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Graduation Rates of English Learners: A Bayesian Analysis

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Abstract
The present study examined the high school graduation rate of English learners (EL) in a south-eastern U.S. state. Specifically, the study examined (a) the overall distribution of school system EL graduation rates compared to the graduation rates of all students; (b) variations in the 2017-2020 EL graduation rates; and (c) variations in 2020 EL graduation rates across school systems located in rural areas, towns, suburban areas, and cities. Analyses included 51 school systems that reported the 2020 EL graduation rate. Results showed that EL graduation rates were consistently lower than the graduation rates of all students. Non-parametric and Bayesian repeated-measures analyses of variance showed non-significant variations in 2017-2020 EL graduation rates. Non-parametric and Bayesian one-way analysis of variance showed that school systems located in rural areas had significantly higher 2020 EL graduation rates than school systems located in cities and suburban areas. These findings suggest that EL students who attend public high schools located in suburban and city areas are less likely to earn high school diplomas.

Keywords: graduation rate, English learners, Bayesian analysis, Bayesian analysis of variance.

Introduction

An Examination of the Graduation Rate of English Learners: A Bayesian Approach

In recent years educators and policymakers focused on improving public high school graduation rates. As a result, the average graduation rate of public high school students in a south-eastern U.S. state increased every year. In the past five years, the average graduation rate has gradually increased from 79.4% in 2017 to 83.8% in 2020 (State Department of Education, 2020).

Historically, the graduation rate of English Learners (EL) has reportedly been lower than the overall public school graduation rate. This gap has been consistent both at the national and the state level (U.S. Department of Education, 2020). Figure 1 illustrates the gap between the state-level graduation rate of all students and the EL graduation rate.

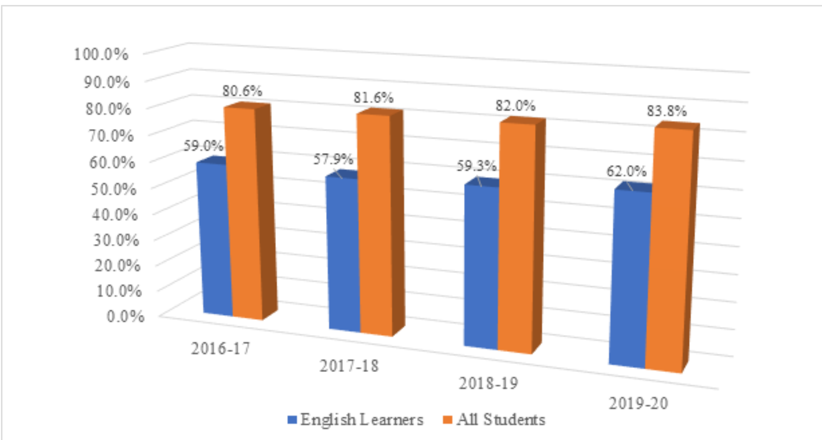

Fig. 1: Graduation Rates of All Students and EL Students (State Department of Education, 2020).

For an extended time, many states and school systems did not report EL graduation rates. Although the No Child Left Behind (NCLB) act required this information to assess yearly progress, states and school systems continued to inconsistently report EL graduation rates (Kanno & Cromley, 2013). In more recent years, the EL population increased dramatically, and states reported EL graduation rates more systematically. Nevertheless, very few researchers examined these data.

Current literature on this topic includes very little information on the factors that may influence the EL graduation rate or the strategies that schools may use to improve this outcome. One of the few studies on this topic (Gwynne et al., 2012) showed that in the Chicago Public Schools, EL students had lower overall grade point averages and were less likely to graduate and more likely to drop out than non-EL students. This study showed that ninth grade course performance predicted graduation in the same way for EL and non-EL students; further, ninth-grade academic performance was a stronger predictor of EL graduation than language proficiency or interruptions in students' education. Similar studies are needed to examine the EL graduation rates with data from more recent years and data from other states and school systems.

Objectives

Graduation rates are an essential measure of student success and an important indicator of school effectiveness. Data reported by the State Governor's Office of Student Achievement (2020) shows a large gap between the graduation rate of all students and the graduation rate of EL students and indicates that this discrepancy persists across time. The purpose of the current research is two-fold. The first objective is to examine the EL public high school graduation rate and determine whether this school outcome varies significantly across years and by location. Specifically, the current study addressed the following research questions:

Q1. What is the distribution of the public high school EL graduation rate across the state?

Q1.1. How does the public high school EL graduation rate compare to the graduation rate of all students in the state?

Q1.2. To what extent did the public high school EL graduation rate change across years?

Q2. To what extent does the public high EL school graduation rate vary across urban areas, suburban areas, towns, and rural areas?

The second objective of the current study was to demonstrate the application of Bayesian data analysis procedures. Although Bayesian analyses have been around for a long time (Edwards et al., 1963), these procedures are computationally complex; therefore, they have not been used much in educational research and are not as widespread as frequentist procedures. New developments in statistical software now facilitate the application of these methods. Bayesian techniques rely on different philosophical assumptions than the traditional frequentist procedures. They are instrumental with smaller sample sizes and data that do not meet the assumption of normality (Kaplan, 2014). In the current study, the researcher applied Bayesian procedures in conjunction with analogous non-parametric techniques. Non-parametric outcomes ease the interpretation of the results and complement findings obtained through Bayesian analyses. Although they address the same research questions, the non-parametric and the Bayesian approaches rely on different assumptions, employ distinct computation procedures, and estimate different statistics. Using them in conjunction provides a more comprehensive representation of the data.

Method

Data Sources

Data for the current study consist of the average four-year adjusted graduation rates reported by public school systems. The State Governor's Office of Student Achievement provides these data to the public (2020). The state calculates the four-year adjusted cohort graduation rate by dividing the number of students who graduate in four years with a regular high school diploma by the number of students representing the adjusted cohort for the graduating class (State Department of Education, 2020).

The current study used the system level graduation rates rather than the school-level data and focused on the school systems that reported an EL graduation rate in 2020. Analyses excluded school systems reporting "too few students" or "no data" for computing EL graduation rates (State Governor's Office of Student Achievement, 2020). Additionally, analyses excluded three state charter schools because they did not represent specific school systems and could not be included in comparative analyses by location. These schools reported extremely low 2020 EL graduation rates (between 0.0% and 6.3%). The remaining 51 school systems were included in this study. Due to these changes, the current sample's overall average graduation rates differ from the reported state-level average graduation rates. For comparison purposes, the present study also used all students' graduation rates for the selected school systems. Additionally, graduation rates from the previous three years (2017, 2018, and 2019) were compiled for the 51 school systems in the sample to allow for comparisons across years. The researcher used the expectation maximization algorithm to impute missing values for the few school systems that did not report EL graduation rates in previous years.

Data Analysis

Descriptive Analysis

The first step in analyzing the data was conducting a detailed descriptive analysis of graduation rates. Descriptive procedures were employed for all research questions to (a) examine the location and spread of the 2020 graduation rate of EL students; (b) compare the 2020 graduation rate of EL students to the overall graduation rate of all students in the state; (c) examine the graduation rate of EL students across years (2017 – 2020); and (d) examine the 2020 graduation rate of EL students across school systems located in towns, cities, rural areas, and suburban areas.

The researcher examined the distribution of graduation rates by calculating descriptive statistics such as the mean, median, standard deviation, variance, interquartile range, and indices of skewness and kurtosis. Further, the author examined variables using histograms and boxplots. Histograms illustrate the frequency of graduation rates and help determine the distribution shape, spread, location. Similarly, boxplots reflect the distribution location and spread while also graphically indicating the location of the median value, the interquartile range, and outliers.

Comparisons across Years

In addition to the descriptive procedures, the researcher used Friedman's and Bayesian one-way repeated measure analysis of variance by ranks to examine changes across time in EL graduation rates. These procedures helped determine whether EL graduation rates changed significantly across the years 2017, 2018, 2019, and 2020.

Friedman's one-way repeated measure analysis of variance is a non-parametric procedure that helps compare the distribution of a variable across three or more related samples (MacFarland & Yates, 2016). Non-parametric analyses of variance do not rely on the assumption of a normal distribution; therefore, researchers can use them with data that are not normally distributed or with smaller samples. Non-parametric procedures do, however, assume that the variance of the variable of interest is roughly equal across groups (MacFarland & Yates, 2016). To examine the equality of variance, the author employed Mauchly's test of sphericity. This procedure uses an equally-spaced polynomial contrast to test the null hypothesis that the orthonormalized transformed dependent variables' error covariance matrix is proportional to an identity matrix (Mauchly, 1940). Traditional analyses of variance focus on mean differences across samples; in contrast, non-parametric analyses of variance examine differences in median values and use the $\chi 2$ distribution to determine significance (MacFarland & Yates, 2016). The significance level for the current study was .05.

The Bayesian one-way repeated measures analysis of variance helped compare school system mean graduation rates across the four years (2017-2020). This procedure assumes that each unit has a single measurement at each time point (Lee & Wagenmakers 2013; Jeffreys, 1961). In addition to group means and variances, Bayesian analyses estimate the marginal posterior distribution of parameters and provide 95% credible intervals for the group means. Credible intervals represent a domain within a posterior distribution that represents the most likely location of a parameter. Credible intervals are similar to the confidence intervals obtained from frequentist procedures but rely on different assumptions. In Bayesian analysis, intervals have fixed bounds and variable parameters. In contrast, frequentist intervals have variable limits and set parameters. Another distinction is that credible intervals rely on the observed data's prior distribution, whereas frequentist confidence intervals do not (Edwards et al., 1963; Lee, 1997).

Additionally, Bayesian analysis includes the computation of a Bayesian factor. This coefficient represents the natural ratio of the alternative hypotheses' marginal likelihood and the null hypotheses' marginal likelihood (Lee & Wagenmakers 2013; Jeffreys, 1961). It indicates whether the observed data changed the probability of the alternative hypothesis in reference to the null hypothesis (Jackman, 2009). Unlike frequentist methods, Bayesian analysis does not reference a specific sampling distribution to determine the probability of a test statistic; all inferences rely on the observed data rather than what might be observed using a multitude of random samples (Jackman, 2009). Table 1 provides the commonly used thresholds used to determine the extent to which a set of observed data supports the null and the alternative hypotheses.

Table 1: Significance Levels of Bayes Factors (Jeffreys, 1961).

Bayesian Factor (BF)	2log (BF)	Evidence for the alternative hypothesis
<1	<0	Negative (support the null)
1-3	0-2	Weak evidence
3-12	2-5	Positive (support the alternative)
12-150	5-10	Strong evidence
>150	>10	Very strong evidence

Comparisons by Location

To examine differences by location, the author compared the 2020 graduation rate of EL students across school systems located in cities (n=12), towns (n=8), rural areas (n=20), and suburban areas (n=11). The researcher weighted school system graduation rates by location to account for the groups' disproportionality and ensure that the four regions have an equal impact on the results. The researcher compared the four groups using the Kruskal-Wallis H test for independent samples and Bayes one-way analysis of variance.

Kruskal-Wallis H test for independent samples is a rank-based non-parametric procedure used to determine if a variable differs significantly across three or more groups. This procedure is analogous to the frequentist one-way analysis of variance and an extension of the Mann-Whitney U test for more than two independent groups. The test relies on the χ^2 distribution to determine whether differences among groups are statistically significant (Kruskal & Wallis, 1952). The level of significance for the current study was .05. The Kruskal-Wallis H procedure is an omnibus test; when χ^2 is significant, researchers use pairwise comparisons to determine where the significant differences occur. A *p*-value adjusted for multiple comparisons is then used to determine statistical significance for each pair (Siegel & Castellan, 1988). In the current study, the author used the Bonferroni correction for multiple tests to adjust *p*-values for multiple comparisons.

The Bayes one-way analysis of variance tested the hypothesis that the mean 2020 graduation rate was equal across the four regions. One advantage of Bayesian analysis is that it uses prior information to estimate the posterior distribution of a parameter. Such information may come from preliminary research or data from previous studies and represents an informative prior (Kaplan, 2014). A conjugate informative prior relies on the assumption that the informative prior, when combined with the likelihood function, yields a posterior distribution of the same type as the primary distribution (Kaplan, 2014). In the current study, the author used the average graduation rate of the previous three years (2017 – 2019) to specify conjugate priors. Results included the Bayes factors and the posterior means and 95% credible intervals of each group.

Results

Descriptive Results

In the school systems included in the study, the 2020 EL graduation rate had a relatively symmetrical distribution (Figure 2). The mean graduation rate for these systems was 71.36%, with a standard deviation of 13.58%. As indicated in Table 2, this rate was 16.8% lower than the overall graduation rate of all students, which had a mean of 88.16% and a standard deviation of 5.2% (Table 2). Although both distributions are roughly symmetric, EL graduation rates have a much wider spread, with a minimum of 44.00% and a maximum of 100% (Figure 3).

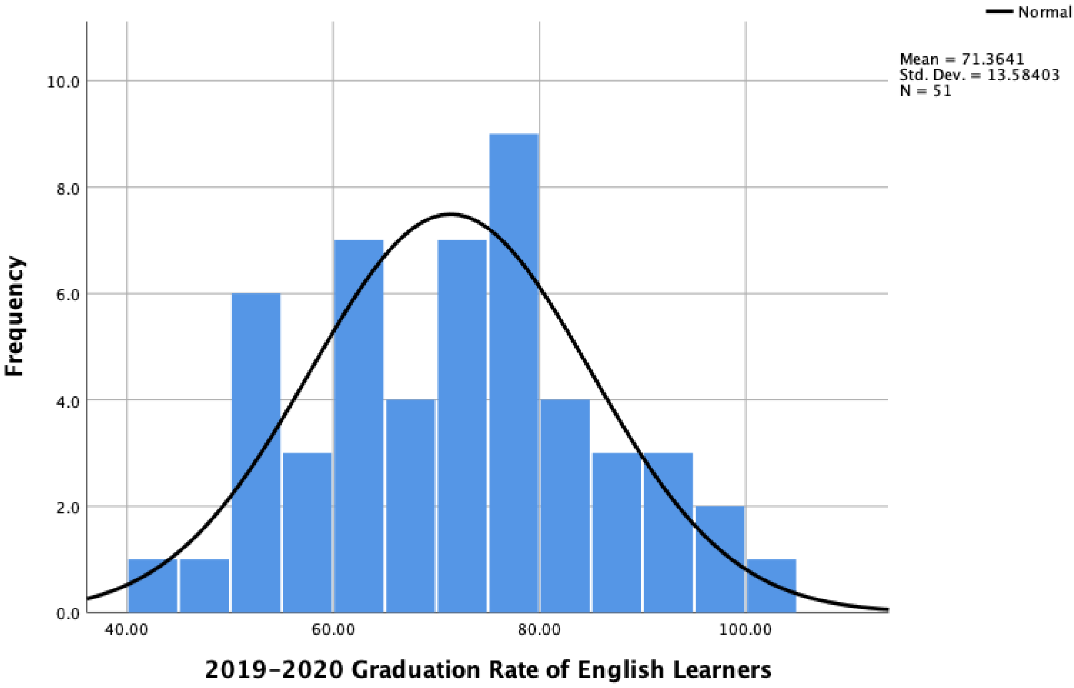

Fig. 2: Distribution of 2020 School System EL Graduation Rates

Table 2: 2020 Descriptive Statistics of School System Graduation Rates.

	All Students	EL students
Mean	88.16	71.36
Median	89.37	72.73
Variance	29.341	184.526
Std. Deviation	5.417	13.584
Minimum	76	44
Maximum	100	100
Interquartile Range	6	20
Skewness	-0.542	0.122
Kurtosis	0.109	-0.666

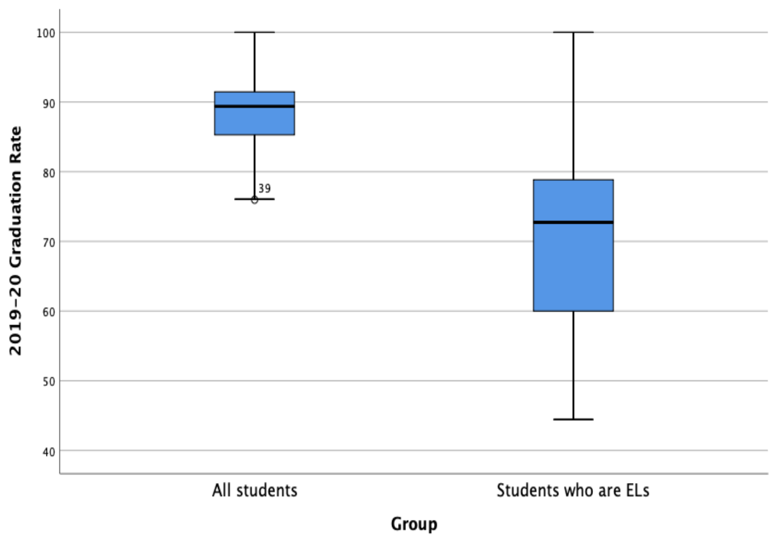

Fig. 3: Distribution of the 2020 Graduation Rates of All Students and EL Students.

Comparisons across Years

The EL average graduation rate of the school systems in our sample has increased across the years. Specifically, the EL average graduation rate shifted from 69.49% in 2017 to 71.36% in 2020. Similarly, the minimum graduation changed from 33.3% in 2017 to 44.44% in 2020.

Table 3 reports descriptive statistics for 2017, 2018, 2019, and 2020 EL graduation rates. As illustrated in Figure 4, all four distributions are roughly symmetric, with slight differences in location due to the gradual increase of the median graduation rates; however, the 2018 and the 2020 distributions have a wider spread, and the 2017 distribution has several outliers (Figure 5).

Table 3: Descriptive Statistics of the 2017-2020 EL Graduation Rates.

	2017	2018	2019	2020
Mean	69.4888	69.951	70.7329	71.3641
Median	69.49	69.95	70.73	72.73
Variance	168.066	191.654	146.612	184.526
Std. Deviation	12.96403	13.84392	12.10833	13.58403
Minimum	33.3	37.1	41	44.44
Maximum	93.8	100	92.9	100
Interquartile Range	13	17.2	18.6	20
Skewness	-0.452	-0.188	-0.18	0.122
Kurtosis	0.48	-0.071	-0.355	-0.666

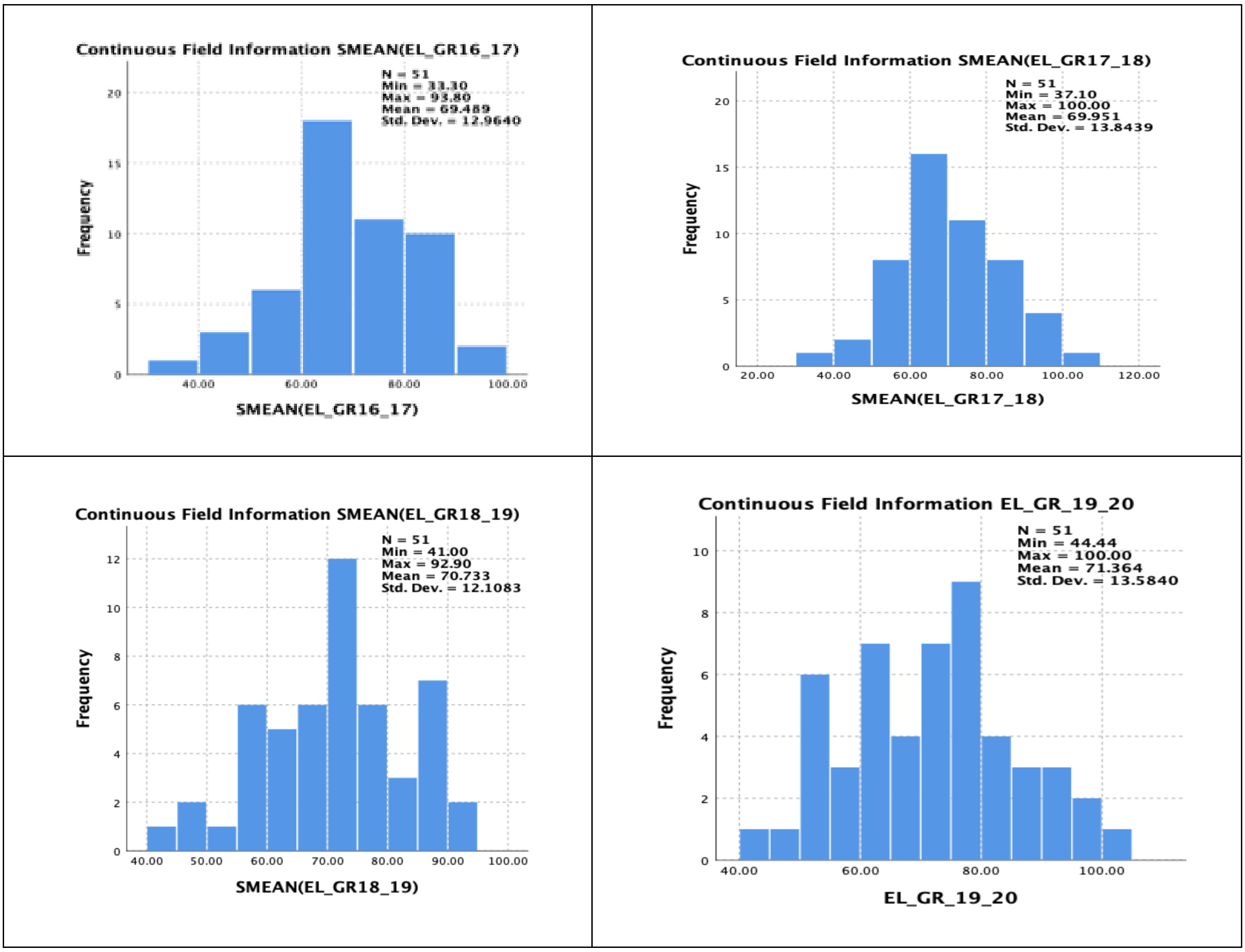

Fig. 4: Histograms of the 2017 – 2020 School System EL Graduation Rates.

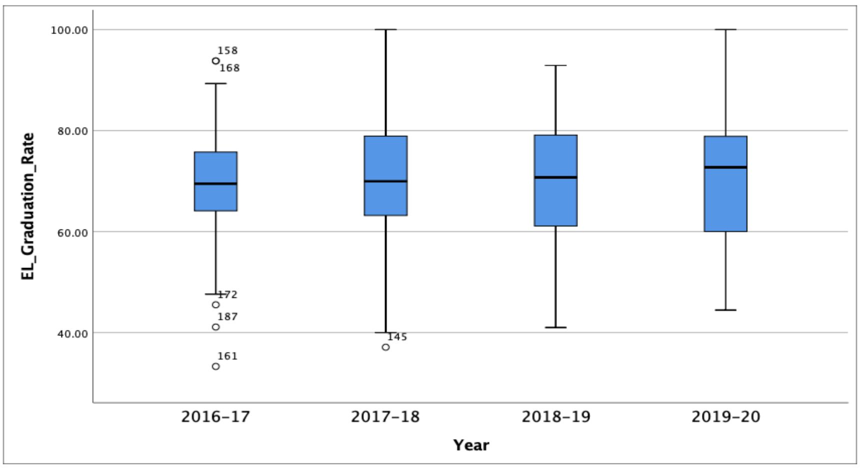

Fig. 5: Boxplots of the 2017-2020 School System EL Graduation Rates.

Results from Friedman's two-way analysis of variance by ranks for related samples showed that EL graduation rates' distribution did not change significantly across years ($\chi^2_{(3)}$=4.267, asymptotic *p*-value =.236). Figure 6 illustrates the four distributions using ranks.

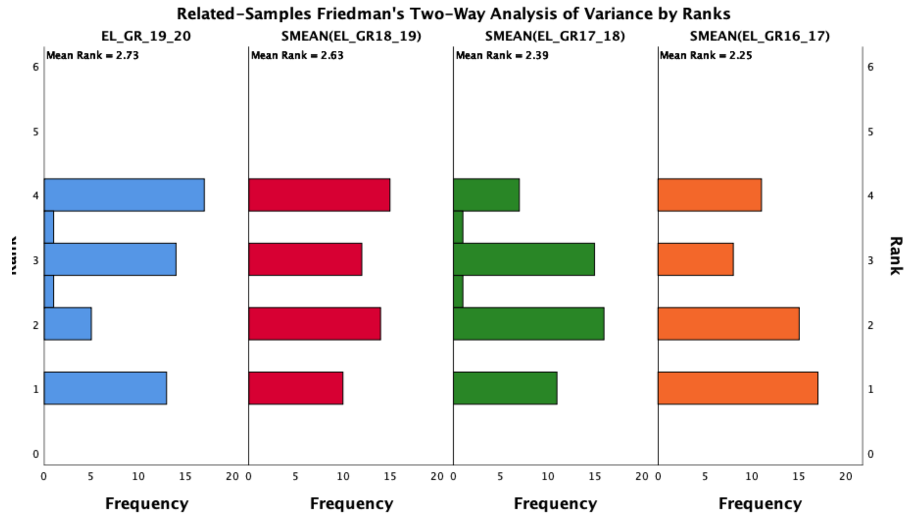

Fig. 6: Rank-Based Distribution of the 2017-2020 EL School System EL Graduation Rates.

Mauchly's test of sphericity yielded an average $\chi^2_{(3)}$ of 10.420, with a *p*-value of .01. This result indicates that variations across samples were not statistically significant, and the four groups met the assumption of sphericity. The Bayes one-way repeated measures ANOVA yielded a Bayes factor of .003. This coefficient supports the null hypothesis that the average EL graduation rate did not change significantly across years. Table 4 reports the descriptive statistics of the 2017-2020 posterior distributions estimated using the Bayesian Central Limit Theorem. These statistics include the 95% credible intervals for the 2017-2020 graduation rates. Although these intervals shifted from (65.92% - 73.06%) in 2017 to (67.79% - 74.93) in 2020, the change across time was not significant.

Table 4: Bayesian Parameters of the 2017-2020 Distribution of EL Graduation Rates[a]

Year	Posterior			95% Credible Interval	
	Mode	**Mean**	**Variance**	**Lower Bound**	**Upper Bound**
2017	69.4886	69.4886	3.320	65.9173	73.0599
2018	69.9511	69.9511	3.320	66.3798	73.5224
2019	70.7333	70.7333	3.320	67.1620	74.3046
2020	71.3641	71.3641	3.320	67.7928	74.9354

Posterior distribution was estimated based on the Bayesian Central Limit Theorem.

Comparisons by Location

School systems located in rural areas reported the highest average graduation rates for EL students (*M*=79.54%, *SD*=12.24), followed by systems located in towns (*M*=72.85%, *SD*=11.04), cities (*M*=64.95%, *SD*=12.42), and suburban areas (*M*=62.42, *SD*=10.48). Descriptive statistics for the graduation rates reported by systems located in the rural areas, towns, cities, and suburban areas are reported in Table 5. As indicated in Figure 7, the shape, location, and spread of these distributions vary across regions. School systems located in cities and suburban areas have similar median and minimum EL graduation rates; however, some school systems located in city areas reported much higher EL graduation rates, with a maximum of 90.91% (versus 77.7% in suburban systems). Similarly, school systems located in towns and rural areas have a similar median graduation rate of EL students; nevertheless, the minimum (60.00%) and the maximum (100%) values are higher for the school systems located in rural areas.

Table 5: Descriptive Statistics for the 2020 EL Graduation Rates by Location.

	Location			
	City	**Rural**	**Suburb**	**Town**
N	12	20	11	8
Percent	23.5	39.2	21.6	15.7
Mean	64.9467	79.539	62.4227	72.8475
Median	62.115	76.765	63.18	75.325
Variance	154.359	149.942	109.77	121.99
Std. Deviation	12.4241	12.2451	10.47712	11.0449
Minimum	47.73	60	44.44	53.13
Maximum	90.91	100	77.7	85
Range	43.18	62.42	33.26	31.87

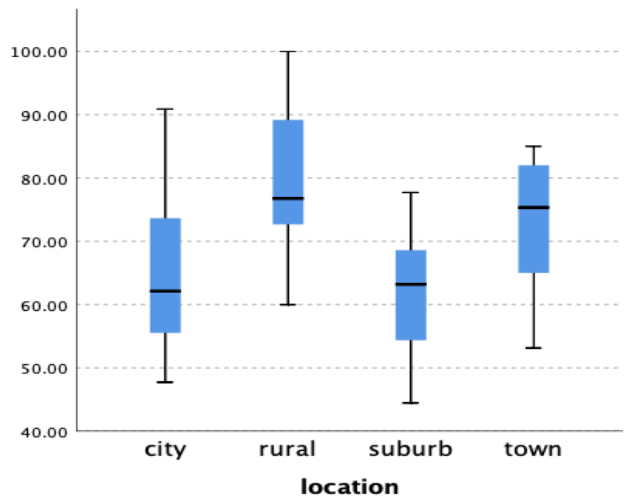

Fig. 7: Distribution of 2020 EL Graduation Rates by School System Location.

The Kruskal-Wallis test for independent samples yielded significant differences in the EL graduation rates' distributions across the four locations ($\chi^2_{(3)}$=15.373, asymptotic *p*=.002). Pairwise comparisons by the school system location showed that differences were significant between suburban and rural school systems (test statistic=3.255, asymptotic adjusted *p*=.007) and between school systems located in cities and school systems in rural areas (test statistic=-3.105, asymptotic adjusted *p*=.011). Table 6 reports the results of all pairwise comparisons.

Table 6: Pairwise Comparison of 2020 EL Graduation Rates by Location.

Sample 1-Sample 2	Test Statistic	SE	Std. Test Statistic	Asymptotic *p*	Asymptotic Adjusted *p*[a]
suburb-city	1.515	7.168	.211	.833	1.000
suburb-town	-13.869	6.726	-2.062	.039	.235
suburb-rural	20.982	6.446	3.255	.001	.007
city-town	-12.354	6.557	-1.884	.060	.357
city-rural	-19.467	6.270	-3.105	.002	.011
town-rural	7.113	5.760	1.235	.217	1.000

a. Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. The significance level is .05. Significance values have been adjusted by the Bonferroni correction for multiple tests.

The Bayes one-way analysis of variance yielded a Bayes factor of 18.024, representing robust evidence that differences across regions are significant. Table 7 reports the Bayesian estimates for the posterior distributions of 2020 EL graduation rates by location. Suburban school systems had the lowest posterior mean (62.503) and the largest variance (10.435), with a 95% credible interval of (56.150 – 68.855). In contrast, school systems located in rural areas had the largest posterior mean (79.284), the lowest variance (5.963), and a 95% credible interval of (74.482 – 84.086). One can note that credible intervals for school systems located in rural areas do not overlap with credible intervals for the school systems located in suburban areas and cities.

Table 7: Bayesian Estimates of 2020 EL Graduation Rates by Location[a,b,c]

Location	Posterior			95% Credible Interval	
	Mode	Mean	Variance	Lower Bound	Upper Bound
city	65.030	65.030	9.632	58.926	71.133
rural	79.284	79.284	5.963	74.482	84.086
suburb	62.503	62.503	10.435	56.150	68.855
town	72.972	72.972	7.366	67.635	78.310

a. Dependent Variable: 2020 El Graduation Rate
b. Model: location
c. Assumed conjugate priors.

Discussion

The study showed that public high school EL graduation rate is lower than all students' graduation rate, and this discrepancy has been stable across years. This finding is consistent with the overall state-level graduation rates reported by the State Department of Education (State Department of Education, 2020) and with the national level gap in graduation rates (U.S. Department of Education, 2020). Disaggregated data were not available to determine whether these differences were statistically significant. Nevertheless, the magnitude and consistency of the discrepancy in graduation rates should concern educators because individuals who do not have a high school diploma are at a higher risk of lower earnings and unemployment than individuals who earn a high school diploma (U.S. Department of Education, 2017).

Another concerning finding is that the graduation rate of EL students did not improve significantly across years. Although data from the current sample showed a very slight increase (less than one percentage) from one year to another, both non-parametric and Bayesian analyses showed that these changes were not statistically significant. Although the overall graduation rates have gradually improved across the years, EL graduation rates did not follow the same trend.

As educators, we expect EL students to encounter more learning difficulties; however, such large differences in graduation rates and the improvement over time reflect the limited effectiveness of school systems in addressing these students' educational needs. It is important to note that some school systems consistently reported very high graduation rates of EL students. Such school systems may share their practices to improve EL students' graduation rates across the state.

Analyses from the current study yielded significant variations in EL students' graduation rate by school system location. Specifically, school systems located in rural areas were most successful in graduating EL students, followed by school systems located in towns, cities, and suburban areas. Results showed that rates were similar across rural areas and towns and between city areas and suburban areas; significant differences occurred between school systems located in rural and suburban areas and between school systems located in rural areas and cities. These findings suggest that EL students who attend public high schools located in suburban areas and city areas are less likely to earn a high school diploma. Therefore, it is essential to examine successful practices used in school systems from rural areas and apply these effective strategies, to the extent possible, in less successful school systems.

In addition to reporting findings regarding EL students' graduation rate, the current study illustrates the application and interpretation of Bayesian procedures in educational research. Bayesian analyses helped address limitations related to sample size and allowed the researcher to compare group means when the traditional frequentist techniques were not applicable. Additionally, Bayesian analyses allowed the researcher to use data from prior years to inform current analyses.

In summary, the present study represents a first step in examining the graduation rate of public school EL students in the state. This examination relied on publicly available data reported by the State Department of Education. Analyzing the potential impact of other factors such as socioeconomic status, cultural differences, length of time in the U.S., etc., was not within the current study's scope.

Such analyses may provide useful information to educators and school systems aiming to improve EL graduation rates. Further research using multi-level analyses is also needed to take into account variations across schools and variations across school systems. Additionally, a thorough qualitative examination of successful schools and school systems' practices may provide useful information for improving the graduation rate of EL students across the state.

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