AN ANALYSIS OF HIGH SCHOOL STUDENTS TAKING STATISTICS USING THE HSLS:09 DATASET

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In this study I report results of an quantitative analysis using a large scale public dataset (HSLS:09) to investigate which students are taking statistics courses in high school to begin to understand the access students have to opportunities to learn statistics concepts and practices in high schools in the United States. The main result of this study is that predominantly the top academically performing high school students are earning credit for taking statistics. This is concerning as all students should have experiences learning concepts and practices from statistics to be prepared to engage in and play active roles in today's data centric societies. In line with the conference theme of looking forward, implications for future research and policy are discussed.

Keywords: Data Analysis and Statistics, Equity and Diversity, High School Education

Background and Statement of Problem

Society today is drenched in data (Steen, 2001). Individuals are surrounded by data aimed at influencing their decisions about what school policies to implement, politician to vote for, or medicine to use. Statistics, the science of data, is becoming an increasingly important discipline for people to be familiar with the key concepts and practices of, because of society's reliance on data (Ben-Zvi & Garfield, 2008). As Franklin et al. (2007) states, "every high school graduate should be able to use sound statistical reasoning to intelligently cope with the requirements of citizenship" (p.1). For students to develop sound statistical reasoning it is important that a goal of public K-12 education is to provide students with opportunities to have rich learning experiences with concepts and practices of statistics if they are going to be critical citizens in today's data-driven societies.

Teaching statistics in the K-12 setting is firmly rooted in the mathematics curriculum and access and opportunities to learn are crucial equity issues to consider in mathematics education (Gutiérrez, 2009; Schmidt & McKnight, 2012). In the United States, students' opportunities to learn mathematics have been found to vary greatly due to the decentralized nature of education in the U.S. (Schmidt & McKnight, 2012). The implementation of the Common Core State Standards for Mathematics (CCSSM; National Governor's Association Center for Best Practices (NGA Center) & Council of Chief State School Officers (CCSSO), 2010) was meant to serve as a unifying force to reduce some of the variation in the mathematics content covered across states in the U.S. However, not all states have signed on to adopt the standards, and other states have begun to modify the standards to be implemented in an attempt to distance themselves from some of the controversy and politics around the standards (Orrill, 2016). In the CCSSM, data analysis and statistics have gained emphasis in grades 6-12 compared to most previous state standards. However, there has also been the loss of much of the statistics and probability content at the K-5 level, which could have serious ramifications in the future (Lubienski, 2015).

It is important to point out that standards are not the only factor influencing curriculum as classroom teachers and local contexts have a direct influence on the enacted curriculum students experience in the classroom (Remillard & Heck, 2014). However, this is a unique issue in the

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case of statistics because although the instruction of statistics is firmly rooted in the mathematics curriculum at the K-12 level, statistics is a distinct discipline with concepts and practices that are non-mathematical (Cobb & Moore, 1997; Groth, 2013). This can cause problems because many K-12 mathematics teachers have often had little to no prior coursework in statistics (Franklin et al., 2015; Shaughnessy, 2007), which could have very serious repercussions for the opportunities students have to learn statistics in school. Since the enactment of mathematics curriculum varies greatly from classroom to classroom based on a number of factors (Remillard & Heck, 2014; Schmidt & McKnight, 2012), it is very difficult to study what opportunities students have to learn statistics concepts and practices on any kind of large scale.

In this study, I used the National Center for Educational Statistics' (NCES) High School Longitudinal Study of 2009 (HSLS:09) public access dataset to begin to investigate which students are earning statistics credit in high school in an effort to better understand high school students access to opportunities to learn statistics concepts and practices. More specifically, I investigated the following research questions:

1. What relationship is there between demographic characteristics (i.e. sex, race, and SES) of students who earned at least one credit of statistics and those that did not?
2. What relationship is there between the academic performance of students who earned at least one credit of statistics and those that did not?
3. What relationship is there between the beliefs/attitudes of students who earned at least one credit of statistics and those that did not?

Conceptual Framework

This study is framed in a larger equity framework, specifically investigating issues around achievement and access, which are dimensions of what Rochelle Gutiérrez (2009) refers to as the dominant axis of equity. Gutiérrez (2002) states a basic definition of equity as being the, "erasure of the ability to predict students' mathematics achievement and participation based solely on characteristics such as race, class, ethnicity, sex, beliefs and creeds, and proficiency in the dominant language" (p.153). Drawing upon this definition this study is focused on the characteristics of race, class, sex, and beliefs and whether or not there is a relationship between students' statistics course taking and such characteristics, in an effort to begin to investigate the equity in student's participation in opportunities to learn statistics concepts and practices. To consider the issue of achievement in this study, students' mathematics achievement in terms of algebraic reasoning as well as their achievement in terms of their GPAs was considered in relation to whether or not they earned at least one credit in statistics or not.

Mode of Inquiry

Data source

The public access dataset from the HSLS:09 was the data source for this study. The goal of the HSLS:09 is to provide data to "better understand the impact of earlier educational experiences (starting at 9th grade) on high school performance and the impact of these experiences on the transitions that students make from high school to adult roles" (Ingels et al., 2015, p. 6). As such, the HSLS:09 was designed to gather data on a sample that is nationally representative of students entering 9th grade in 2009 (n=23503). One of the goals of the HSLS:09 is to provide data to investigate, "the nature of the paths into and out of STEM (science, technology, engineering, and mathematics) curricula" (Ingels et al., 2015, p. 6). At this point data is available for the base year (Fall 2009), first follow-up (Spring 2012), post-secondary status

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update (Summer/Fall 2013), and high school transcript report (2013-2014).

Methods

For this study, quantitative methods were employed to investigate variables related to students' demographics, mathematics course taking, academic performance, and beliefs/attitudes towards math and science. Students' mathematics course taking was considered in terms of whether or not they earned at least one credit in statistics/probability in high school and what was the highest level mathematics course students took in high school. As a note, AP Statistics course taking was not included in this analysis, because that data is only available in the restricted use data file. The HSLS:09 has a number of different academic performance variables, which include students' performance on a mathematics assessment designed to assess students' algebraic reasoning. In this analysis, I chose to use students' theta score for their performance on the mathematics assessment, which provides a norm-referenced measurement of achievement, for the base year assessment and the first follow-up assessment. Students' mathematics, STEM, and all academic course GPAs were also used as performance variables. Finally students' identity, self-efficacy, utility of and interest beliefs/attitudes towards mathematics and science, which were measured as normalized scale variables during the base year and the first follow-up, were considered. A complete listing of the variables and their description that were used in the analysis can be found in Table 1.

An initial exploratory data analysis (Tukey, 1977) was conducted and important descriptive statistics are reported in the results. An inferential analysis of the data was then done to address the research questions to investigate the relationship between students' demographics, academic performance and beliefs/attitudes and whether they earned credit for taking a statistics course of not. The inferential statistics used included two-sample t-tests for scale variables, which included variables for students' academic performance, beliefs/attitudes towards math and science, and SES, grouped based on whether or not they had at least one credit of statistics. In other words, the specific relationship that was investigated was whether or not there were differences in the variables considered, between the two groups. For categorical demographic variables, chi-square tests were used to determine if there were associations between the variables and the two groups considered. Standardized residuals were also employed in the case of statistically significant results of the chi-squared tests to get a better idea of which categories were significantly different from what was expected. Design effects normalized analytic weights were used for all inferential statistics. Effects sizes are reported for the quantitative variables by converting the t-test statistics to r and then using the commonly used cutoff's of $r=.1$ for small, $r=.3$ for medium, and $r=.5$ for large effect sizes (Field, 2013). Effect sizes for the categorical variable χ^2-test statistics are reported using Cramer V and the same cutoffs of .1, .3, and .5.

The method of focusing on transcript data to investigate students' course taking is not new. The transcript studies conducted periodically as part of the National Assessment of Educational Progress (NAEP) have been a source of such information over the past few decades. Based on such information, it was recently reported that, statistics/probability course taking in high school increased from 1% of high school graduates in 1990 to 11% in 2009 (NCES, 2016). Unfortunately, the NAEP transcript data is also limited in the information it collects on students, as it is focused mostly on transcript data of course taking and is only linked to students' performance on the NAEP assessment in 12th grade in some cases. The HSLS:09 public access dataset includes significantly more variables related to students' course taking, academic performance, demographics, and beliefs/attitudes towards mathematics and science, making it useful to investigate factors related to who the students are that are taking statistics courses.

Table 1: List of variable names and the descriptions from the HSLS:09 codebook (Ingels et al., 2015) for the variables analyzed in this study.

Variable Name	Description of Variable
X3T1CREDSTAT	Indicates at least one Carnegie unit in Statistics/Probability, does not include AP Statistics
X3THIMATH	Highest Mathematics course
X3TWHENALG1	Indicates the grade level the student took Algebra I.
X1TXMTH & X2TXMTH	The mathematics theta score represents the student's ability level on a continuous scale. The theta score provides a norm-referenced measurement of achievement, that is, an estimate of achievement relative to the population (fall 2009 9th graders) as a whole. It provides information on status compared to peers.
X1MTHID & X2MTHID	This variable is a scale of the sample member's math identity. Sample members who tend to agree with the statements "You see yourself as a math person" or "Others see me as a math person" will have higher values.
X1MTHUTI & X2MTHUTI	This variable is a scale of the sample member's perception of the utility of mathematics; higher values represent perceptions of greater mathematics utility.
X1MTHEFF & X2MTHEFF	This variable is a scale of the sample member's math self-efficacy; higher values represent higher math self-efficacy.
X1MTHINT	This variable is a scale of the sample member's interest in his or her base-year math course; higher values represent greater interest in the base-year math course.
X1SCIID & X2SCIID	This variable is a scale of the sample member's science identity. Sample members who tend to agree with the statements "You see yourself as a science person" or "Others see me as a science person" will have higher values for X2SCIID.
X1SCIUTI & X2SCIUTI	This variable is a scale of the sample member's perception of the utility of science; higher values represent perceptions of greater science utility.
X1SCIEFF & X1SCIEFF	This variable is a scale of the sample member's science self-efficacy; higher X2SCIEFF values represent higher science self-efficacy.
X1SCIINT	This variable is a scale of the sample member's interest in his or her base-year science course; higher values represent greater interest in the base-year science course.
X3TGPAMAT	GPA in Mathematics.
X3TGPASTEM	GPA in STEM courses.
X3TGPAACAD	GPA in Academic courses.
X1SEX	Student's sex
X1RACE	Student's race/ethnicity-composite
X1SES	Socio-economic status composite for base year
X2SES	Socio-economic status composite for first follow-up year

Results

Of the sample of students, there was not transcript data available for 1575 (6.7%) of the students. 19748 (84%) students did not earn any credit in statistics/probability, and 2180 (9.3%) students earned at least one credit in statistics/probability, which in looking back is slightly lower than the 11% of students reported in 2009 NAEP transcript study (NCES, 2016).

Demographic Characteristics

In considering the relationship between students' demographic characteristics and whether or not they earned at least one credit in statistics, the characteristics of sex, race, and SES were investigated. In comparing sex to earning statistics credit, there was no significant association (χ^2=0.538, df=1, p=0.463). The association between race and earning statistics credit was statistically significant (χ^2=17.923, df=7, p=0.012). However, the effect size was small (Cramer V=.083). In looking at the standardized residuals of the observed and expected cell counts the only significant residual (those ≥±1.96) was for Asian students earning a credit in statistics with z=2.8, meaning there were significantly more Asian students who earned at least one credit in statistics than expected. A further caution is that three of the expected counts where less than

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five, though that only constitutes 18.8% of the cells, which is below the 20% cutoff that is generally considered acceptable (Field, 2013). Finally, in considering the relationship between SES and earning statistics credit there were statistically significant differences between the groups in both the base and first follow-up years, the results of which can be seen in Table 2. The group differences in SES also had small effect size.

Table 2: Difference in scale variables between students who did not earn any credits in statistics/probability versus those who earned at least one credit in statistics/probability.

	≥1 Stat Cred Mean (SD)	No Statistics Mean (SD)	t	df	Mean Diff (SE)	95% CI of Diff	Effect Size (r)
BY Math theta score	.563(.893)	-.089(.937)	-10.51***	2581	-.652(.062)	[-.773, -.530]	.203
FY Math theta score	1.295(1.102)	.538(1.123)	-10.28***	2581	-.758(.074)	[-.902, -.613]	.198
BY Math Identity	.350(.970)	-.014(1.002)	-5.46***	2548	-.364(.067)	[-.495, -.233]	.108
FY Math Identity	.331(1.047)	-.003(.997)	-5.02***	2510	-.334(.066)	[-.464, -.203]	.100
BY Math Utility	.018(.981)	-.001(1.001)	-.270	2277	-.019(.070)	[-.155, .118]	.006
FY Math Utility	.176(.979)	.018(.991)	-2.40*	2503	-.158(.066)	[-.287, -.029]	.048
BY Math SE	.225(.919)	-.007(1.012)	-3.31**	2269	-.231(.070)	[-.368, -.094]	.069
FY Math SE	.180(1.014)	.004(.996)	-2.64**	2477	-.176(.067)	[-.307, -.045]	.053
Interest F09 math	.277(.992)	-.014(.993)	-4.16***	2227	-.290(.070)	[-.427, -.154]	.088
BY Science Identity	.245(.978)	.006(.993)	-3.62***	2542	-.239(.066)	[-.369, -.109]	.072
FY Science Identity	.248(1.007)	-.008(.997)	-3.87***	2495	-.257(.066)	[-.387, -.126]	.077
BY Science Utility	.071(1.014)	.004(.989)	-.95	2088	-.067(.071)	[-.207, .072]	.021
FY Science Utility	.015(.071)	-.001(.069)	-3.44**	2487	-.016(.005)	[-.025, -.007]	.069
BY Science SE	.217(.991)	-.006(.985)	-3.15**	2079	-.223(.071)	[-.362, -.084]	.069
FY Science SE	.209(.968)	.004(1.005)	-3.05**	2437	-.205(.067)	[-.337, -.073]	.062
Interest F09 science	.127(.996)	-.014(1.009)	-1.93	2040	-.141(.073)	[-.285, .002]	.043
GPA STEM courses	2.889(.722)	2.297(.930)	-9.76***	2576	-.592(.061)	[-.711, -.473]	.189
GPA all courses	3.023(.684)	2.456(.889)	-9.79***	2576	-.567(.058)	[-.680, -.453]	.189
GPA Math	2.811(.810)	2.218(.974)	-9.32***	2576	-.594(.064)	[-.719, -.469]	.181
BY SES Composite	.281(.780)	-.109(.745)	-7.83***	2581	-.390(.050)	[-.487, -.292]	.152
FY SES Composite	.306(.717)	-.0750(.715)	-7.85***	2394	-.381(.049)	[-.476, -.286]	.158

Note. Equal variance assumed for independent t tests. *p<.05, **p<.01, ***p<.001. BY=Base Year, FY=First Follow-up Year.

Beliefs/Attitudes

Looking at the belief/attitude scale score variables (see Table 2); during the base year students who earned at least one credit in statistics/probability had significantly stronger mathematics and science identities, mathematics and science self-efficacy beliefs, and interest in their 9th grade mathematics course than students who did not. This pattern continued for the identity and self-efficacy variables in the first follow-up of the study. There was no difference in the mathematics or the science utility scale scores during the base year of the study. However, at the time of the first follow-up, students who earned at least one credit in statistics/probability had significantly higher mathematics and science utility scale scores than students who did not. It seems that over the course of three years of high school education the population of students who earned at least one credit in statistics/probability by the end of high school, were students who began to view mathematics as more useful on average than students who did not, whose average scale score changed minimally from the base year to the first follow-up year. The same cannot be said in the case of science where the scale score for both populations decreased on average from the base year to the first follow-up year. It is important to acknowledge that there is no way of knowing when students earned at least one credit in statistics, so no inferences should be made that temporal shifts in beliefs and attitudes might be influenced by statistics course taking. It is also important to note that even though a number of the belief/attitude variables differed significantly between the groups, none of the differences had more than small effect sizes, and quite a few were below the r=.1 cutoff for small effect sizes.

Academic Performance

In looking at the mathematics course taking of those students who earned at least one credit in statistics/probability, a striking trend emerges that students taking statistics are largely the top mathematics students. Nearly half (n=1053) of the students earning statistics/probability credit in high school completed Algebra I in 8^{th} grade, just over a quarter took statistics as their most advanced mathematics course in high school, and in fact over a quarter of students took calculus in high school (see Table 3). This trend is also supported by the mathematics performance of students who earned a statistics/probability credit versus those who did not (see Table 2). Students who earned at least one credit in statistics/probability had significantly higher theta scores on the algebraic reasoning assessment on average in both the base year and the first follow-up than students who did not earn a statistics/probability credit. This same trend can be seen in the GPA of students' mathematics courses taken in high school, and in their GPA for STEM courses, and all academic courses (see Table 2). Furthermore, the differences had small to moderate effect sizes. These results seem to indicate that the students who earned at least one credit in statistics/probability may include more than just top performing mathematics students, but perhaps even the top performing students in general.

Table 3: Frequency of students' highest level mathematics course taken for students who earned at least one credit in statistics/probability

X3 Highest level mathematics course taken/pipeline	Frequency of students who earned at least one credit in statistics/probability
No Math	0
Basic math	0
Other math	0
Pre-algebra	0
Algebra I	0
Geometry	0
Algebra II	0
Trigonometry	0
Other advanced math	0
Probability and statistics	697
Other AP/IB math	260
Precalculus	596
Calculus	144
AP/IB Calculus	483
Total	2180

Discussion and Scholarly Significance

Considering the results as a whole the two most significant factors that differed between the group of students who earned at least one credit in statistics and the group of students that did not were academic performance and SES. Though there are other factors that differed with statistical significance between the two groups, they were all of small or less effect sizes and given the large sample size should be considered with caution as only small differences are needed for statistical significance, which may not be significant in a practical sense. One possible reason, for predominantly top academically performing students earning at least one credit in statistics is that they have more time in their schedule to take additional mathematics courses like statistics.

Most states require at least three years of mathematics, which generally includes an Algebra I, Geometry, Algebra II trajectory or a more integrated Math I, Math II, Math III trajectory where the various strands of mathematics are taught together over three years. That means that students who take the typical 9th grade mathematics course of Algebra I or Math I in 8th grade have more time to take statistics as an elective course in their junior or senior year.

The cohort of students in the HSLS:09 were in high school during the very beginning of the influence of the CCSSM (NGA Center & CCSSO, 2010), which does recommend that statistics concepts be included in all students' high school mathematics education. However, the enacted curriculum that students experience is generally carried out by the classroom teacher who mediates the influence that official curriculum, such as the CCSSM, have on the enacted curriculum (Remillard & Heck, 2014) and as I discussed earlier, statistics has a unique position in this regard as many mathematics teachers have often had little to no prior experience with learning statistics (Shaughnessy, 2007). Though the results here do not show that all students do not have access to opportunities to learn statistics, they do point out that there may, at the very least, be an issue in how statistics courses are offered or advertised to students, or perhaps in students' perceptions of the usefulness of statistics, or who should take it. The results do show that the majority of students are not earning any credits in statistics/probability, which means if they are not experiencing statistics in their other mathematics courses, they are not having any experiences with statistics in high school. It is important that more research is done around students' opportunities to learn statistics at the K-12 level especially in the context of the enacted curriculum that students experience and how students are provided access to opportunities to learn statistics at the school level.

A limitation in this analysis is that using the HSLS:09 data it is only possible to determine which students earned at least one credit of statistics/probability in high school. It does not provide information on specific course performance, when the student took the course, or identify those students who were enrolled in a statistics/probability course but did not earn credit, which limits the results reported. Furthermore, it is not possible to determine the quality of the students' instruction or whether or not they had any opportunities to learn statistics in any of their other courses. However, given the current dearth of empirical research looking at the teaching or learning of statistics on any kind of large scale, these results help to give some idea of patterns in statistics course taking, which have implications for further research and for policy. Another limitation is not having transcript data on who earned credit for AP Statistics. However, given that AP courses are advanced courses the inclusion of such data would have likely only amplified the results as the students often taking AP courses are generally high performing and of a higher SES. However, it is still important that future analyses include such data.

Related to the equity framework used in this study, the results reported here are significant in that if the goal of education is democratic equality, preparing students to participate as critical citizen's in society where statistical reasoning is crucial, than there is a serious issue in that it appears that predominantly only the top performing students in high school are earning credits in statistics/probability. It is promising that students' sex was found to have no association with their taking of statistics. However, race does appear to have a weak association and there are significant differences in the academic performance and SES of those who earned credit in statistics and those who did not, which points to inequity in students' access to statistics. Going back to Gutiérrez's (2009) equity framework, it is also important to point out that using this data, equity can only be considered through the dominant axis, which means there is still the issue of the critical axis of equity, namely identity and power, to consider in future work. Though the

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variables of math and science identity were considered in the HSLS:09, they are different than the identity construct that Gutiérrez (2009) discusses. The identity variables in the HSLS:09 consider an individual's identity relative to its alignment with the discipline, whereas Gutiérrez (2009) is looking at identity from the perspective of the individual and how they see themselves in relation to the discipline and curriculum. It is crucial, that if we are to achieve the promise of equal educational opportunity, that all students should have experiences learning statistics concepts and practices, and that they have experiences in seeing themselves in the curriculum and considering how to read and write the world with statistics (Weiland, 2017).

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