achievement will be focused on third grade reading and eighth grade mathematics. Third grade reading is an important data set from an educational policy perspective. With the passage of Move on When Ready, Arizona House Bill 2732, current Arizona policy requires schools starting in the 2013-2014 school year to retain students who do not pass the third grade AIMS reading exam. The third grade AIMS reading exam is also a measure of basic reading skills as opposed to a more content and literary analysis orientation that is present in the eight grade AIMS reading exam.

The focus on the eighth grade AIMS mathematics data is deliberate as well. The skills assessed by the eighth grade AIMS mathematics exam measure a student’s preparedness for high school mathematics. Success in mathematics has been seen as a gateway to success in high school and college, as well as the foundation to meet the economic need to create more students proficient in science, technology, engineering, and math.

Also included in the information provided by the Arizona Department of Education were demographic variables used to describe characteristics of the neighborhoods and student populations at each school. For race and ethnicity, the number and percentage of black, Hispanic, American Indian, Asian, and white students were provided. Also included was the number and percentage of the school's population currently receiving special education services by category. These variables are of great interest in contextualizing the circumstances in which these schools exist and will offer some assistance in understanding what relationships are detected between the two data sets.

The Arizona Department of Education also provided information regarding free and reduced lunch, the typical indicator of poverty for a school. The free and reduced lunch data set provided by school the number of students eligible for free lunch, reduced lunch, and the combined number and percentage of students eligible for free and reduced lunch.

To improve the amount of data for each of the schools with third graders and eighth graders taking the AIMS test, two methods for determining the percentage of students at a school who qualify for free and reduced lunch were applied.

The first method was to look at the March, 2005 Free and Reduced Lunch report on the Arizona Department of Education website to see if data for the school was somehow missed. The data for schools were fixed this way.

The second method was to identify the census tract in which the school in question was located and to take the average of the percentages of free and reduced lunch of the schools in that same census tract. One assumption behind this method is that the socioeconomic status is relatively similar throughout the census tract, meaning that a similar level of income will be shared throughout the tract. A second assumption is that the school draws students from within the census tract. Combining these assumptions would imply that a school would draw from families with similar economic circumstances from within the same census tract. 47 schools had data calculated and furnished in this manner. Appendix B documents the schools and percentages of free and reduced lunch that were added to the data base.

Lead Index. The risk of being poisoned by lead is quantified with the Lead Poisoning Risk Index (LPRI), a formula devised by the Arizona Department of Health Services. As part of the Arizona Childhood Lead Poisoning Targeted Screening Plan, the LPRI quantifies the potential for being exposed to lead based on several contributing factors. Data from this source is aggregated at the census tract level. For each census tract in Arizona, an index score was calculated using a formula, with higher scores indicating a higher risk of exposure to lead.

Responding to the CDC's 1997 publication *Screening Young Children for Lead Poisoning: Guidance for State and Local Public Health Officials*, Arizona created the Lead Poisoning Screening Coalition. The Lead Poisoning Screening Coalition was charged with assessing lead exposure in the state and determining the appropriate method of lead screening. The Lead Poisoning Screening Coalition created a Lead Poisoning Risk Index using blood lead data, housing data, demographic data about children, and data on sources of lead which allowed communities at the highest risk of lead exposure to be identified by census tract (CITE the 2005 plan). The Arizona Department of Health Services developed a plan for screening the children of Arizona with the goal of identifying and then offering assistance to the families of children with elevated levels of lead in their blood. Most recently updated in 2005, Arizona's Childhood Lead Poison Targeted Screening Plan documents, through the use of the Lead Poisoning Risk Index (LPRI) and census tract data, high risk zip codes and census tracts for exposure to lead for the entire state of Arizona.

The Lead Poisoning Risk Index consists of the following formula:

$$LPRI = (A + B + C + D + (E/(F \times G)))$$

A = percentage of total population being children age zero to five years of age

B = percentage of total housing stock built prior to 1960

C = percentage of total households being exclusively Spanish speaking.

D = percentage of families with children aged birth to four years of age whose 1999 income was below the poverty level.

E = Number of children from birth to year five who had a blood lead level of 10µg/dL or higher.

F = number of children aged one day to five years old.

G = Average Arizona Health Care Cost Containment System (AHCCCS) screening percentage = 0.117.

Applied to all census tracts in Arizona, the statewide average risk index is 0.299. According to the Arizona Department of Health Services for the purpose of its lead screening program, census tracts considered to be at high risk of exposure to lead contained a LPRI score greater than 0.359, resulting in 322 census tracts being declared high risk.

There are two exceptions to the 0.359 as the threshold to declaring a census tract at risk. Two scenarios presented themselves to the Arizona Department of Health that prompted census tracts with lower scores to be declared at risk. One exception was a finding of lead in the drinking water by the Arizona Department of Health Services Environment Health Consultation Services Program. The second exception was made for census tracts where there were more than three children within the census tract were found to have elevated blood lead levels (Arizona Department of Health Services, 2005). There will be census tracts with LPRI scores lower than the official threshold declared to be at risk.

For the purpose of this study, a portion of the LPRI distribution will be focused on for analyses. The Arizona Department of Health Services declared a threshold of 0.359 for census tracts to be declared high risk for the purpose of economically focusing limited resources for conducting blood lead screenings for children. I, too, will use this threshold, and separate out those indices and their corresponding census tracts that were declared to be at risk of being poisoned by lead. Those census tracts not declared to be a risk will be categorized and used for comparative purposes. Those LPRI scores and census tracts declared to be at risk will be in the Risk category. Those census tracts and LPRI scores declared not to be at risk will be in the No Risk category.

To better understand the distribution of LPRI scores in the Risk category, a new mean and standard deviation will be calculated. Only those LPRI scores associated with high risk census tracts will be used to determine a new mean. This newly calculated mean and standard deviation will allow a second categorization of the LPRI to take place based on a stratification of risk. The LPRI scores in the

Table 2

Number of Schools in Each Category as Determined by the LPRI

Type of Risk	Schools	Percent	Cumulative Percent
No Risk	1493	71.20	71.20
Risk	604	28.80	100.00
Total	2097	100.00	
	Schools	Percent	Cumulative Percent
Very High	36	6.00	6.00
High	49	8.10	14.10
Moderately high	162	26.80	40.90
Moderately low	268	44.40	85.30
Low	81	13.40	98.70
Very Low	8	1.30	100.00
Total	604	100.00	

Risk category will then be separated into six new categories based on a range of scores within one, two and three or more standard deviations above and below the mean. The various groupings and separations of the LPRI will facilitate risk-differentiated descriptive and correlation analyses.

As the various categorizations of the LPRI are applied to other variables of interest, some results are to be expected simply because of the components in the formula that created the index. One component of the formula used to create the LPRI, the percentage of total households that exclusively speak Spanish, will include the presence of Arizona's Hispanic population. Any analysis of race relative to the LPRI should indicate a positive relationship between the risk index and the percentage of Hispanics in the schools in that census tract.

A second component in the LPRI formula, the percentage of families with young children with incomes below the poverty level, is going to represent poverty in a very similar manner to the percentage of students in a school that qualify for free or reduced lunch. Here, too, there will be an expected positive relationship with the LPRI and the percentage of free and reduced lunch. Similarly, household composition, particularly households headed by single parents, should also show a similar relationship. Typically, income levels for single parent families are lower than for those headed by married couples, and they more often approach the poverty level. Though not always the case, in general, the analysis of the LPRI relative to household composition will need to be looked at carefully knowing that its close proximity to poverty may be represented naturally within the formula for the LPRI.

Census 2000. To add another dimension of analysis, census tract demographic information from the 2000 census was included. Total population size was provided as well as totals aggregated by age range categories. The census data also described household composition, looking at head of household by gender or marital status and the presence of children in the house, offering a third dimension to the context existing within each school and neighborhood in each census tract.

Combining the data gathered from ABEC, the Arizona Department of Education, and the 2000 census, the total database is rich with information, encompassing 2097 schools. Individual variables and their respective levels are listed in Table 1.

Analysis

A variety of statistical analyses will be employed in this study, progressing from descriptive statistics to a multivariate regression. Analyses will start by highlighting the distribution of the data, will proceed to determining the relationship between exposure to lead and school level achievement and sociodemographic variables, and will end with an attempt to determine what factors are at play in the relationships explored.

Descriptive Statistics. Descriptive statistics will be run on all variables of interest. Key census information, the LPRI and the school level third grade AIMS reading and eighth grade AIMS math achievement data will all be described. Descriptive statistics for the school level achievement data will be run for each of the four performance levels as well as for the broader category of those that did not pass. With the LPRI being a primary independent variable of interest, the various categorizations of the LPRI will be used to better understand how school level race, poverty, special education and achievement data as well as census tract level household composition is distributed relative to the risk of being poisoned by lead.

Descriptive statistics will assist with understanding how academic achievement data is distributed as well as help illuminate the frequency of a variety of other school and census tract level variables.

Bivariate Correlations. Bivariate correlations will be used to determine the strength and direction of the relationship between the LPRI and school level variables for achievement, ethnicity, poverty, and special education. For example, analyses will explore the relationship between the LPRI and the school level percentages of students who did not pass the exam as well as the percentage for ethnicity (black, Hispanic, white, Asian, and Native American), percentage of students who qualify for free and reduced lunch, and percentage of students in special education.

Table 3 represents how the data gathered by these analyses will be represented. With each analysis of a relationship, the correlation coefficient will be squared, providing a coefficient of determination, which Salkind (2007, p. 128) defines as, "exactly how much of the variance in one variable can be accounted for by the variance in another variable."

Multivariate Regression Analysis. The final step of analysis will involve multivariate regression analyses. This analysis is particularly important and appropriate in helping illuminate possible mediating or confounding interactions between multiple independent variables (Miller, 2005). For a

Table 3

LPRI, Third Grade Reading and Variables of Interest Correlations

		LPRI	3rd Grade % Not Pass	SLD	ED	Special Ed	Married	Male	Female	Total F/R Percentage	White	Hispanic	African American	Asian	Native American
LPRI	Pearson Correlation														
	Sig. (2-tailed)														
	N														
3rd Grade % Not Pass	Pearson Correlation														
	Sig. (2-tailed)														
	N														
SLD	Pearson Correlation														
	Sig. (2-tailed)														
	N														
ED	Pearson Correlation														
	Sig. (2-tailed)														
	N														
Special Education	Pearson Correlation														
	Sig. (2-tailed)														
	N														
Married	Pearson Correlation														
	Sig. (2-tailed)														
	N														
Male	Pearson Correlation														
	Sig. (2-tailed)														
	N														
Female	Pearson Correlation														
	Sig. (2-tailed)														
	N														
Total F/R Percentage	Pearson Correlation														
	Sig. (2-tailed)														
	N														
White	Pearson Correlation														
	Sig. (2-tailed)														
	N														
Hispanic	Pearson Correlation														
	Sig. (2-tailed)														
	N														
African American	Pearson Correlation														
	Sig. (2-tailed)														
	N														
Asian	Pearson Correlation														
	Sig. (2-tailed)														
	N														
Native American	Pearson Correlation														
	Sig. (2-tailed)														
	N														

multivariate regression analysis, the equation $Y = \alpha + \beta_1 + \beta_2 + \ldots \beta_k + \varepsilon$ can be used to determine how the dependent variable is impacted by the independent variable when controlled for two or more additional confounding independent variables. In this case, the variables in the equation stand for:

Y = Dependent variable

α = Independent variable

ε = Error coefficient

β_k = Control variable

The relationship of academic achievement and the risk of lead poisoning could be confounded by school specific demographic variables such as race and poverty or census tract variables for head of household composition. To better understand this multivariate interaction, one multivariate regression analysis will look at the relationship between a LPRI score and student performance on AIMS controlling for race (black, white, Hispanic, Asian, Native American), poverty (percentage of free/reduced lunch), placement in special education (percentage of students with specific learning disabilities and emotional disabilities), and household composition (married, female, male head of household with children).

For the purpose of this study, the equation would be $Y = \alpha + \beta_1 + \beta_2 + \varepsilon$ and the variables, listed in Table 6, stand for:

Y = percentage of students who did not pass the third grade AIMS reading or eighth grade AIMS math exam

α = LPRI

ε = Error coefficient

Table 4

Relationship Between Third Grade Reading, Lead, and Key Demographic and Census Variables

Cluster	Variables	Model 1	2	3	4	5
	Constant (Sig.)					
LPRI	3+ SD Above					
	2 SD Above					
	1 SD Above					
	1 SD Below					
	2 SD Below					
Race	Hispanic					
	African American					
	Asian					
	Native American					
Poverty	Free/Reduced Lunch					
	Interaction					
Special Education	Overall					
	SLD					
	ED					
Census	Married					
	Father					
	Mother					
F-statistics (*df*)						
Adjusted R^2						
Unweighted schools total						

Note. *p< 0.05. ** p< 0.01

β_1 = School Demographics

β_{1a} Race
β_{1a1} = Percent Hispanic
β_{1a2} = Percent Native American
β_{1a3} = Percent African American
β_{1a4} = Percent Asian

β_{1b} Poverty
β_{1b1} = Percent Free and Reduced Lunch

β_{1c} Special Education
β_{1c1} = Percent Overall
β_{1c2} = Percent Specific Learning Disabled
β_{1c3} = Percent Emotionally Disabled

β_2 = Census
β_{2a} = Head of Household with Children
β_{2a1} = Married
β_{2a2} = Mother
β_{2a3} = Father

Summary

The data for this study will come from several sources. The number and percentage of students who scored at each of the four performance levels on the third grade AIMS reading and eighth grade AIMS math tests along with sociodemographic data for ethnicity, poverty, and special education participation for each school will come from the Arizona Department of Education. The Lead Poisoning Risk Index data will be provided by the Arizona Department of Health Services. Demographic and socioeconomic data on Arizona's families and children will be provided by the U.S. Census Bureau. This study will seek to understand the relationship between academic achievement via the AIMS test at grades 3 and 8 and the Lead Poisoning Risk Index, controlling for a variety of confounding demographic and census variables.

Chapter 4

Results

This chapter presents results on the relationships between the risk of lead poisoning, academic achievement and school and community demographics. For all variables of interest, descriptive statistics as well as results from bivariate correlation and multivariate regression analyses will be presented.

Descriptive Statistics

To gain an understanding of the variables of interest, descriptive statistics were applied. Census variables, school variables, and the Lead Poisoning Risk Index (LPRI) were of primary interest.

Census Variables. Census tract level community characteristics from the 2000 census were analyzed. Information describing the census tracts as well as the homes and people that reside within the tracts were the focus of these analyses.

Population. Data from the 2000 census describes who lives within Arizona and each of its census tracts. Arizona's population of 6.4 million residents is predominantly white with a strong Hispanic presence. Arizona's residents are 58% white, 21% Hispanic, and 5% Native American. The other 16% of the state's population falls into several categories (see Table 5).

From an age perspective, there appears to be a relatively even distribution statewide across major age categories. For the categories relevant to this study, children under the age of 18 represent 28.2% of the state's population. Within this group, 20.4% are children between age 5 and 18, while children under 5 years old make up 7.8% of the state's population. See Appendix A for other age category percentages for Arizona.

Tract Size. The census tract, a basic unit of data aggregation used by the U.S. Census, varies in size both from an area and a population perspective. Looking first at area, census tracts in Arizona are generally small in size. Most of Arizona's census tracts (87%) are less than 100 square miles, and 75% of the census tracts are actually less than 10 square miles. The smallest tract is 0.12 square miles.

Table 5

State Race and Ethnicity Percentages

Race	Percent
White	58.02
Hispanic	21.32
African American	2.26
Asian	1.19
Native American	5.07
Hawaiian	0.10
Multi Race	2.30
Other	9.74

However, despite the large percentage of small sized tracts, the mean area of a census tract is 174.75 square miles (SD = 523.40), a value larger than might be anticipated. This results from a few very large tracts that bias the mean upwards. A small number of tracts (28) are larger than 1000 square miles with three over 3000 square miles and one tract over 5000 square miles. Even with 75% of tracts being less than 10 square miles, the few big tracts over 1000 square miles are significant outliers in total size relative to the rest of the tracts. These large area census tracts contain 94 schools (4.5%) included in this study.

Population totals for census tracts vary considerably. The mean population count for a census tract is 7109 people (SD = 3,673). But the range is from a census tract of 118 people to that of 24,419 people. Other than the exceptionally largest 3% of tracts which are over 15,000 people, most tracts are under 10,000 people.

Households. Census 2000 data also provides information on the number and composition of households within each census tract. The mean number of households per census tract is 1,984 (SD = 1101), yet the number per tract varies considerably from as few as 25 households per tract to a maximum of 7,783 households. More detailed descriptive analyses concerning household composition in census tracts is presented later in this chapter.

Looking within each household, specifically households with children, the head of the household is either a married couple or single parents. Within each tract, married couples with children typically head 26% of households, while single fathers or mothers head 3% and 8% of households, respectively. Later in this chapter, household composition variables will be analyzed relative to the level of risk for lead poisoning. Homes with children headed by males, females, and married couples will be the specific variables of interest.

School Variables. A variety of information specific to the schools within each census tract was reviewed. Variables of interest were race, percentage of students eligible for free and reduced lunch, special education participation, and student achievement in reading and math.

School Race. Demographic information provided by the Arizona Department of Education shows a racial composition in schools slightly different than the overall state means for race. The typical school in Arizona has a student body that is 49% white, 36% Hispanic, 9% Native American, 5% African American and 2% Asian. There is a notable change in the percentage of students who are white and Hispanic in Arizona's schools, with fewer white students and more Hispanic students than the overall state percentages. This is likely due to differences in the average age of the two populations, with the mean age of white Arizonans considerably older than that of Hispanic Arizonans.

By school, there is a wide range of representation of particular races. There are schools that are exclusively white, Hispanic or Native American, while the largest percentage of African American students at a particular school is over 90%. The highest concentration at any school for Asian students is only 15%.

Looking specifically at Native American students, there is a very wide distribution of students across the state with a high concentration of Native American students in a small number of schools. Sixty percent of Arizona's schools have a student body with less than three percent being Native American, while ninety percent of Arizona's schools have a student body with less than 20% being Native American.

Another characteristic of the distribution of students in Arizona's schools is the lack of representation of a particular race at many schools. Almost all of Arizona's schools have students who are white or Hispanic. Asian students, on the other hand, are missing from far more schools. Because only 2% of the state's student population is Asian, 22% of the state's schools have no Asian students.

Free and Reduced Lunch. Poverty, as measured by the percentage of students at a school who qualify for free and reduced lunch, has a presence across the entire state of Arizona. In Arizona's schools 58% of the students qualify for free and reduced lunch (SD = 0.28). To qualify for free lunch, a family of four in

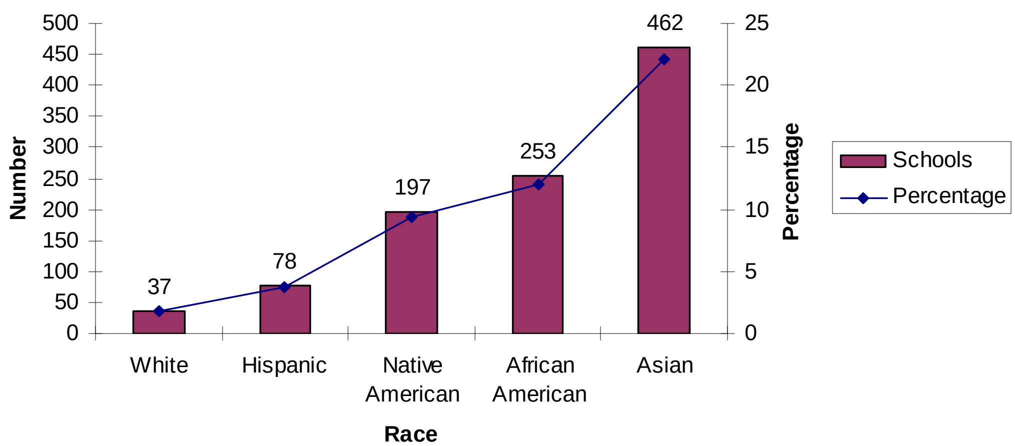

Figure 1. Number and percentage of schools without students of a particular race or ethnicity.

2005 needed an annual income of $25,155 or less, while reduced lunch eligibility required an annual income of $35,798. Looking at incomes in general, with a statewide median income of $47,315 for the state of Arizona, 19.8 % of families with children under the age of 18 live in poverty (U.S. Census, 2006). Poverty, operationalized as the percentage of students eligible for free and reduced lunch, is another variable of interest discussed later in this chapter as it is reviewed relative to the risk of lead poisoning.

Special Education. Students who receive special education services represent a population in each school that is of special interest in this study. In the typical Arizona school, the mean percentage of special education students is 13% (SD = 0.06). Special education consists of 12 specific categories. The two most prominent categories are specific learning disability (SLD) with a mean percent of 8% (SD = 0.05) and emotionally disabled (ED) with a mean of 1% (SD = 0.03). The SLD and ED categories of special education services are of interest in this study because of their possible connection to lead (Surkan et al., 2007). The overall percentage as well as the categorical percentages for SLD and ED will be used in further analysis .

Student Achievement. Arizona's students are tested at all grade levels from grade two through grade ten. For the purpose of this study, analyses will focus on grades three and eight. For grade three, 1017 schools have students taking the AIMS test. At the eighth grade level, there are 626 schools with students taking the eighth grade test. The differing counts of schools at each grade level are a result of how Arizona schools are organized by grade level. Arizona elementary schools are kindergarten through sixth grade (K-6) with students transitioning to a grade seven and eight middle school or they are kindergarten through fifth grade (K-5) with students transitioning to a grade six

Table 6

Mean Percent of School Population by Special Education Categories

Categories	Percent
Speech/Language	4.17
Specific Learning Disability (SLD)	7.77
Emotionally Disabled(ED)	1.05
Moderately Mentally Disabled (MoMD)	0.38
Visually Impaired	0.06
Hearing Impaired	0.23
Other Health Impairment (OHI)	0.78
Orthopedic Impaired	0.10
Traumatic Brain Injury (TBI)	0.03
Multiple Disabilities	0.07
Multiple Disabilities with severe sensory impairment	-
Autism	0.22
Overall	13.41

Note. Dashes indicate the percentage is less than 0.01%.

through eight junior high. Usually, several elementary schools feed into a single middle or junior high school which explains the difference between the grade three and grade eight totals.

In order to pass the exam, a student must score in the top two categories of Meets or Exceeds. A student who scores in the Falls Far Below or Approaches categories does not pass the exam. For the third grade AIMS reading exam, 63% of students pass. Fifty-two percent of the students pass the eighth grade AIMS math test. One exceptional difference between the typical performances on each exam is the percentage of students who score at the lowest level, “Falls Far Below.” In the third grade AIMS reading exam, 10% of the students fall into this category, while 27% of the students taking the eighth grade AIMS math exam fall into the “Falls Far Below” category. Student achievement, particularly the percentage of students who do not pass the third grade reading and eighth grade math AIMS exams, is a dependent variable of interest that will be will be analyzed later in this chapter relative to the level of risk of lead poisoning.

Table 7

State AIMS Percentages for Third Grade Reading and Eighth Grade Math by Performance Level

	Not Passing				Passing			
	Falls Far Below		Approaches		Meets		Exceeds	
Grade	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Third Grade Reading	0.10	0.10	0.26	0.13	0.54	0.15	0.09	0.09
Eighth Grade Math	0.27	0.18	0.20	0.09	0.42	0.17	0.10	0.11

Lead Poisoning Risk Index

The Lead Poisoning Risk Index (LPRI) is used by the Arizona Department of Health Services (DHS) to determine the risk of being exposed to and poisoned by lead throughout Arizona. The LPRI is reported by census tract. The statewide mean for the LPRI as determined by DHS is 0.30 for all indices and census tracts in the state of Arizona. For the purposes of its targeted lead screening program, DHS determined that census tracts with an index greater than or equal to 0.36 were considered at risk of being exposed to lead and thus would be targeted for tests to measure the children's blood lead level. Of the 2097 schools used in this study, 604 are in high risk census tracts.

Table 8

Lead Poisoning Risk Index (LPRI) Descriptive Statistics

	Schools in high risk census tracts	Mean risk level	Standard deviation	Minimum risk level	Maximum risk level	Risk level range
LPRI	604	0.63	0.23	0.12	1.16	1.04

The LPRI is the primary independent variable of interest in this study. To best understand lead and its relationship to achievement and the various school and census variables, those census tracts and indices declared by DHS to be at risk of lead exposure were separated out as a unique group and will be placed in a category called Risk. From this point forward in the results, reference to the LPRI is to only those indices and the corresponding census tracts declared to be at risk.

To better understand the LPRI scores for those census tracts in the Risk category, a new mean and standard deviation was calculated. Only those LPRI scores associated with high risk census tracts were used to determine a new mean. The new LPRI mean is 0.63 with a standard deviation of 0.23. This newly calculated mean and standard deviation will allow a second categorization of the LPRI to take place based on a stratification of risk. From this point forward, all reference to the mean of the LPRI will be to the newly calculated mean.

In further analyses, the LPRI is divided into categories relative to this newly calculated mean to examine the relationship between lead and other variables of interest like race, poverty, special education, head of household composition and student achievement. The first step in the analyses to follow was to separate Arizona's schools into two groups relative to the risk of being poisoned by lead. There are those schools in census tracts declared to be at risk (n=604) of being poisoned by lead. The other group consists of those schools in census tracts that are not considered to be at risk of being poisoned by lead (n=1493).

A second approach to categorizing the LPRI was to create categories for census tracts, and the schools within them, whose LPRI scores fell in a range of scores within one, two and three or more standard deviations above and below the mean. This will create six new categories: three above the newly calculated mean and three below it (See Table 2). The various groupings and separations of the LPRI will facilitate risk-differentiated descriptive, correlation, and multivariate regression analyses. Though the number of cases decreases considerably at the farthest ends of the distribution, it does allow for analyses using schools with the highest and lowest risk of lead exposure.

Lead and Race

When the racial composition of schools in Arizona is viewed through the LPRI categorizations, the percentage of white students decreases and the percentage of Hispanic students increases as the risk of lead exposure increases.

The same holds true for Native American students: higher percentages of Native American students are found at schools with higher risks of lead poisoning.

Table 9

Categories of Risk Based on Range of LPRI Scores

Relation to the mean	Level of risk	Range of LPRI
Above	Very High	1.09 - 1.157
	High	0.86 - 1.08
	Moderately high	0.63 - 0.85
Below	Moderately low	0..40 - 0.62
	Low	0.17 - 0.39
	Very Low	0.12 - 0.16

Compared to the state mean percentages, schools residing in census tracts with an increased risk of lead poisoning have more minority students and fewer white students. In the census tracts with a risk of lead poisoning, the mean percentage of white students at a school is 0.43 (SD = 0.30), a percentage six percentage points less than the state mean. The mean percentage of Hispanic students for schools in the Risk category is 0.41 (SD = 0.30), an amount five percentage points above the state mean. There are fewer minority students and more white students in schools with increased risk of lead poisoning.

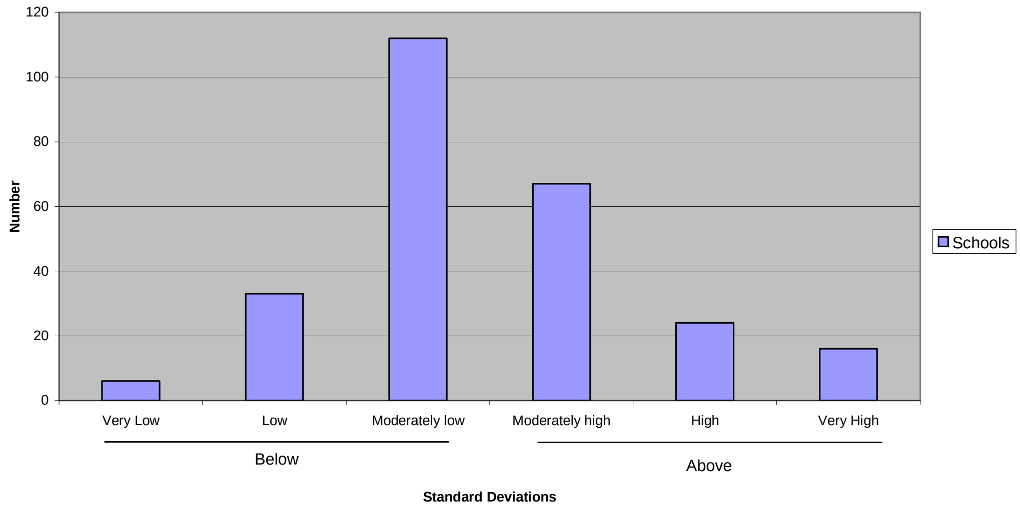

Figure 2. Third grade schools by LPRI categorizations (n = 258).

For the typical No Risk school, the mean percentage of white and Hispanic students is 0.52 (SD = 0.31) and 0.33 (SD = 0.28) respectively. These mean percentages are nine percentage points higher for white students and eight percentage points lower for Hispanic students, compared to the typical Risk school (See Table 10).

Separating by the LPRI categories shows the percent of Hispanics at the typical school increases as the risk of lead increases. From the Low risk category through the Very High risk category, the percentage of white students is below the state average while the mean percentage for Hispanics is above the state average. At the highest level of risk, Very High, the mean percentage of Hispanic students at a school is 0.50 (SD = 0.36), an amount 14 percentage points above the

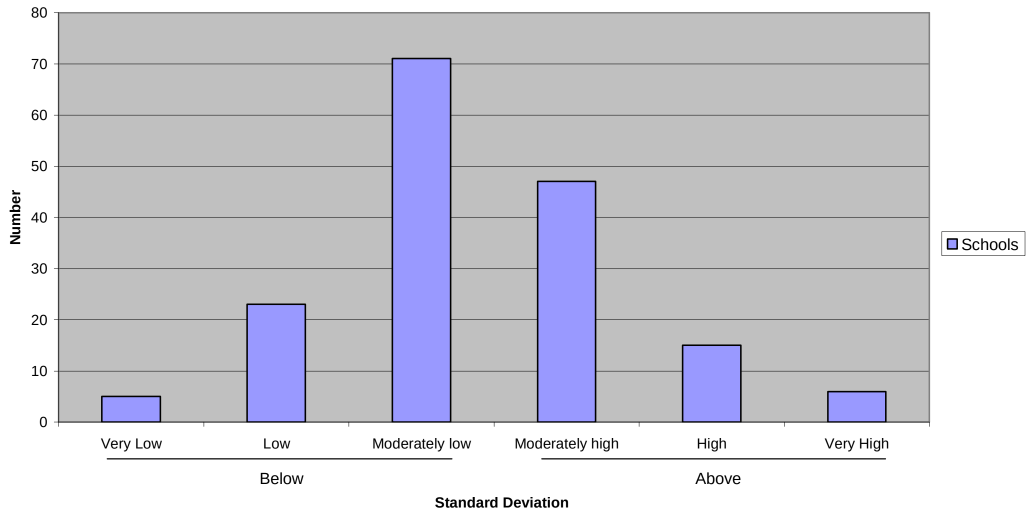

Figure 3. Eighth grade schools by LPRI categorizations (n = 167).

state mean for this group. At this highest level of risk, the mean percentage of white students, 0.43 (SD = 0.35), is six percentage points below the state mean.

It isn't until a school is located in a census tract three standard deviations below the mean, in the Very Low risk category before the mean percentages of whites and Hispanics are above and below their respective means. Though the number of schools is small, (five), the fact remains that at the lowest end of the LPRI risk distribution, the typical school has a mean percentage of white students of 0.91 (SD = 0.02) and a mean percentage of Hispanic students of 0.05 (SD = 0.03). These percentages are considerably different from the state mean percentages. Schools only at the lowest level of risk have student bodies that are much more likely to be white and much less likely to be Hispanic.

Table 10

Mean School Race and Ethnicity Percentages for Risk and Non-risk Schools as Determined by the LPRI

Method	Category	White	Hispanic	Black	Asian	Native American
Risk of poisoning by lead	State	0.49 (0.31)	0.36 (0.29)	0.05 (0.06)	0.02 (0.02)	0.09 (0.22)
	Schools with no risk	0.52 (0.31)	0.33 (0.28)	0.05 (0.06)	0.02 (0.02)	0.08 (0.21)
	Schools with risk	0.43 (0.30)	0.41 (0.30)	0.03 (0.04)	0.01 (0.01)	0.11 (0.22)
Ethnic and racial composition by six categories of risk	Very High	0.43 (0.35)	0.50 (0.36)	0.02 (0.02)	0.01 (0.01)	0.04 (0.07)
	High	0.28 (0.22)	0.52 (0.32)	0.03 (0.04)	0.01 (0.02)	0.16 (0.24)
	Moderately high	0.40 (0.30)	0.44 (0.32)	0.04 (0.04)	0.01 (0.01)	0.11 (0.22)
	Moderately low	0.46 (0.29)	0.38 (0.28)	0.04 (0.05)	0.01 (0.02)	0.11 (0.21)
	Low	0.43 (0.29)	0.38 (0.28)	0.02 (0.03)	0.01 (0.02)	0.16 (0.30)
	Very Low	0.91 (0.02)	0.05 (0.03)	0.02 (0.01)	0.02 (0.01)	0.00 (0.00)

Note. Mean percent is reported with standard deviation in parentheses.

An exception in the results of the LPRI by race and ethnicity is the decreasing mean percentage of Native American students at a school as the level of risk of lead poisoning increases. From the Low risk category to the High Risk category, there is a greater percentage of Native American students at schools. However, at either end of the distribution, in those census tracts with the greatest and the least risk of lead poisoning, the mean percentage of Native American students is 0.04 and 0.00 respectively, totals five and nine percentage points below the state mean.

Lead and Poverty

The percentage of poor students at a school increases as the risk of lead exposure increases. Statewide, the mean percentage of poor students at a school is 0.58 (SD = 0.28). When Arizona's schools are separated into those with a risk of exposure to lead and those with no risk, there is a 12 percentage point difference in the percentage of students in poverty. For schools in the No Risk category, the mean percentage of poor students is 0.54 (SD = 0.29) while for schools in the Risk category, the mean percentage of poor students is above the state mean at 0.66 (SD = 0.23).

When the LPRI is separated by standard deviation, the percent of poverty continues to increase as the level of risk of poisoning by lead increases. The mean percentage of poor students at a school ranges from a mean of 0.64 (SD = 0.22) in the Moderately Low category to the highest mean percentage of 0.73 (SD = 0.20) in the High risk category (see Table 11). The mean percentages are 6 to 15 percentage points higher than the state mean. The exception to this pattern is at the farthest ends of the distribution, with cases in the Very Low risk category. When the risk of lead exposure is the least, the mean percentage of poor students at a school is 0.08 (SD = 0.03), a percentage considerably below the state mean average of 0.58 (SD = 0.28).

Table 11

Percentage of Students Eligible for Free and Reduced Lunch by Level of Risk as Determined by the LPRI

Category	Level of Risk	Percentage	Standard Deviation
Risk of poisoning by lead	State	0.58	0.28
	No Risk	0.54	0.29
	Risk	0.66	0.23
Poverty by categories of risk	Very High	0.71	0.24
	High	0.73	0.20
	Moderately high	0.70	0.20
	Moderately low	0.64	0.22
	Low	0.66	0.22
	Very Low	0.08	0.03

Lead and Heads of Households with Children

As the risk of poisoning by lead increases, the percentage of households with children headed by married couples declines. Within a census tract statewide, the mean percentage of households headed by married couples is 0.26 (SD = 0.10). Splitting the state's census tracts into groups that are either at risk of being poisoned by lead or not at risk, census tracts in the No Risk category have more homes headed by married parents. Conversely, census tracts in the Risk category have a smaller percentage of households headed by married parents, a percentage that is four percentage points less than the state mean.

When the LPRI is categorized by standard deviation, though not a linear increase, the mean percentage of households headed by married parents decreases as the level of risk increases. In the Very Low risk category, the mean percentage of household headed by married parents 32%. At the other end of the distribution in the High risk category, the mean percentage is half as much,16%.

Table 12

Mean Percent of Head of Households With Children for Risk and Non-risk Census Tracts as Determined by the LPRI

		Married		Single Father		Single Mother	
Method	Category	Mean	SD	Mean	SD	Mean	SD
Risk of poisoning by lead	State	0.26	0.10	0.03	0.01	0.08	0.04
	Census tracts with no risk	0.27	0.10	0.03	0.01	0.07	0.04
	Census tracts with risk	0.22	0.09	0.03	0.01	0.08	0.04
Level of risk by standard deviation	Very High	0.16	0.06	0.02	0.01	0.09	0.04
	High	0.24	0.05	0.03	0.01	0.09	0.03
	Moderately high	0.24	0.11	0.03	0.01	0.08	0.04
	Moderately low	0.22	0.10	0.03	0.01	0.08	0.04
	Low	0.21	0.09	0.03	0.01	0.08	0.05
	Very Low	0.32	0.00	0.03	0.00	0.03	0.00

As for households with children headed by single parents, as the risk of being poisoned by lead increases, there is little change in the percentage. The exception is at the three or more standard deviation below the mean category.

Only 3% of households are headed by single mothers. The other categories all have 8% or 9% of households headed by single mothers.

Lead and Student Achievement

The risk of being poisoned by lead and student achievement variables were investigated next. Performance on the third grade AIMS reading test and the eighth grade AIMS math test were reviewed relative to the risk of being poisoned by lead.

Third Grade Reading. When third grade AIMS reading achievement is analyzed relative to the presence of lead, as the risk of poisoning by lead increases, the mean percentage of students who do not pass the exam increases. To determine the percentage of students at a school that do not pass the exam, the percentage of students who score at the "Falls Far Below" (FFB) level is combined with the percentage of students who scored at the "Approaches" range.

Performance on the third grade AIMS reading exam shows a higher mean percentage of students who do not pass the exam in schools in the Risk category. This mean percentage is higher at schools in census tracts with a risk of being poisoned by lead than the typical failure rate at schools in the No Risk category and the state mean as well. The mean percentage of non-passers in the Risk category is 41%, a mean percentage six percentage points higher than schools with No Risk and three percentage points higher than the state mean for non-passers.

Table 13

Third Grade AIMS Reading Percentages for Risk and Non-risk Schools as Determined by the LPRI

Method	Category	% Not Passing	Not Passing: FFB	Not Passing: Approach	Passing: Meet	Passing: Exceed
Risk of poisoning by lead	State	0.38	0.11 (0.12)	0.27 (0.15)	0.53 (0.16)	0.09 (0.10)
	Schools with no risk	0.35	0.10 (0.11)	0.25 (0.13)	0.54 (0.15)	0.10 (0.09)
	Schools with risk	0.41	0.13 (0.13)	0.28 (0.14)	0.51 (0.17)	0.07 (0.09)
Level of risk by standard deviation	Very High	0.39	0.09 (0.08)	0.30 (0.15)	0.53 (0.14)	0.08 (0.09)
	High	0.44	0.15 (0.13)	0.29 (0.12)	0.48 (0.15)	0.08 (0.09)
	Moderately high	0.46	0.14 (0.10)	0.32 (0.12)	0.48 (0.14)	0.06 (0.07)
	Moderately low	0.41	0.12 (0.10)	0.29 (0.14)	0.52 (0.16)	0.07 (0.08)
	Low	0.34	0.11 (0.10)	0.23 (0.15)	0.55 (0.15)	0.11 (0.11)
	Very Low	0.14	0.03 (0.03)	0.11 (0.06)	0.70 (0.09)	0.16 (0.07)

Note. Mean percent is reported with standard deviation in parentheses.

Separating the LPRI by standard deviations above and below the mean shows a continuation of elevated mean percentages of students who do not pass the third grade AIMS reading exam. For schools in census tracts with a Moderately Low level of risk, 41% of students did not pass the reading exam, an amount three percentage points higher than the state mean of 38%. Schools in census tracts that have a risk level that ranges from Moderately Low to Very High have mean percentages of students who fail the exam at rates that are higher than the state mean.

An exception to the pattern of elevated mean percentages of students who do not pass the third grade AIMS reading test as the risk of lead increases is at the extreme end of the distribution at Low and Very Low risk levels. In the Low risk category, the mean percentage of students not passing the exam is 0.34 while at the Very Low level, the mean percentage of students who fail is 0.14. These percentages are all lower than the state mean failure percentage of 0.38.

Eighth Grade Math. Reviewing eighth grade math achievement relative to the risk of lead poisoning, once again it is seen that students fail the AIMS test at a greater rate as the risk of lead poisoning increases. Combining the mean percentage of students who score at the "Falls Far Below" (FFB) and "Approaches" levels and do not pass the eighth grade AIMS math exam, the state mean at a typical school is 48%. Separating Arizona's schools into those with a risk of lead poisoning and those with no risk, the percentage of non-passers changes as the risk changes. Schools in the No Risk category have a mean percentage of non passers of 46% while schools in the Risk category have a mean of 50% non-passing.

Schools in the Risk category, regardless of how the LPRI is stratified and categorized, have mean percentages of students who do not pass the eighth grade AIMS math test is greater than the state average. The only exception to this pattern begins at the Low risk level. It is at this level and below that the mean percentage of non-passers approaches the state mean. At the lowest level of risk,

Table 14

Eighth Grade AIMS Math Percentages for Risk and Non-risk Schools as Determined by the LPRI

			Not Passing		Passing	
Method	Category	% Not Passing	FFB	Approach	Meet	Exceed
Risk of poisoning by lead	State	0.48	0.28 (0.21)	0.20 (0.12)	0.41 (0.19)	0.09 (0.11)
	Schools with no risk	0.46	0.27 (0.18)	0.19 (0.08)	0.43 (0.16)	0.09 (0.11)
	Schools with risk	0.50	0.28 (0.20)	0.22 (0.14)	0.40 (0.19)	0.08 (0.10)
Level of risk by standard deviation	Very High	0.50	0.30 (0.14)	0.20 (0.06)	0.39 (0.15)	0.10 (0.11)
	High	0.49	0.26 (0.18)	0.23 (0.10)	0.43 (0.17)	0.06 (0.07)
	Moderately high	0.48	0.28 (0.16)	0.20 (0.10)	0.43 (0.14)	0.08 (0.08)
	Moderately low	0.50	0.29 (0.17)	0.21 (0.11)	0.40 (0.17)	0.09 (0.11)
	Low	0.46	0.25 (0.22)	0.21 (0.15)	0.43 (0.25)	0.10 (0.17)
	Very Low	0.27	0.12 (0.03)	0.15 (0.05)	0.57 (0.06)	0.13 (0.08)

Note. Mean percent is reported with standard deviation in parentheses.

the Very Low risk category, the mean percentage of students who did not pass the eighth grade AIMS math test is 27%, an amount 21 percentage points lower than the state mean of 48%.

Bivariate Correlations

Third Grade Reading. Bivariate correlation analyses assessed the relationship between lead risk, as measured by the LPRI, and student achievement, race, poverty, special education, and head of household composition. This was followed by inspecting the correlations between student achievement and race, poverty, special education, and head of household composition. The final step was to look at poverty's relationship with race and head of household composition. This pattern of correlation analyses will take place for schools with third grade students and then schools with eighth grade students. There is a weak positive correlation between the LPRI and the percentage of third grade students who do not pass the AIMS reading test ($r = 0.12$, $p<0.06$).

The relationship between the LPRI and race is weak and negative. Other than the weak, positive correlation for the percentage of students at a school who are Hispanic and the LPRI ($r = 0.20$, $p<0.01$), all other correlations between race and the LPRI are negative. While the correlation for the percentage of white students at a school and the LPRI is -0.15 ($p<0.05$), correlations between the LPRI and the percentages of students at a school who are African American, Asian, or Native American are not statistically significant and very weak in nature. The relationship between student achievement and the percentage of students who qualify for free and reduced lunch is positive and statistically significant ($r = 0.20$, $p<0.01$).

Table 15

LPRI, Third Grade Reading and Variables of Interest Correlations

		LPRI	3rd Grade % Not Pass	SLD	ED	SpEd	Married	Male	Female	Total F/R Percentage	White	Hispanic	African American	Asian	Native American
LPRI	Pearson Correlation	1													
	Sig. (2-tailed)														
	N	258													
3rd Grade % Not Pass	Pearson Correlation	.118	1												
	Sig. (2-tailed)	.058													
	N	258	1017												
SLD	Pearson Correlation	.035	.262	1											
	Sig. (2-tailed)	.581	.000												
	N	258	1017	1017											
ED	Pearson Correlation	-.094	.019	.212	1										
	Sig. (2-tailed)	.133	.542	.000											
	N	258	1017	1017	1017										
SpEd	Pearson Correlation	-.028	.123	.774	.431	1									
	Sig. (2-tailed)	.655	.000	.000	.000										
	N	258	1017	1017	1017	1017									
Married	Pearson Correlation	.034	-.181	-.171	-.041	-.153	1								
	Sig. (2-tailed)	.586	.000	.000	.197	.000									
	N	258	1017	1017	1017	1017	1017								
Male	Pearson Correlation	.009	.232	.063	-.020	.004	.492	1							
	Sig. (2-tailed)	.889	.000	.044	.525	.888	.000								
	N	258	1017	1017	1017	1017	1017	1017							
Female	Pearson Correlation	.119	.307	.068	-.029	-.008	.408	.853	1						
	Sig. (2-tailed)	.056	.000	.031	.364	.810	.000	.000							
	N	258	1017	1017	1017	1017	1017	1017	1017						
Total F/R Percentage	Pearson Correlation	.197	.797	.271	-.052	.097	-.256	.288	.379	1					
	Sig. (2-tailed)	.002	.000	.000	.117	.003	.000	.000	.000						
	N	244	915	915	915	915	915	915	915	915					
White	Pearson Correlation	-.154	-.729	-.177	.085	-.001	.173	-.184	-.332	-.814	1				
	Sig. (2-tailed)	.015	.000	.000	.008	.973	.000	.000	.000	.000					
	N	250	986	986	986	986	986	986	986	889	986				
Hispanic	Pearson Correlation	.200	.587	.054	-.124	-.085	-.120	.174	.240	.712	-.834	1			
	Sig. (2-tailed)	.002	.000	.090	.000	.007	.000	.000	.000	.000	.000				
	N	250	986	986	986	986	986	986	986	889	986	986			
African American	Pearson Correlation	-.039	.131	-.020	.113	.046	-.094	.050	.068	.093	-.185	.086	1		
	Sig. (2-tailed)	.536	.000	.525	.000	.147	.003	.117	.032	.006	.000	.007			
	N	250	986	986	986	986	986	986	986	889	986	986	986		
Asian	Pearson Correlation	-.012	-.464	-.234	.004	-.129	.113	-.160	-.166	-.575	.354	-.353	.128	1	
	Sig. (2-tailed)	.856	.000	.000	.901	.000	.000	.000	.000	.000	.000	.000	.000		
	N	250	986	986	986	986	986	986	986	889	986	986	986	986	
Native American	Pearson Correlation	-.068	.301	.254	.026	.148	-.085	.033	.176	.235	-.328	-.213	-.145	-.188	1
	Sig. (2-tailed)	.283	.000	.000	.417	.000	.008	.300	.000	.000	.000	.000	.000	.000	
	N	250	986	986	986	986	986	986	986	889	986	986	986	986	986

The relationship between the LPRI and special education near zero, and as might be expected, are not statistically significant. The correlation between the LPRI and the overall percentage of students in special education as well as the percentage of students who are ED are -.0.03 ($p=0.66$) and -0.09 ($p=0.89$) respectively.

A weak positive relationship exists between the LPRI and head of household with children. Though the relationship between the LPRI and households with children headed by married couples and single fathers is statistically insignificant, the correlation between the LPRI and households headed by single mothers is 0.12 ($p<0.06$).

The relationships between student achievement and race and ethnicity are varied both in magnitude and direction. The correlation between the percentage of students who did not pass the third grade AIMS reading test and the percentage of students at a school who are white or Asian is a strong -0.73 ($p<0.01$) and a moderate -0.46 ($p<0.01$), respectively. The correlation of the percentage of students at a school who are Hispanic and the percentage who did not pass third grade AIMS reading test is a moderately strong 0.59 ($p<0.01$), while there is a weak correlation for Native American students and third grade AIMS reading non-passers ($r= 0.30$, $p<0.01$).

A strong significant positive relationship exists between poverty and not passing the third grade AIMS reading tests. The correlation between the percentage of students who qualify for free and reduced lunch and the percentage of students who don’t pass the third grade AIMS reading test is 0.80 ($p<0.01$).

The correlation between achievement and special education is positive and statistically significant for the overall percentage of students in special education and the percentage of students who are SLD. The correlation between the percentage of students who did not pass the third grade AIMS reading test and the overall percentage of students in special education and the percentage of students with SLD are 0.12 ($p<0.01$) and 0.26 ($p<0.01$) respectively.

Student achievement and head of household composition share a statistically significant weak relationship. The correlation between households with children headed by single mothers and fathers and the percentage of students who did not pass the third grade AIMS reading test are 0.31 ($p<0.01$) and 0.23 ($p<0.01$) respectively. A weak negative correlation of -0.18 ($p<0.01$) exists between household headed by married parents and the percentage of third grade AIMS reading non-passers.

Race and poverty are significantly correlated but the magnitude of the correlation depends on the racial or ethnic category being analyzed. The percentage of students at a school who are white or Asian have a moderate to strong negative correlation with the percentage of students who qualify for free and reduced lunch of -0.81 ($p<0.01$) and -0.58 ($p<0.01$) respectively. The correlation between the percentage of Hispanic students and the percentage of third grade AIMS reading non-passers is 0.71 ($p<0.01$). To a lesser magnitude, a correlation of 0.24 ($p<0.01$) exists between the percentage of students who are Native American and the percentage of students who do not pass the third grade AIMS reading test.

The relationship of poverty and head of household with children composition is modest but statistically significant. The correlation between the percentage of students who qualify for free and reduced lunch and the number of households headed by single mothers and single fathers is 0.38 ($p<0.01$) and 0.29 ($p<0.01$), respectively. A negative correlation of -0.26 ($p<0.01$) exists between married couples and the percentage of students who qualify for free and reduced lunch.

Eighth Grade Math. Bivariate correlation analyses were also run for schools that had eighth grade students taking the AIMS math test to assess the relationship between achievement, lead, race, poverty, special education, and head of household composition (Table 16). When the LPRI is correlated with the percentage of students who did not pass the eighth grade AIMS math test, the relationship is nearly zero ($r=0.07$, $p=0.41$).

The relationship between the LPRI and race and ethnicity is generally weak in nature, and dependent upon which racial or ethnic group is analyzed. A weak negative correlation exists between the LPRI and the percentage of students at a school who are white, Native American, and Asian, although it is statistically insignificant. A positive correlation exists between the LPRI and the percentage of Hispanic students at a school ($r = 0.23$, $p<0.01$).

There is a weak positive relationship between the LPRI and poverty ($r=0.15$, $p=0.08$). Further, there is little or no correlation between the LPRI and eighth grade special education. Not one relationship is statistically significant and the correlations are weak at best. The strongest relationship is between the LPRI

Table 16

LPRI, Eighth Grade Math and Variables of Interest Correlations

		LPRI	% eighth Math NonPass	SLD	ED	Special Ed	Married	Male	Female	Total F/R Percentage	White	Hispanic	African American	Asian	Native American
LPRI	Pearson Correlation	1													
	Sig. (2-tailed)														
	N	167													
% Eighth Math NonPass	Pearson Correlation	.065	1												
	Sig. (2-tailed)	.406													
	N	167	620												
SLD	Pearson Correlation	.052	.278	1											
	Sig. (2-tailed)	.508	.000												
	N	167	620	621											
ED	Pearson Correlation	-.025	.105	.189	1										
	Sig. (2-tailed)	.746	.009	.000											
	N	167	620	621	621										
Special Ed	Pearson Correlation	-.059	.276	.762	.498	1									
	Sig. (2-tailed)	.449	.000	.000	.000										
	N	167	620	621	621	621									
Married	Pearson Correlation	.121	-.132	-.150	-.083	-.198	1								
	Sig. (2-tailed)	.119	.001	.000	.040	.000									
	N	167	620	621	621	621	621								
Male	Pearson Correlation	.087	.139	.030	-.059	-.056	.584	1							
	Sig. (2-tailed)	.264	.001	.451	.140	.164	.000								
	N	167	620	621	621	621	621	621							
Female	Pearson Correlation	.216	.187	.022	-.074	-.076	.486	.851	1						
	Sig. (2-tailed)	.005	.000	.578	.065	.057	.000	.000							
	N	167	620	621	621	621	621	621	621						
Total F/R Percentage	Pearson Correlation	.145	.691	.272	-.078	.191	-.229	.182	.273	1					
	Sig. (2-tailed)	.074	.000	.000	.078	.000	.000	.000	.000						
	N	154	507	508	508	508	508	508	508	508					
White	Pearson Correlation	-.114	-.586	-.181	.120	-.044	.175	-.084	-.235	-.750	1				
	Sig. (2-tailed)	.149	.000	.000	.003	.283	.000	.039	.000	.000					
	N	161	599	600	600	600	600	600	600	494	600				
Hispanic	Pearson Correlation	.229	.397	.070	-.128	-.033	-.120	.081	.110	.619	-.752	1			
	Sig. (2-tailed)	.003	.000	.087	.002	.422	.003	.048	.007	.000	.000				
	N	161	599	600	600	600	600	600	600	494	600	600			
African American	Pearson Correlation	.043	.237	-.048	.064	.068	-.060	.033	.044	.106	-.246	.134	1		
	Sig. (2-tailed)	.584	.000	.244	.115	.098	.140	.419	.280	.019	.000	.001			
	N	161	599	600	600	600	600	600	600	494	600	600	600		
Asian	Pearson Correlation	-.015	-.442	-.234	.026	-.170	.101	-.135	-.142	-.568	.329	-.265	.055	1	
	Sig. (2-tailed)	.847	.000	.000	.530	.000	.014	.001	.000	.000	.000	.000	.175		
	N	161	599	600	600	600	600	600	600	494	600	600	600	600	
Native American	Pearson Correlation	-.132	.277	.204	-.027	.100	-.083	.015	.191	.232	-.391	-.270	-.161	-.226	1
	Sig. (2-tailed)	.095	.000	.000	.505	.015	.042	.712	.000	.000	.000	.000	.000	.000	
	N	161	599	600	600	600	600	600	600	494	600	600	600	600	600

and the overall percentage of students in special education at a school ($r= -0.06$, $p>0.05$).

The correlation between the LPRI and head of household with children composition is generally positive but weak. The relationships between the LPRI and households with children headed by married couples is 0.12 ($p<0.12$), while it is 0.09 ($p<0.26$) for the LPRI and single fathers, correlations that are weak and statistically insignificant. The correlation between the LPRI and households headed by single mothers is positive and statistically significant 0.22 ($p<0.01$).

Student achievement and its relationship to the other variables is of great interest. Statistically significant positive relationships exist between special education and the percentage of eighth grade students who do not pass the AIMS math test. The correlation between the percentages of students who are ED and eighth grade non-passers is quite low, but significant ($r = 0.10$, $p<0.01$). Both the overall percentage of special education students and the percentage of students who are SLD share the same positive relationship with the percentage of students who did not pass the eighth grade AIMS math test ($r = 0.28$, $p<0.01$).

A statistically significant relationship exists between head of household composition and student achievement. The percentage of eighth grade students who do not pass the AIMS math test has a weak and negative relationship with the number of households with children headed by married couples ($r=-0.13$, $p<0.01$). The relationship between eighth grade AIMS math non-passers and households headed by single fathers and mothers are positive and weak but statistically significant ($r=0.14$, $p<0.01$ and 0.19 $p<0.01$, respectively).

There is a strong positive relationship between not passing the eighth grade AIMS math test and the percentage of students who qualify for free and reduce lunch ($r = 0.69$, $p<0.01$).

The relationship between student achievement and race or ethnicity is statistically significant for all racial and ethnic categories, yet is weak to moderate in magnitude. For the percent of students at a school who are white and Asian, a negative correlation exists with not passing the eighth grade AIMS math test ($r = -.0.59$, $p<0.01$ and -0.44, $p<0.01$, respectively). The correlation between not passing the eighth grade AIMS math test and the percentage of Hispanic and Native American students at a school is 0.40 ($p<0.01$) and 0.28 ($p<0.01$) respectively. A positive relationship exists between the percentage of students who don't pass the eighth grade AIMS math test and the percentage of students at a school who are African American ($r = 0.24$, $p<0.01$).

Poverty and race share a moderate, statistically significant relationship. Three moderate to strong relationships exists between the percentage of poor students and the percentage of students at a school who are white, Asian, or Hispanic. The percentage of students at a school who are white and Asian have a negative statistically significant correlation with poverty ($r= -0.75$, $p<0.01$ and -0.57, $p<0.01$, respectively). The correlation of the percentage of students who qualify for free and reduced lunch and the percentage of Hispanic students at a school is 0.62 ($p<0.01$).

Poverty also displays a statistically significant positive relationship with the number of households with children headed by single parents. The correlation between poverty and single mother and single father headed households is 0.27 ($p<0.01$) and 0.18 ($p<0.01$) respectively.

Multivariate Regression Analyses

Multivariate regression analyses were conducted to determine the effect of the LPRI, race, poverty, special education eligibility and head of household composition on academic achievement. Table 17 contains the results of five multivariate regression models for third grade AIMS reading achievement, using various school and census variables. Table 18 contains those models predicting achievement on the eighth grade AIMS math test at those schools with an LPRI score.

Third Grade Reading. Model 1, predicting the percentage of students at a school who do not pass the third grade AIMS reading test as a function of the six LPRI categories, is significant ($F=4.09$, $p<0.01$) but not strongly predictive ($r^2 = 0.06$). In this model, the higher the risk of being poisoned by lead, the higher the predicted percentage of students at a school that do not pass the third grade AIMS reading exam. For example, schools at the highest level of risk have approximately 39% of students who do not pass. Conversely, for schools in the lowest level of risk, in the Very Low category, only 14% of students are predicted to not pass.

In Model 2, with the addition of race along with the LPRI, the predictive value increases considerably ($r^2 = 0.48$). As the effect of race and the LPRI on achievement is discovered, none of the LPRI categories remain statistically significant, while all race and ethnicity categories are significant ($p<0.01$).

Table 17

Relationship Between Third Grade Reading, Lead, and Key Demographic and Census Variables

Cluster	Variables	Model 1	Model 2	Model 3	Model 4	Model 5
	Constant (Sig.)	.138 (.083)	.134 (.043)*	.100 (.108)	.074 (.277)	.025 (.749)
LPRI	Very High	.254 (.007)**	.051 (.498)	-.028 (.757)	-.013 (.891)	-.003 (.975)
	High	.301 (.001)**	.077 (.294)	-.034 (.689)	-.021 (.803)	-.020 (.810)
	Moderately High	.318 (.000)**	.106 (.127)	-.014 (.843)	-.002 (.974)	.011 (.885)
	Moderately Low	.267 (.001)**	.077 (.255)	-.042 (.533)	-.029 (.668)	-.017 (.805)
	Low	.202 (.020)*	.028 (.693)	-.087 (.231)	-.069 (353)	-.051 (498)
Race	Hispanic		.363 (.000)**	.170 (.000)**	.184 (.000)**	.153 (.005)**
	African American		.718 (.004)**	.389 (.116)	.387 (.119)	.311 (.218)
	Asian		-2.372 (.001)**	-1.148 (.109)	-1.084 (.134)	-1.027 (.156)
	Native American		.473 (.000)**	.316 (.000)**	.318 (.000)**	.269 (.000)**
Poverty	Free/Reduced Lunch			.396 (.000)**	.391 (.000)**	.366 (.001)**
	Interaction			-.042 (.764)	-.041 (.771)	-.005 (970)
Special Education	Overall				-.066 (.817)	-.012 (.966)
	SLD				.123 (.181)	.027 (.943)
	ED				1.245 (.181)	1.151 (.216)
Census	Married					.032 (.763)
	Father					1.513 (.152)
	Mother					.115 (.737)
F-statistics (*df*)		4.09 (5)	26.41 (9)	25.21 (11)	19.86 (14)	16.71 (17)
Adjusted R^2		0.057	0.479	0.530	0.528	0.531
Unweighted schools total		258	250	237	237	237

Note. *p< 0.05. ** p< 0.01

Relative to white students, increases in the percentage of minority students at a school are associated with higher predicted failure rates on the third grade AIMS reading test. For a 10 percentage point increase in the percentage of Hispanic students at a school, it is predicted that 3.6% more students would not pass the exam ($t=10.89$, $p<0.01$). An exception to this pattern involves the percentage of Asian students at a school. For every one percent increase in the percentage of Asian students at a school, it is predicted that 2.3% fewer students will fail the exam ($t=-3.38$, $p<0.01$).

Model 3 adds poverty along with the LPRI and race to predict achievement. After including the percentage of poor students at a school and an interaction variable to account for the remaining variance between poverty and the LPRI, the predictive value of the model increased ($r^2 = 0.53$) and maintained its significance ($F=25.21$, $p<0.01$).

The addition of free and reduced lunch to the model confines the negative effect of poverty on achievement. For every 10% of students at a school who qualify for free and reduced lunch, there is a predicted 4% increase in the percentage of students who do not pass the third grade AIMS reading test.

Independent of poverty, the effect of the LPRI categorizations' influence on achievement approaches zero, none of which are statistically significant. After accounting for poverty, the influence of race on predicted achievement is reduced in all categories, but is still statistically significant for Hispanic, and Native American students ($p<0.01$ for each).

Model 4 adds the influence of special education to the effects that race and ethnicity, poverty, and the LPRI have on third grade reading achievement. The predictive value doesn't change ($r^2 = 0.53$), and the presence of special education is statistically not significant. One note to make is the influence of the percentage of emotionally disabled (ED) students at a school may have on the predicted percentage of students who do not pass the third grade reading AIMS exam. For each percent of ED students at a school, it is predicted that 1.25% more students would not pass the AIMS test ($p<0.18$)

After accounting for special education, the influence of the LPRI continues to get closer to zero. As for race, previous statistically significant variables of percentage of Hispanic and Native American students and the percentage of free and reduced lunch maintain their significance.

Model 5, which includes census variables for the percentage of households with children headed by married or single parents, is predictive ($r^2 = 0.53$) and statistically significant ($F=16.71$ (17), $p<0.01$).

Independent of other variables, census variables for head of households with children are not significant in any category. Notably, however, for single fathers, though not significant ($p=0.15$), for each percent of households in a census tract that are headed by a single father, there is a predicted 1.5% increase in the percentage of students who do not pass the exam.

As for the effect of head of households with children variables on the other model variables, very little changes from Model 4. The coefficients for the LPRI categorizations remain near zero, and though their effect is slightly decreased, the statistical significance remains for the percentage of students at a school who are Hispanic or Native American, or if students qualify for free and reduced lunch.

Eighth Grade Math. The initial model predicting the percentage of students at a school who would not pass the eighth grade AIMS math exam as a function of the LPRI categorizations is neither significant ($F=1.11$, $p<0.32$) nor predictive ($r^2 = 0.01$).

For Model 1, the higher the risk of lead, the higher the percentage of students predicted to not pass the eighth grade AIMS math test. For schools in the Moderately Low category, , 49% of the students are predicted to not pass AIMS. Conversely, for schools in the Very Low category, 27% of students are predicted to not pass AIMS.

Model 2, which includes the presence of race and ethnicity with the LPRI, leads to an increase in predictive value ($r^2 = 0.45$) and is also statistically significant ($F=15.54$, $p<0.01$). Compared to white students, as the percentage of minority students at a school increases, so too does the predicted percentage of students who would not pass the eighth grade AIMS math test. All categories are statistically significant. Specifically, for every 10 percent increase in the percentage of students at a school who are African American, there is 10 percent more students who are predicted to not to pass the AIMS test ($t=2.98$, $p<0.01$). As the percentage of either Native American or Hispanic students at a school increases by 10%, approximately 4% more students are predicted to not pass the eighth grade AIMS math test.

Table 18

Relationship Between Eighth Grade Math, Lead, and Key Demographic and Census Variables

Cluster	Variables	Model 1	Model 2	Model 3	Model 4	Model 5
	Constant (Sig.)	.268 (.005)**	.269 (.000)**	.243 (.001)**	.222 (.005)**	.311 (.001)**
LPRI	Very High	.234 (.067)	-.001 (.994)	.029 (.811)	.055 (.657)	.004 (.974)
	High	.222 (.042)*	-.023 (788)	-.015 (.887)	.003 (.980)	-.039 (.720)
	Moderately High	.207 (.038)*	-.005 (.951)	-.054 (.518)	-.041 (.629)	-.080 (.358)
	Moderately Low	.229 (.020)*	.012 (.874)	-.052 (.512)	-.048 (.552)	-.104 (.219)
	Low	.192 (.066)	-.034 (.672)	-.109 (.225)	-.112 (.217)	-.167 (.079)
Race	Hispanic		.398 (.000)**	.318 (.000)**	.334 (.000)**	.354 (.000)**
	African American		1.006 (.003)**	.952 (.006)**	.800 (.028)*	.957 (.011)**
	Asian		-2.467 (.015)*	-1.941 (.057)	-1.872 (.069)	-1.991 (.054)*
	Native American		.443 (.000)**	.366 (.000)**	.374 (.000)**	.413 (.000)**
Poverty	Free/Reduced Lunch			.328 (.031)*	.340 (.028)*	.376 (.015)*
	Interaction			-.237 (.273)	-.274 (.211)	-.287 (.190)
Special Education	Overall				.464 (.150)	.315 (.334)
	SLD				-.493 (.237)	-.498 (.230)
	ED				-.360 (.698)	-.441 (.634)
Census	Married					-.344 (.028)*
	Father					1.958 (.192)
	Mother					-.407 (.379)
F-statistics (*df*)		1.18 (5)	15.54 (9)	12.64 (11)	10.04 (14)	8.82 (17)
Adjusted R^2		0.005	0.450	0.464	0.461	0.473
Unweighted schools total		167	161	149	149	149

Note. *p< 0.05. ** p< 0.01

An exception is with the percentage of Asian students at a school. For every percent increase, there will be 2.5% fewer students predicted to not pass ($T=-2.47$, $p<0.02$).

Model 3 takes poverty and includes it with race and ethnicity, and the LPRI. Model 3 has a higher predicted value ($r^2 = 0.46$) and is also statistically significant ($p<0.01$).

As the percentage of students who qualify for free and reduced lunch increases, the greater the percentage of students who are predicted not to the eighth grade AIMS math exam. As the free and reduced lunch percentage goes up by 10%, a school is predicted to see a 3.7% increase in the percentage of students who do not pass.

After accounting for poverty, the LPRI categorization coefficients approach zero and continue not to be statistically significant. All categories of race and ethnicity, on the other hand, though diminished in influence are statistically significant. A 10% increase in the percentage of students at a school who are Hispanic or Native American would predict approximately 3% more students not passing, while as the percentage of African American students increases by 10%, approximately 10% more students are predicted not to pass.

Model 4 adds the percentage of students at a school in special education to the variables of LPRI, race and ethnicity, and poverty. This model's predictive value ($r^2 = 0.46$) and significance ($p<0.01$) are the same as Model 3. The presence of students in special education has no statistical significance and changes little relative to the other variables in the model.

Model 5 adds census variables for the heads of households with children to the LPRI, race, poverty, and special education. This model is slightly more predictive ($r^2 = 0.47$) and is statistically significant ($p<0.01$).

The percentage of households with children headed by married or single parents is not statistically significant. However, the percentage of households headed by single fathers has a predicted impact on the percentage of students not passing the eighth grade AIMS math test. A 10% increase in the percentage of households headed by single fathers is predicted to have a 20% increase in the percentage of students at a school that would not pass the AIMS math exam.

Independent of the head of household with children variables, the LPRI categories have no significance. Race plays a slightly bigger role as there is a predicted impact on achievement as the percentage of students at a school who are either Hispanic, African American or Native American increases. These all maintain their statistical significance ($p<0.01$). A similar slight increase in effect is seen relative to poverty. Accounting for the heads of households with children finds the impact of poverty predicting a third of a percent more students not passing the eighth grade AIMS math test for each 1% increase in the amount of poverty at a school.

Portraiture

Race, poverty, special education, and census variables were included with the LPRI in five different models to predict third and eighth grade achievement on AIMS. Model 5, which contains all of the variables, is predictive of the third grade AIMS reading achievement ($r^2 = 0.53$) and of the eighth grade AIMS math achievement ($r^2 = 0.47$), both of which are statistically significant ($p<0.01$). But what does it look like when a real set of demographic and census variables are used representing real schools? Using unstandardized residual values (the difference between the predicted value and the real value), the LPRI and student population counts for third grade schools and eighth grade schools, it is possible to go beyond the macro view provided by large scale data analysis and delve deeper into the microcosm in which the schools exist and better understand the varying pictures of predictability.

To select schools of interest, the first step was to identify those schools with the largest positive or negative residuals. Secondly, using these high residual schools, the corresponding LPRI values were reviewed, looking for the highest LPRI values. Once a set of high residual, high LPRI schools were found, this group was narrowed further after looking at student population counts for each school. These three steps identified sizeable schools with a high risk of being poisoned by lead and a residual value that was considerably off from what was predicted by the multivariate regression analyses.

Residuals. The residual values for both third and eighth grade schools have similar distributions. Residuals for third grade schools whose students take the AIMS reading test range from –0.43 to 0.35 with a standard deviation of 0.13 while the residuals for eighth grade schools whose students take the AIMS math exam range from –0.35 to 0.43 with a standard deviation of 0.13. The residuals for both kinds of schools have approximately 50% of their values in the -0.10 to 0.10 range and 70% of their values between -0.15 and 0.15.

Mountain Oak School. Nestled in a neighborhood in Prescott, Arizona, Mountain Oak School is an elementary charter school that uses a Waldorf Methods approach of integrating music and arts with academics. It has been in operation in Prescott since 1999. Mountain Oak's students are 91% white and 8% Hispanic with 44% of the student body qualifying for free and reduced lunch. These percentages place Mountain Oaks' student body below the state average for poverty by 14 percentage points and almost twice the state mean for percentage of white students at a school. The school also resides in a census tract that caries with it the highest LPRI value of 1.157. This LPRI is in the highest level of risk category, more than three standard deviations above the mean. Mountain Oak School is a predominantly white school with a moderately low level of poverty indicators that based on the multivariate regression analyses would predict a relatively low failure rate on third grade AIMS reading, but it also is located in a census tract with the highest risk level for lead poisoning.

The multivariate regression analyses predicts that Mountain Oak School would have 25% of its school fail the third grade AIMS reading test. However, its residual of 0.22 means 47% of Mountain Oak students failed. For some reason, more students failed than were predicted to fail.

One element to be considered is the school's proximity to the Iron King Mine and the Humboldt Smelter. In business since the late 1800's, the Iron King Mine and accompanying smelter were processing 1000 tons of ore a day until the mid 1960's. In March of 2008, the Iron King Mine and Humboldt Smelter were proposed as additions to the National Priorities List as a Superfund site. Elevated levels of lead and other heavy metals were found in soil, groundwater, surface water, and sediments. Mountain Oak's proximity to the Iron King Mine and Humboldt Smelter is worth looking at relative to the difference in predicted and actual failure rates on the AIMS test.

One other element of third grade AIMS reading achievement at Mountain Oak School is the fluctuation of scores from 2005 – 2008. There is a low failure rate of 12% in 2006 and a high of 66% in 2008. The fluctuation more than likely stems from the small number of students in each grade level. With only 17 students testing, significant changes in failure rates can result from only a sample with only a few students.

Mexicayotl Academy. Another interesting case is the Mexicayotl Academy in Nogales, Arizona. A high poverty (93.5%), exclusively Hispanic school, Mexicayotl Academy offers a Montessori learning experience with a strong multicultural element integrated into school activities and academics. The Mexicayotl Academy is especially useful for this comparison of predicted performance versus reality as it offers instruction in grades kindergarten through eighth grade, allowing the predictive nature of the multivariate regression analysis to be applied at two different times, but at the same school.

Located within two miles of the U.S. Mexico international border, the Mexicayotl Academy is in a census tract with an LPRI score of 1.006, placing it two standard deviations above the mean of census tracks at risk. With such high poverty, high Hispanic population, and in such a high LPRI census track, this school should have a high failure rate.

Mexicayotl Academy exhibits a high degree of variance in the achievement of its third and eighth grade students, a dynamic that is reflected in its different residual values. Model 5 of the multivariate regression analysis predicts 55% of third graders would fail the AIMS reading test, yet the residual of 0.34 indicates that 89% failed. For eighth graders, the multivariate regression analyses predicted 60% to fail the eighth grade AIMS math test, yet the residual was -0.27, meaning only 33% of eighth graders failed. How is it that the same school with the same variables and similar predictive models would have such varied failure rates?

The fluctuations in the scores probably result from such a low student count being tested. With fewer than 20 students being tested, the performance of a student or two would dramatically affect the failure rate for the school.

Summary

This chapter presented results of descriptive, correlation, and multivariate regression analyses for the LPRI and a variety of school and census variables. What was sought was understanding of the relationships between the risk of lead poisoning, academic achievement and school and community demographics. Chapter 5 will synthesize these results into a discussion about what was found, the impact on professional practice, and the avenues for future research.

Chapter 5

Discussion and Implications

This is a study that started to be about lead and how bad it is for children. Lead, from before birth and throughout the rest of a person's life, is associated with developmental, behavioral and intelligence problems. In humans, bodies and brains are permanently altered by the presence of lead. Behavior becomes less controlled and more antisocial and delinquent. With the loss of IQ, achievement suffers. When these impacts on individuals are combined and extrapolated to economic and social patterns, the presence of lead burdens society with costs for dealing with its results (incarceration, healthcare, special education) and at the same time chokes off revenues via loss of additional taxes resulting from better employment for better educated people. Lead is a double edged sword that chokes off revenues and augments the cost to society.

And yet – lead is not a factor in this study. At least not at the level studied here. Lead's clear substantiation as a harmful toxin shows powerful effects on individuals. However, to really understand its effect on achievement, individual student achievement data is needed. The trees need to be seen, not just the forest. The school level aggregated data provides a rich picture of school level achievement, but at that level of aggregation what gets masked is the impact of lead on individual students' achievement.

Further complicating the clarity of lead's impact is the lack of certainty as to whether poisoned students were a part of the student body. The LPRI quantified a degree of risk for census tracts based on common lead poisoning factors, but whether students were poisoned or not is not known.

A third factor for why lead is not a factor in this school level analysis is an issue of mobility. With census tracts labeled as having a certain level of risk for being exposed to and poisoned by lead, there is an assumption that students from that tract attend schools in that tract. However, with school boundaries not being tied to census tracts and with Arizona's open enrollment laws and numerous charter schools of choice, students can attend schools where they choose. A school chosen by a family may be in another part of town or within a different census tract. It is feasible that students may live in a tract with one level of risk and attend a school in a tract of a different level of risk. There was no way of knowing where students lived in relation to their school or census tract boundary.

The current state of Arizona's economy exacerbates the issue of mobility. As homes are foreclosed upon, as jobs are lost, and as the pinch of the recession feels more like a bite, families have been forced to move to other neighborhoods, cities, or states. Whether it's to take advantage of the newest, cheapest apartment deal, or the need for families to share a home, family movement and mobility can cloud the impact lead risk by census track has on individual student achievement.

Race and Poverty

What is a factor in this study is race and poverty. In Arizona's schools, higher levels of poverty and higher percentages of Hispanic, African American and Native American students are associated with higher failure rates on the third grade AIMS reading and eighth grade AIMS math tests.

This is not to say lead has no effect, only that if those effects exist, they are weak because of the inexactitude of using census tract data to infer risk. What was found was that schools in census tracts declared not to be at risk of exposure to lead look different than schools with risk. No Risk schools have fewer minority students, lower rates of free and reduced lunch and lower failure rates on the AIMS test. Risk schools have more minorities, more poverty and more failure.

Part of this elevated percentage of minorities and poverty in a school at risk of lead exposure is to be expected as core components of the formula used to create the LPRI are elements of race and poverty. But when correlations and multivariate regression analyses showed the impact of lead on achievement was weak at best, and as race and poverty were included, the predictive value of lead approached zero and lost its statistical significance. Lead in a sense was replaced by two more powerful variables – race and poverty.

Achievement on third grade AIMS reading and eighth grade AIMS math is tied to race and poverty. As the percentage of a school's Hispanic, African American, or Native American population increases, the percentage of students who fail the AIMS exam increases as well. As the percentage of students who qualify for free and reduced lunch increases at a school, so too does the percentage of students who fail their AIMS tests. And it should be no surprise, in schools with high poverty, there are also high percentages of minority students (Table 19). Conversely, white and Asian students are more prevalent in low poverty, higher performing schools. Figure 4 graphically displays this very dynamic. Race, poverty, and achievement are intimately linked.

Table 19

Percent of Race at a School by Level of Poverty

Poverty level of the school (percent free and reduced lunch)	White	Hispanic	African American	Asian	Native American
Less than 10%	86	7	2	4	1
10% - 24.9%	76	14	4	4	2
25% - 49.9%	65	24	5	2	4
50% - 74.9%	46	39	5	1	8
75% or more	18	60	5	1	17

These results are very similar to work that has been done highlighting the poverty, race, achievement connection (Berliner, 2006; Orfield & Lee, 2005). Some students, typically Hispanic students, attend neighborhood schools where a majority of the school population is living in poverty (Saporito & Sohoni, 2007). The typical white or Asian student attends schools with the lowest share of poverty while the typical Hispanic, African American, or Native American student attends schools with the highest rates of poverty (Orfield & Lee, 2005). Applying this high minority, high poverty mixture to achievement, Berliner's (2006) analysis of international test scores highlighted how non-poor students and white students regardless of poverty level competed very well against the other wealthy OECD countries. Conversely, Berliner also pointed out that Hispanic students, African American students, and high poverty students, taken as individual groups, were near the bottom of international performance. What is known after this study is that the greater the degree of poverty in schools, the more likely it is to find greater percentages of students who are Hispanic, African American, and Native American. It also means there will be a greater percentage of students who fail their third grade reading and eighth grade math AIMS tests (Table 20).

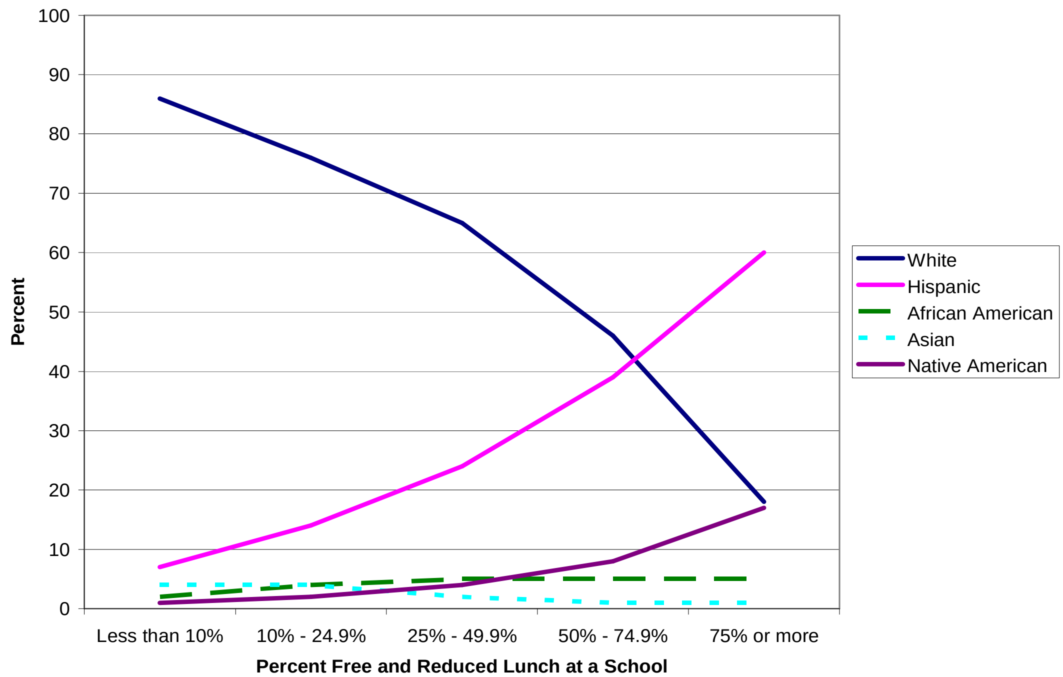

Figure 4. Percent of race at a school by level of poverty

Policy Implications

Results from this study carry with them some possible policy implications for state education leaders to consider. School accountability, elementary retention policies, high school graduation rates and college readiness are all possible focuses for reflection and consideration.

Move On When Reading. For Arizona, the race, poverty, achievement connection is about to be felt in a new manner. When Arizona's legislature passed Arizona House Bill 2732, the Move On When Reading legislation, it laid out the requirements for a benchmarked level of reading proficiency for all third grade students. Those that don't achieve the mark will be retained in third grade. Based on this study, what can be predicted is that the children who will be retained will be poor, Hispanic, African American, and Native American.

Table 20

Third Grade Reading and Eighth Grade Math Mean Failure Rates for Schools With Risk of Poisoning by Lead

Poverty level of the school (percent free and reduced lunch	Third grade AIMS reading failure rate		Eighth grade AIMS math failure rate	
	Schools	Mean (SD)	Schools	Mean (SD)
75% or more	99	0.56 (0.17)	54	0.62 (0.19)
50% - 74.9%	91	0.36 (0.14)	59	0.46 (0.14)
25% - 49.9%	30	0.30 (0.14)	27	0.37 (0.21)
10% - 24.9%	8	0.16 (0.10)	4	0.27 (0.09)
Less than 10%	7	0.11 (0.07)	4	0.25 (0.08)
State Average		0.36		0.46

Particularly problematic with this new high stakes accountability structure is the continued focus of consequences applied to a vulnerable population who are products of an environment over which they have no control. The children predicted to fail are more likely to live in a neighborhood that is rife with inadequacies – inadequate nutrition, housing, safety, healthcare, childcare, employment, opportunity (Berliner, 2006, Orfield & Lee, 2005). These neighborhoods, in which the students spend a majority of their time, impact children in ways over which the schools have no control and for which they will be held accountable.

Math Readiness. Turning to this study's other achievement data set, eighth grade AIMS math, there are similarly grave concerns for students' success in high school and beyond that are linked to race and poverty. Though there is no high stakes retention looming for eighth graders, advocates for the Move on When Reading legislation are already seeking ways to include other opportunities to limit promoting students not showing proficiency via the AIMS test at other grade levels. What complicates the eighth grade math achievement scenario is the simultaneous increasing of overall credits required to graduate, an increase within those overall credits of the number of math courses needed to graduate, and the high stakes portion of passing the tenth grade AIMS test. With the evidence in this study of the predictive power that the percentages of minority students and free and reduced lunch has on failure, there is a great likelihood that schools with high percentages of poverty and minority populations will continue to have high percentages of students not pass the eighth grade AIMS test. With such a high likelihood of not passing the eighth grade AIMS math test, and since it is a measure of preparedness for high school mathematics, the potential for success in earning the additional math credits and passing the tenth grade AIMS test is bleak. Though there is no high stakes testing accountability measure in eighth grade, the high stakes test two years later looms large on the horizon for both Arizona's teachers and students.

Again, an accountability measure will be applied that focuses solely on the workings of the school and does nothing to ameliorate the factors of poverty in the neighborhoods from which these students come. Instead of making kids smarter, this high stakes testing accountability structure has the potential to create more non-graduates with its mismatched focus on school and student accountability instead of social remedies. Add to it the potential increase in drop outs from the test based retention policies of Move On When Reading, this math related second consequence continues to punish our poorest minority students and will lay the blame for that failure on schools. How can this be a good thing?

School Accountability. Stepping away from student level data and consequences and turning now to school level accountability, results from this study challenge the structure, focus, and wisdom of school accountability systems that place so much stock in standardized state assessments like AIMS. Though this study may have started inquiring about lead as an out of school factor that might impact achievement, what was found was that poverty and race are the big players. This being the case, the appropriateness of labeling schools and ratcheting up consequences for patterns of poor school performance is called into question when so much of the school performance is attributable to factors beyond the school's control. With such a strong relationship between poverty and minority representation in schools and failure rates on the state's assessments, with such a vigorous predictive value for failure rates based on poverty and race, how can the state and the federal government focus exclusively on the context within a school as a method of educational reform when in reality it is the context within which the school is situated, the context of the racial and socioeconomic conditions of the neighborhood, that has such a huge impact on achievement? Is it right to ignore the powerful external factors at play in effecting student achievement and yet still apply consequences like public labeling, school take-overs and school closings knowing they are only and exclusively focusing on a small part of a very large equation? How can this be a good thing?

On a smaller scale, within school districts, a common practice that should be vigorously questioned based on this study's results is the use of state assessments as a portion of performance based incentive plans. Similar to the state and federal accountability conversation, questions surface about the appropriateness of attaching rewards or punishments to performance on the state assessments when there is such a large acknowledged impact from a context beyond the control of a specific school or district.

By no means does the impact of poverty and race on achievement let teachers, schools, or districts off the hook for using data to improve instruction and learning. The instructional pattern in classrooms across the state should constantly involve assessing students, offering corrective instruction, and reassessing the learning of students. But attaching incentives or punishments to standardized state assessments that when aggregated at the school level are so powerfully impacted by the percentage of students at the school who are poor or minority, doesn't seem appropriate or meaningful. Though the loss of a bonus is something very different than having a school closed or taken over, there still seems to be something wrong with a cycle of rewards that doesn't account for the context within which the teacher and the school operates.

Change in Professional Practice

Looking forward as I internalize this study's findings, and as I find the similarities between these results and the work of so many other researchers related to race, poverty and achievement, my professional practice will be altered.

As a leader of a school with in increasing percentage of poor and minority students, understanding the connection between race, poverty, and achievement will push me to consider both my school and the community in which my school resides when planning improvement efforts. As community needs change and grow, structures within my school can be created to bridge the need gap. As the percentage of families who do not speak English increase in my community, then my school's perspectives on Spanish language and culture needs to be examined, perhaps changed. Acknowledging the language needs by making obvious in print and presentation a willingness and ability to conduct business in Spanish will allow our services to more readily be received by our families. Our website and our publications need to have a Spanish option. Interpreting services will be needed for our verbal communications, whether over the phone or in person at meetings at the school. Those changes will likely not make our students smarter, but it will allow for an easier partnering with our families to collaborate with them in building successful experiences for their children.

As poverty and health care needs in the community continue to grow, our structure needs to account for that. My school has seen the percentage of free and reduced lunch increase by 30 percentage points over the last eight years, indicating a trend that predictively does not bode well for school achievement. I will need to be an advocate for more professional development for teachers to handle more impoverished children, and I will need to work to insure more community resources for our families. More effective school systems, including better trained and skilled teachers, complemented by better supported and serviced families beats our current "treat all schools the same" approach to serving kids.

The problem faced is twofold. One, unless the factors that exist in the neighborhoods in which the children and their families live are addressed, the impact of effective teachers' will be mitigated by neighborhood forces much greater and stronger than them. The other problem is that unless the contextual neighborhood factors are accounted for, teachers who are currently working in high poverty, high minority schools may be labeled as ineffective as their absolute results are lower than those in schools with more fortunate demographics. Until the context in which these schools and families exist are addressed, it doesn't seem right to label teachers and move them around when we need to be concerning ourselves with more important matters of improving the lives of our children and their families.

Future Research

Lead is bad for kids, and yet, due to the level of data aggregation, this study was unable to determine the impact lead has on the academic experience of poisoned children. This needs to be investigated further. The Arizona Department of Health Services maintains a registry of children who have been poisoned by lead. Using these children's elevated blood lead levels and then following their academic experience as they progress through the education system would provide a true picture of lead's impact on academic achievement. Those data were unavailable to this researcher.

One shortcoming of this study is the use of the LPRI, a measure of the risk of being exposed to and poisoned by lead. Future research on actual sources of lead within urban areas, their proximity to schools and residential areas and the resultant impact on the health and achievement would allow for a better understanding of lead's presence within communities and its academic impact on children.

Research is also needed to quantify the long term benefits of an investment in support of social programs to prevent problems associated with lead and poverty instead of planning on supporting the remediation of problems once they exist. The current mindset in the Arizona state legislature is to cut services for the most vulnerable populations, the children, the elderly, the disabled, and the sick. And yet what seems unquestioned is support for jails and prisons. As a state, our legislature is willing to sacrifice the investment in potential and is willing to invest in dealing with the consequences. A cost analysis should be done measuring the return on investment that would result from increased funding for healthcare, early childhood care, welfare to work programs, housing and education, and so forth. We need studies that measure the savings from the lack of lost wages and productivity due to healthier families not missing work due to illness, the reduction in services for incarcerating criminals, providing special education to poisoned children, or remediating ill prepared children. There also should be measures of the additional revenues generated from taxes from a greater number of high wage jobs filled by better educated people.

Conclusion

Lead is a powerful neurotoxin that permanently damages the bodies and brains of thousands of children each year. In census tracts with a risk of being poisoned by lead, there are schools with higher percentages of students that are poor and minority compared to those schools with no risk of being poisoned by lead. Yet when achievement is analyzed at the school level, lead's impact practically disappears, being replaced by two more powerful forces – poverty and race. The higher the percentage of students at a school on free and reduced lunch and the higher the percentage of students at a school that are Hispanic, African American or Native American, the greater the percentage of students who fail the third grade AIMS reading and eighth grade AIMS math tests. If we are to get better achievement results, we need to mitigate the effects of poverty on the lives of our students. If we are to better our schools, if we are to better prepare our students for a productive future, we need to account for the context within which schools operate and improve the neighborhoods and the quality of life for the families of our students. It is the focus on the context within which schools operate that will make us great gains and not our current singular focus on reform efforts exclusively on the context within schools.

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APPENDIX A

ADDITIONAL TABLES AND FIGURES

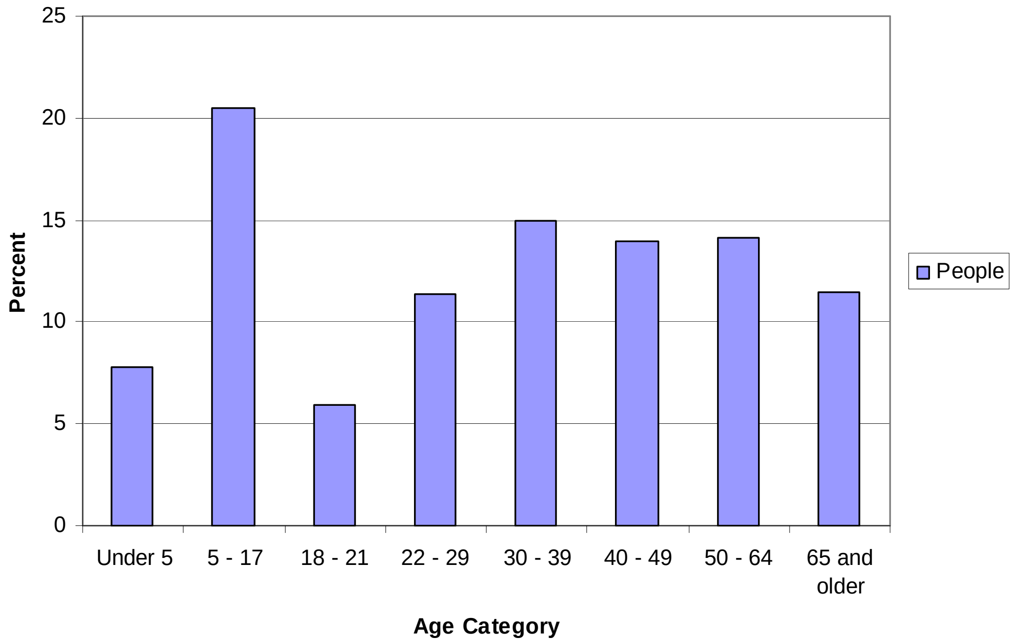

Figure A1. Percent of state population by age category

Table A1

Descriptive Statistics for Area and Population of Census Tract

	Range	Minimum	Maximum	Mean	Std. Deviation
Area (Square Miles)	5077.14	0.12	5077.26	174.75	523.40
Population	24301.00	118.00	24419.00	7108.71	3672.57

Table A2

Descriptive Statistics for Number of Students at a School

	Range	Minimum	Maximum	Mean	Std. Deviation
Number of Students	5427	3	5430	550.94	496.70

Table A3

Census Tract Composition by Level of Risk

Method	Category	Households		Housing Units		Population	
		Mean	SD	Mean	SD	Mean	SD
Risk of poisoning by lead	State	1983.55	1111.29	2283.97	1338.66	7108.71	3672.57
	No Risk	1932.20	974.18	2217.32	1221.70	6842.14	3346.27
	Risk	2110.45	1386.30	2448.74	1580.41	7767.65	4308.84
Level of risk by standard deviation	Very High	1923.31	850.44	2338.28	1225.75	7781.78	3606.62
	High	1864.06	515.33	2098.31	539.00	1595.57	2434.97
	Moderately High	2588.38	2040.24	2896.78	2200.14	9676.82	6104.92
	Moderately Low	2044.86	1057.39	2388.83	1342.89	7322.68	3016.01
	Low	1625.73	1062.37	2025.44	1245.67	5743.78	3550.75
	Very Low	1889.00	0.00	2312.00	0.00	5508.00	0.00

Table A4

Number of Schools in each LPRI Risk Category - Statewide

Method	Category	Frequency	Percent	Cumulative Percent
Risk of poisoning by lead	No Risk	1493	71.20	71.20
	Risk	604	28.80	100.00
	Total	2097	100.0	
		Frequency	Percent	Cumulative Percent
Above and below the mean	High Risk	247	40.89	40.89
	Low Risk	357	59.11	100.00
	Total	604	100.00	
		Frequency	Percent	Cumulative Percent
Quartile	High	144	23.84	23.80
	Medium High	148	24.50	48.30
	Medium Low	155	25.66	74.00
	Low	157	25.99	100.00
	Total	604	100.00	
		Frequency	Percent	Cumulative Percent
Level of risk by standard deviation	Very High	36	5.96	6.00
	High	49	8.11	14.10
	Moderately high	162	26.82	40.90
	Moderately low	268	44.37	85.30
	Low	81	13.41	98.70
	Very Low	8	1.32	100.00
	Total	604	100.00	

Table A5

Number of Schools in each LPRI Risk Category - Third Grade

Method	Category	Frequency	Percent	Cumulative Percent
Above and below the mean	High Risk	107	41.47	41.47
	Low Risk	151	58.53	100.00
	Total	258	100.00	
		Frequency	Percent	Cumulative Percent
Quartile	High	58	22.48	22.48
	Medium High	69	26.74	49.22
	Medium Low	60	23.26	72.48
	Low	71	27.52	100.00
	Total	258	100.00	
		Frequency	Percent	Cumulative Percent
Level of risk by standard deviation	Very High	16	6.20	6.20
	High	24	9.30	15.50
	Moderately high	67	25.97	41.47
	Moderately low	112	43.41	84.88
	Low	33	12.79	97.67
	Very Low	6	2.33	100.00
	Total	258	100.00	

Table A6

Number of Schools in each LPRI Risk Category - Eighth Grade

Method	Category	Frequency	Percent	Cumulative Percent
Above and below the mean	High Risk	68	40.72	40.72
	Low Risk	99	59.28	100.00
	Total	167	100.00	
		Frequency	Percent	Cumulative Percent
Quartile	High	36	21.56	21.56
	Medium High	40	23.95	45.51
	Medium Low	42	25.15	70.66
	Low	49	29.34	100.00
	Total	167	100.00	
		Frequency	Percent	Cumulative Percent
Level of risk by standard deviation	Very High	6	3.59	3.59
	High	15	8.98	12.57
	Moderately high	47	28.14	40.72
	Moderately low	71	42.51	83.23
	Low	23	13.77	97.01
	Very Low	5	2.99	100.00
	Total	167	100.00	

Table A7

Mean Percentage of School Level Demographic Information by Level of Risk

Category	Race				
	White	Hispanic	Black	Asian	Native American
State	0.49 (0.31)	0.36 (0.29)	0.05 (0.06)	0.02 (0.02)	0.09 (0.22)
No Risk	0.52 (0.31)	0.33 (0.28)	0.05 (0.06)	0.02 (0.02)	0.08 (0.21)
Risk	0.43 (0.30)	0.41 (0.30)	0.03 (0.04)	0.01 (0.01)	0.11 (0.22)
	Head of Household				Poverty
	Married	Father	Mother		F/R Lunch
State	486.30 (289.98)	55.60 (33.77)	144.62 (96.08)		0.58 (0.28)
No Risk	505.24 (290.85)	54.29 (31.83)	136.35 (90.57)		0.54 (0.29)
Risk	439.49 (282.64)	58.84 (37.99)	165.06 (105.82)		0.66 (0.23)
	Special Education				
	SLD	ED	Overall		
State	0.08 (0.05)	0.01 (0.04)	0.13 (0.09)		
No Risk	0.08 (0.05)	0.01 (0.03)	0.13 (0.08)		
Risk	0.08 (0.05)	0.01 (0.05)	0.14 (0.10)		

Note. Mean percent is reported with standard deviation in parentheses.

Table A8

Mean School Race and Ethnicity Percentages for Risk and Non-risk Schools as Determined by the LPRI

Method	Category	White	Hispanic	Black	Asian	Native American
Risk of poisoning by lead	State	0.49 (0.31)	0.36 (0.29)	0.05 (0.06)	0.02 (0.02)	0.09 (0.22)
	Schools with no risk	0.52 (0.31)	0.33 (0.28)	0.05 (0.06)	0.02 (0.02)	0.08 (0.21)
	Schools with risk	0.43 (0.30)	0.41 (0.30)	0.03 (0.04)	0.01 (0.01)	0.11 (0.22)
Above and Below the Mean	High	0.38 (0.30)	0.47 (0.33)	0.03 (0.04)	0.01 (0.01)	0.11 (0.21)
	Low	0.46 (0.29)	0.38 (0.28)	0.04 (0.04)	0.01 (0.02)	0.12 (0.24)
Quartile	High	0.37 (0.30)	0.49 (0.33)	0.03 (0.04)	0.01 (0.01)	0.09 (0.17)
	Medium High	0.43 (0.30)	0.42 (0.32)	0.04 (0.05)	0.01 (0.02)	0.11 (0.23)
	Medium Low	0.48 (0.28)	0.34 (0.26)	0.04 (0.05)	0.01 (0.02)	0.13 (0.21)
	Low	0.43 (0.29)	0.40 (0.29)	0.03 (0.04)	0.01 (0.02)	0.12 (0.27)
Ethnic and racial composition by six categories of risk	Very High	0.43 (0.35)	0.50 (0.36)	0.02 (0.02)	0.01 (0.01)	0.04 (0.07)
	High	0.28 (0.22)	0.52 (0.32)	0.03 (0.04)	0.01 (0.02)	0.16 (0.24)
	Moderately high	0.40 (0.30)	0.44 (0.32)	0.04 (0.04)	0.01 (0.01)	0.11 (0.22)
	Moderately low	0.46 (0.29)	0.38 (0.28)	0.04 (0.05)	0.01 (0.02)	0.11 (0.21)
	Low	0.43 (0.29)	0.38 (0.28)	0.02 (0.03)	0.01 (0.02)	0.16 (0.30)
	Very Low	0.91 (0.02)	0.05 (0.03)	0.02 (0.01)	0.02 (0.01)	0.00 (0.00)

Note. Mean percent is reported with standard deviation in parentheses.

Table A9

Mean School Percentage of Poverty for Risk and Non-risk Schools as Determined by the LPRI

Method	Category	Percent Free and Reduced Lunch
Risk of poisoning by lead	State	0.58 (0.28)
	Schools with no risk	0.54 (0.29)
	Schools with risk	0.66 (0.23)
Above and Below the Mean	High	0.71 (0.20)
	Low	0.63 (0.23)
Quartile	High	0.71 (0.20)
	Medium High	0.71 (0.21)
	Medium Low	0.60 (0.22)
	Low	0.64 (0.25)
Level of risk by standard deviation	Very High	0.71 (0.24)
	High	0.73 (0.20)
	Moderately high	0.70 (0.20)
	Moderately low	0.64 (0.22)
	Low	0.66 (0.22)
	Very Low	0.08 (0.03)

Note. Mean percent is reported with standard deviation in parentheses.

Table A10

Mean School Special Education Percentages for Risk and Non-risk Schools as Determined by the LPRI

Method	Category	SLD	ED	Overall
Risk of poisoning by lead	State	0.08 (0.05)	0.01 (0.04)	0.13 (0.09)
	Schools with no risk	0.08 (0.05)	0.01 (0.03)	0.13 (0.08)
	Schools with risk	0.08 (0.05)	0.01 (0.05)	0.14 (0.10)
Above and Below the Mean	High	0.08 (0.04)	0.01 (0.01)	0.13 (0.05)
	Low	0.08 (0.05)	0.01 (0.04)	0.14 (0.07)
Quartile	High	0.08 (0.04)	0.01 (0.01)	0.13 (0.06)
	Medium High	0.08 (0.05)	0.01 (0.01)	0.14 (0.06)
	Medium Low	0.09 (0.05)	0.01 (0.05)	0.14 (0.07)
	Low	0.07 (0.04)	0.01 (0.01)	0.13 (0.06)
Level of risk by standard deviation	Very High	0.07 (0.03)	0.00 (0.00)	0.11 (0.05)
	High	0.09 (0.04)	0.01 (0.02)	0.14 (0.05)
	Moderately high	0.08 (0.04)	0.01 (0.01)	0.13 (0.06)
	Moderately low	0.09 (0.05)	0.01 (0.04)	0.14 (0.06)
	Low	0.08 (0.05)	0.01 (0.01)	0.13 (0.07)
	Very Low	0.06 (0.03)	0.02 (0.02)	0.12 (0.06)

Note. Mean percent is reported with standard deviation in parentheses.

Table A11

Third Grade AIMS Reading Percentages for Risk and Non-risk Schools as Determined by the LPRI

Method	Category	FFB	Approach	Meet	Exceed	% Not Passing
Risk of poisoning by lead	State	0.11 (0.12)	0.27 (0.15)	0.53 (0.16)	0.09 (0.10)	0.38
	Schools with no risk	0.10 (0.11)	0.25 (0.13)	0.54 (0.15)	0.10 (0.09)	0.35
	Schools with risk	0.13 (0.13)	0.28 (0.14)	0.51 (0.17)	0.07 (0.09)	0.41
Above and Below the Mean	High	0.13 (0.10)	0.31 (0.12)	0.49 (0.14)	0.06 (0.08)	0.44
	Low	0.11 (0.10)	0.27 (0.14)	0.53 (0.16)	0.08 (0.09)	0.38
Quartile	High	0.12 (0.10)	0.28 (0.13)	0.52 (0.14)	0.07 (0.09)	0.40
	Medium High	0.15 (0.10)	0.31 (0.12)	0.48 (0.15)	0.05 (0.06)	0.46
	Medium Low	0.11 (0.09)	0.28 (0.13)	0.52 (0.16)	0.08 (0.09)	0.39
	Low	0.10 (0.10)	0.26 (0.15)	0.54 (0.16)	0.09 (0.10)	0.36
Level of risk by standard deviation	Very High	0.09 (0.08)	0.30 (0.15)	0.53 (0.14)	0.08 (0.09)	0.39
	High	0.15 (0.13)	0.29 (0.12)	0.48 (0.15)	0.08 (0.09)	0.44
	Moderately high	0.14 (0.10)	0.32 (0.12)	0.48 (0.14)	0.06 (0.07)	0.46
	Moderately low	0.12 (0.10)	0.29 (0.14)	0.52 (0.16)	0.07 (0.08)	0.41
	Low	0.11 (0.10)	0.23 (0.15)	0.55 (0.15)	0.11 (0.11)	0.34
	Very Low	0.03 (0.03)	0.11 (0.06)	0.70 (0.09)	0.16 (0.07)	0.14

Note. Mean percent is reported with standard deviation in parentheses.

Table A12

Eighth Grade AIMS Math Percentages for Risk and Non-risk Schools as Determined by the LPRI

Method	Category	FFB	Approach	Meet	Exceed	% Not Passing
Risk of poisoning by lead	State	0.28 (0.21)	0.20 (0.12)	0.41 (0.19)	0.09 (0.11)	0.48
	Schools with no risk	0.27 (0.18)	0.19 (0.08)	0.43 (0.16)	0.09 (0.11)	0.46
	Schools with risk	0.28 (0.20)	0.22 (0.14)	0.40 (0.19)	0.08 (0.10)	0.50
Above and Below the Mean	High	0.28 (0.16)	0.20 (0.10)	0.43 (0.15)	0.08 (0.08)	0.48
	Low	0.27 (0.18	0.21 (0.12)	0.42 (0.19)	0.09 (0.12)	0.48
Quartile	High	0.27 (0.17)	0.23 (0.10)	0.41 (0.16)	0.07 (0.08)	0.50
	Medium High	0.28 (0.16)	0.17 (0.09)	0.45 (0.14)	0.08 (0.08)	0.45
	Medium Low	0.28 (0.16)	0.22 (0.11)	0.40 (0.19)	0.09 (0.12)	0.50
	Low	0.27 (0.19)	0.21 (0.12)	0.42 (0.20)	0.09 (0.13)	0.48
Level of risk by standard deviation	Very High	0.30 (0.14)	0.20 (0.06)	0.39 (0.15)	0.10 (0.11)	0.50
	High	0.26 (0.18)	0.23 (0.10)	0.43 (0.17)	0.06 (0.07)	0.49
	Moderately high	0.28 (0.16)	0.20 (0.10)	0.43 (0.14)	0.08 (0.08)	0.48
	Moderately low	0.29 (0.17)	0.21 (0.11)	0.40 (0.17)	0.09 (0.11)	0.50
	Low	0.25 (0.22)	0.21 (0.15)	0.43 (0.25)	0.10 (0.17)	0.46
	Very Low	0.12 (0.03)	0.15 (0.05)	0.57 (0.06)	0.13 (0.08)	0.27

Note. Mean percent is reported with standard deviation in parentheses.

Table A13

Mean Number of Heads of Households with Children for Risk and Non-risk Census Tracts as Determined by the LPRI

Method	Category	Married	Male	Female
Risk of poisoning by lead	State	486.30 (289.98)	55.60 (33.77)	144.62 (96.08)
	Census tracts with no risk	505.24 (290.85)	54.29 (31.83)	136.35 (90.57)
	Census tracts with risk	439.49 (282.64)	58.84 (37.99)	165.06 (105.82)
Above and Below the Mean	High	501.88 (351.38)	62.07 (41.62)	184.4 (116.3)
	Low	396.33 (213.13)	56.61 (35.15)	151.68 (95.8)
Quartile	High	491.9 (383.19)	63.78 (43.77)	191.58 (126.73)
	Medium High	457.68 (279.51)	54.76 (36.83)	157.61 (100.70)
	Medium Low	459.36 (234.65)	71.48 (39.33)	192.17 (102.32)
	Low	354.67 (189.04)	45.68 (25.44)	121.01 (72.73)
Level of risk by standard deviation	Very High	304.44 (158.32)	45.17 (16.95)	161.5 (75.72)
	High	454.9 (158.82)	62.08 (20.5)	160.5 (47.54)
	Moderately high	559.97 (403.62)	65.82 (48.8)	196.72 (135.32)
	Moderately low	408.69 (209.30)	60.59 (36.73)	163.30 (99.75)
	Low	335 (217.56)	44.11 (27.91)	122 (74.22)
	Very Low	603 (0.00)	50 (0.00)	63 (.000)

Note. Mean percent is reported with standard deviation in parentheses.

APPENDIX B

SCHOOLS WITH FREE AND REDUCED LUNCH PERCENT CREATED

Table B1

Third Grade Schools and Method Used to Generate Free and Reduced Lunch Percentage

Tract	Method	School	% F/R Lunch
4025002000	Average	American Heritage Academy	0.54
4019000600	Average	AmeriSchools Academy - Country Club	0.55
4027000800	Average	AmeriSchools Academy - Yuma	0.57
4019002200	Average	Arizona Virtual Academy	0.82
4013106900	Average	Bennett Academy	0.77
4025002000	Average	Center for Creative Education Charter School	0.54
4025001600	Average	Chester Newton Charter and Montessori School	0.59
4003000500	Average	Double Adobe Elementary School	0.68
4019000800	Average	Highland Free School	0.56
4003001600	Average	Imagine Charter School at Sierra Vista	0.54
4027010901	Average	James D Price School	0.52
4013105002	Average	Kachina Country Day School #1	0.07
4025000900	Average	Mountain Oak Charter School	0.44
4003000300	Average	New West School	0.39
4005001100	Average	Pine Forest School	0.21
4027000200	Average	Roosevelt School	0.76
4025001800	Average	Sedona Charter School	0.34
4013030378	Average	Stepping Stones Academy	0.08
4005000300	Average	The Peak School	0.49
4009991300	Average	Triumphant Learning Center	0.59
4015940400	Average	Valentine Elementary School	0.80
4025001000	Average	Willow Creek Charter School	0.37
4021000500	In database	Ray Primary School	0.65
4021941200	In database	Akimel O'Otham Pee Posh (3rd & 4th)	0.91
4003000300	Benson Middle School	Benson Primary School	0.40
4003000100	Bowie High School	Bowie Elementary School	0.86
4025000100	Seligman High School	Seligman Elementary School	0.46

Table B2

Eighth Grade Schools and Method Used to Generate Free and Reduced Lunch Percentage

Tract	Method	School	% F/R Lunch
4025001600	Average	Camp Verde Middle School	0.58
4019002100	Average	Cape School-Juvenile	0.85
4011990300	Average	Duncan Elementary	0.41
4007940400	Average	Excel Education Centers San Carlos	0.92
4007001300	Average	Leonor Hambly Middle School	0.72
4021001100	Average	McCray Elementary School	0.69
4011990200	Average	Morenci Junior/Senior High School	0.26
4005000300	Average	Mountain English Spanish Academy of Flagstaff (M.E.S.A.)	0.49
4005000700	Average	Northland Preparatory Academy	0.84
4019000200	Average	Nosotros Academy	0.75
4009991100	Average	Pima Junior High School	0.78
4005001200	Average	Project New Start	0.31
4005000300	Average	Renaissance Magnet Middle School	0.49
4007000500	Average	Shelby School, The	0.55
4025001600	Average	Sunnyside Charter and Montessori School	0.58
4012940200	Average	Wallace Jr High School	0.68
4013106000	Average	Westwind Middle School	0.68
4019000800	Highland Free School	Direct Link I	0.56
4019000800	Highland Free School	Joyce Drake Alternative Middle School	0.56
4025000100	Seligman Elementary	Ash Fork Middle School	0.46