Analyzing Student Success Outcome Variables in Higher Education Utilizing the Chi-Square Test of Independence

Jim K. Rost[1]

[1] Department of Educational Leadership, Middle Tennessee State University, Murfreesboro, Tennessee, USA

Correspondence: Jim K. Rost, Department of Educational Leadership, Middle Tennessee State University, Murfreesboro, Tennessee, USA. E-mail: jim.rost@mtsu.edu

Received: March 12, 2024 Accepted: April 1, 2024 Online Published: April 3, 2024

doi:10.5430/ijhe.v13n2p100 URL: https://doi.org/10.5430/ijhe.v13n2p100

Abstract

For the past two decades student success measures such as student persistence, retention, and graduation rates have been a point of emphasis in higher education. These measures are often directly related to funding formulas for state public colleges and universities. Therefore, analyses of these data have become more critical to evaluating student success initiatives for faculty and administration at many institutions. However, while these data are often widely available there is very little higher education research on how they should be analyzed to assess student success initiatives, program evaluations, or teaching effectiveness at the institutional level.

As student success outcome variables are categorical in nature, linear analyses of these data may prove rather difficult as a dependent variable without a significant amount of transformation. Therefore, the purpose of this article is to provide practitioners with a simple, yet powerful option for analyzing student success outcome variables utilizing the Chi-square test of independence. A case study approach was taken to illustrate how Chi-square can be used to specifically analyze the association between an experiential learning high impact practice and graduation rates among undergraduate students. This case was based on a results and interpretation perspective, rather than step-by-step instruction on how to perform the analysis itself.

Keywords: student success, higher education, graduation rates, categorical data analysis, Chi-Square test

1. Introduction

With the advent of Complete College America (CCA) in 2010, public colleges and universities have collectively moved to an outcomes approach to define student success (Ness et al, 2021). In many cases, state funding and appropriations are dependent on outcome measures such as student persistence, retention, completion, and graduation rates (Hillman et al., 2015; Orr & Usher, 2018; Whitford, 2021). Therefore, proper analyses of these data are imperative to not only understand these rates, but also determine to what extent institutional student success measures or high-impact practices are proving effective or not. Although these data are often reported as rates as expressed by percentage, they are in their simplest form, categorical yes or no variables. These variables describe whether a student has persisted, been retained, or completed and graduated, or not. Since there is already interest in using these forms of data, and it is reasonable to see their use increasingly valued, it is imperative that appropriate tests and statistical analyses be used for these categorical forms of data.

2. Background

2.1 Absence of a Universal Method for Analyzing Graduation Rate Data

Although student persistence, retention, and graduation data are often readily available and reported by institutions and governmental agencies (Yang & Li, 2020), a specific method of data analysis for these variables is very limited in higher education research. For example, performing a search on a Federated Search Engine (Williams, 2010) using the criteria how to analyze higher education graduation rates yielded zero results. Through the key words in the search criteria, Smart Text did produce hundreds of studies reporting the analysis of graduation rates using a variety of statistical techniques. However, there was not a specific or universal method of data analysis in this compilation of articles. Based on the literature, there are certainly effective means of analyzing categorical student success variables such as logistic regression, loglinear analysis, and transforming data into rate ratios for linear analysis (deCastro Galvo et al, 2023; Denning et al, 2022; Wekullo, 2022). However, while these analyses are powerful statistical tools, especially with regards to multiple variable predictors, they also require a fair amount of statistical acumen. Further,

many higher education practitioners may not have been exposed to advanced data analyses or regularly utilize them. Therefore, the purpose of this article is to provide practitioners with a simple, yet powerful option for analyzing student success outcome variables utilizing the Chi-square test of independence for these categorical outcomes.

2.2 The Chi-Square Test of Independence

The Chi-square test of independence has been shown to be one of the most effective hypothesis tests for nominal categorical data (McHugh, 2013). The Chi-square test specifically addresses the bi-modal distribution of the categorical variable that often limits the use of traditional linear analyses. Chi-square can determine and provide information on the significance of group differences, and determine which categories account for these differences and where they may be found (McHugh, 2013). In addition to providing a wealth of information within categories, the use of the Cramer's V strength test allows one to determine how closely independent and dependent variables are associated, and Odds Ratios can be calculated to determine the effect size and likelihood of the association between variables (Field, 2018). This article also follows the premise and example set forth by McHugh (2013) where the efficacy of Chi-square usage for nominal data in biostatics was examined.

3. Case Study

Chi-square hypothesis testing can be used on several different yes or no student success outcome variables (e.g., persistence, retention, graduation, completion). In the following case study, the author chose to examine graduation rates as an exemplar to demonstrate how the Chi-square hypothesis testing may be used for the analysis of student success outcome data:

As many public higher education institutions are being held to student success completion standards for funding formulas and competition for student enrollment, high impact practices (HIPS) are being implemented towards improving student success and graduation rates (Kilgo et al, 2014; Rolden et al, 2020). One of the more prominent HIPS being utilized in higher education is experiential learning (EXL) which has been shown to be an effective program overall in college students (Rodriguez & Albort-Morant, 2019; Rost et al, 2023). For this case, a student success administrator at a public state institution was interested in determining if there was a significant association between students who participated in an EXL program and increased academic performance as measured by six-year graduation rate. After reviewing the institutional graduation data, it was also determined that female students appeared to be graduating at a higher percentage than male students over several cohort years. These data were also consistent with other public state institutions where, as of 2020, 6-year graduation rates indicated that male public college students tended to not graduate as frequently as female students (66% vs. 60%) (National Center for Education Statistics, 2022). Given that the institutional and national data indicated that male students do not graduate at the same frequency as their female peers, examining the effect of participation in this HIP on the lower performing group was warranted. Therefore, the purpose of this case study was to determine if male students participating in an EXL HIP program was associated with increased graduation frequency utilizing the Chi-square hypothesis testing method. The research question and research hypothesis used for this case study are discussed in the methods section of this article.

4. Methods

4.1 Research Question and Research Hypothesis

RQ_1: Is there an association between student participation in an EXL program and graduation frequency among male college students?

H_1: Student participation in an EXL program is associated with graduation frequency among male college students.

4.2 Subject Grouping and Rationale

In this case the dependent variable was frequency of graduation (each student graduated Yes, or No) and the independent variable was participation in an EXL program. Students that completed at least one three-hour credit EXL course were coded as "three or more hours" and students that completed less than three hours of EXL coursework as "0-2 hours". The rationale for coding the independent variable in this fashion was that a three-credit hour class appears to be most representative of a typical course in an EXL program (Rost et al, 2023). For this case, the following two groups were examined on graduation frequency in the Chi-square analysis:

Group 1: Did not participate in the EXL program (0-2 completed EXL hours; N = 13,871)

Group 2: Participated in the EXL program (3 or more completed EXL hours; N = 2,444)

Based on the research question and hypothesis, the researcher was interested in determining if there was an association between participation in an EXL program and graduation frequency among male college students. Additionally, an *Odds Ratio* test was performed to determine if there was more likelihood of graduation frequency for EXL participants than non-participants in this population.

4.3 Chi-square Assumptions

According to Field (2018, p. 849) the following assumptions must be met for an accurate Chi-Square test:

(1) The independent and dependent variables must be categorical

(2) Independence: each person, item, or entity must contribute to only one cell of the contingency table

(3) Expected Frequencies: no more than 20% of expected counts should be less than 5.

4.4 The Contingency Table

The first step in performing the Chi-square hypothesis test is to create a contingency table with categorical dependent and independent variables. A computer statistical program such as the Statistical Package for Social Science (SPSS) can create a contingency table through the Analyze and Crosstabulation commands. In this case, as there were two categories for each variable, a 2X2 (two categories by two categories) contingency table was created. A contingency table contains the number of cases that fall into each category (count), as well as frequencies one might expect to get in those categories by chance (expected frequencies) for each variable event (Field, 2018). The table also produces standardized residuals which may be useful in determining the direction of the effect and "what contributes to the overall association that the Chi-square statistic measures" (Field, 2018, p. 838).

The case results are depicted in a contingency table (Table 1) and illustrate specific and valuable information. First, it was determined that the statistical assumptions for Chi-square were met as the variables were categorical, were independent, and none of the expected counts were less than 5. Secondly, when comparing the Percent Within Hours for EXL Hours and Graduation, the results indicated that Group 1 had a graduation frequency of 35.90% and Group 2 had a graduation frequency of 75.80%. Upon a cursory examination it appears that Group 2 graduates more frequently than Group 1. However, at this stage of the analysis it is only an anecdotal interpretation and must be statistically tested with the Chi-square test.

Table 1. Frequencies of EXL Hours and Graduation among Men (N = 16,315)

			Graduation		
			No	Yes	Total
EXL Hours	0-2	Count	8898	4973	13871
		Expected Count	8067.5	5903.5	13871.0
		% within Hours	64.1%	35.9%	100.0%
		% within Graduation	93.8%	72.9%	85.0%
		% of Total	54.5%	30.5%	85.0%
		Standardized Residuals	9.2	-10.9	
	3 or more	Count	591	1853	2444
		Expected Count	1421.5	1022.5	2444.0
		% within Hours	24.2%	75.8%	100.0%
		% within Graduation	6.2%	27.1%	15.0%
		% of Total	3.6%	11.4%	15.0%
		Standardized Residuals	-22.0	26.0	
Total		Count	9489	6826	16315
		Expected Count	9489.0	6826.0	16315.0
		% within Hours	58.2%	41.8%	100.0%
		% within Graduation	100.0%	100.0%	100.0%
		% of Total	58.2%	41.8%	100.0%

4.5 Interpreting the Chi Square Value

Table 2 shows the Chi-square statistic and its significance value. The value of the Chi-square is given in the table along with the corresponding degrees of freedom and P value for significance. For this case, the value of the Chi-square test statistic was X^2=1363.963. This value is highly significant ($p < 0.001$) indicating that participation in an EXL program was significantly associated with graduation frequency among male college students. Table 2 also depicts other test statistics such as the Likelihood Ratio which may be used in place of the Chi-square test if the sample were small (e.g., less than 50) (Field, 2018).

Table 2. Chi-Square results of association among EXL Hours and Graduation Among Men

	Value	df	Asymptotic Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	1363.963[a]	1	.000	.000		
Likelihood Ratio	1373.569	1	.000	.000		
Linear-by-Linear Association	1363.880[b]	1	.000	.000	.000	.000
N of Valid Cases	13164					

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 1022.54

b. The standardized statistic is 36.931

4.6 Cramer's V Strength Test

As the Chi-square test statistic for association was significant for this case, the next step in the procedure was to determine the relative strength of the association. Statistical strength measures such as the Cramer's V test "allows for a modification of the Chi-square statistic to take sample size and degrees of freedom into account and restrict the range of the statistic to a correlation between 0 and 1" (Field, 2018, p. 841). As in any correlation its relative strength is typically reported as weak when closer to zero and strong when closer to one (Johnson & Christensen, 2020). While the Cramer's V strength of association test has been demonstrated to be one of the most useful for categorical designs, it does tend to produce conservatively low correlational values even with significant results (McHugh, 2013). Table 3 shows the Cramer's V measure of association and was reported as .289 out of a possible 1. These results indicated that there was a very significant ($p < 0.001$), but a relatively weak strength of association between EXL participation and graduation frequency. However, considering the test significance, large sample size and Cramer's V's tendency to under-report, the researcher can be relatively confident in the significance of the Chi-square test statistic.

Table 3. Cramer's V results of association between EXL Hours and Graduation Among Men

		Value	Approximate Significance	Exact Significance
Nominal by Nominal				
	Cramer's V	.289	.000	.000
N of Valid Cases		16315		

4.7 Calculating Odds Ratios

The last step of Chi-square hypothesis testing is calculating the effect size of a significant Chi-square analysis through calculation of the Odds Ratio. The Odds Ratio is especially useful as it will produce the actual odds of this association occurring and in what direction. Unlike the contingency table, Chi-square test statistic, and Cramer's V test that can be computed on a statistical program such as SPSS, Odds Ratios must be hand calculated (Field, 2018). For this case the following formulas and method was used to determine the effect size for the association between student EXL participation and graduation frequency:

$$\text{Odds graduation} = \frac{\text{yes graduation number of students}}{\text{no graduation number of students}} \quad (1)$$

$$\text{Odds} = \frac{\text{Odds ratio results group 1}}{\text{Odds ratio results group 2}} \quad (2)$$

Per these equations using the first "or Count" row in the Contingency Table:

$$\text{Odds graduation} = \frac{4{,}973}{8{,}898} = 0.55 \text{ Group 1 (0-2 EXL Hours)} \quad (3)$$

$$\text{Odds graduation} = \frac{1{,}853}{591} = 3.13 \text{ Group 2 (3 or more EXL Hours)} \quad (4)$$

$$\text{Odds} = \frac{0.55}{3.13} = 0.17 \quad (5)$$

By calculating effect size via the Odds Ratio, the researcher can now determine which group (1 or 2) is more likely to graduate and to what degree. In the example above, the odds that Group 1 will graduate is .17 times as high as Group 2. However, there is another way to express this (Field, 2018) as students in Group 2 are 1/0.17 = 5.71 times more likely to graduate than students in Group 1. These calculations were derived from the total count row for both EXL student categories found in the contingency table in Table 1.

5. Results

As the analysis of this case has been completed, the last step in the process is interpreting and reporting the results. The results of this case can then be interpreted and reported as: Table 1 presents the results of the contingency table used to understand the frequencies between EXL participation and graduation variables among male college students. The contingency table met the chi-square test assumptions, as each subject contributed to one cell of the contingency table and there were no expected counts less than 5. Results from Table 1 demonstrate that there was a significant association between EXL participation and student graduation among men $X^2(1) = 1363.963$, $p < .001$. Cramer's V = .289, $p < .001$ indicated that there was a highly significant, but moderately weak association between the independent and dependent variables. The Odds Ratio showed the odds of male students who participated in the EXL program (75.80%) were 5.71 times more likely to graduate than male students who did not participate in the EXL program (35.90%).

6. Discussion

Based on the results of this case study, the student success administrator was able to glean important empirical evidence regarding the association of participation in an EXL program and graduation success among its male students. Moreover, the results indicated that there was not only a higher percentage of graduates among this population, but the odds of graduation (almost 6 times more likely) for male EXL students. The case study results may be useful to the student success practitioner in a multitude of ways. For example, these results could not only be used to demonstrate program effectiveness, but also used as a basis for program expansion and resource allocation to serve additional students. Furthermore, the student success practitioner can also apply the Chi-square test methodology to examine other HIPS programs on campus and their impact on student success.

As the outcomes for persistence, retention, graduation, and completion rates are at the forefront of funding formulas for many public state institutions, proper analysis and reporting of these data are paramount. Moreover, proper evaluation of High Impact Practices for improving these rates is essential to not only student outcomes, but also funding allocation for programs that have demonstrated success empirically. As discussed throughout this article, the Chi-square test is an excellent tool for higher education administrators and faculty to use to evaluate student success outcome variables simply and effectively. In addition, this type of hypothesis testing can also empirically examine the efficacy of their student success initiatives and High Impact Practices. However, it must also be noted that while Chi-square has been shown to be effective in analyzing these student success variables, it is limited to examining one independent variable at a time. Although one additional control variable can be examined through the layer command (Field, 2018). As such, a more advanced data analysis method such as logistic regression would need to be used if a researcher wished to examine the effect of multiple control and predictor variables on a categorical dependent variable (e.g., graduation).

7. Conclusion

The purpose of this article was to demonstrate the effectiveness of Chi-square hypothesis testing for categorical data based on yes or no outcomes for student graduate rates. This method can also be used to analyze other yes or no outcome data such as student persistence, retention, and completion rates. The author chose to approach this premise

from a results and interpretation perspective, rather than step-by-step instruction on how to perform the analysis itself. However, instruction on how to input/import data into a data analysis program such as SPSS, and perform the crosstabulation Chi-square analysis, can be readily available in a textbook such as Discovering Statistics Using SPSS Statistics 5th Ed. (Field, 2018), or via online, at for example, Laerd Statistics https://statistics.laerd.com/. As student success outcome data are often institutionally and nationally available and these measures are often linked to institutional funding, it is of the greatest import for higher education administrators and faculty to properly analyze them in their natural form.

References

DeCastro Galvo, J., Tucker, F., & Attewell, P. (2023). Bending the curve: Institutional factors associated with graduation rates. *Higher Education Policy,* 1-25. https://doi.org/10.1057/s41307-023-00304-5

Denning, J.T., Eide, E.R., Patterson, R.W., Mumford, K. J., & Warnick, M. (2022). Lower bars, higher college GPAs: How grade inflation is boosting college graduation rates. *Education Next, 22*(1), 56-62.

Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics (5th Ed.).* Thousand Oaks, California: Sage Publications

Hillman, N. W., Tandberg, D. A., & Fryar, A. H. (2015). Evaluating the impacts of "new" performance funding in higher education. *Educational Evaluation and Policy Analysis, 37*(4), 501-519. https://doi.org/10.3102/0162373714560224

Johnson, R. B., & Christensen, L. (2020). *Educational Research: Quantitative, Qualitative, and Mixed Approaches (7th Ed.).* Thousand Oaks, California: Sage Publications

Kilgo, C. A., Ezell Sheets, J. K., & Pascarella, E. T. (2015). The link between high-impact practices and student learning: Some longitudinal evidence. *Higher Education, 69,* 509-525. https://doi.org/10.1007/s10734-014-9788-z

McHugh, M. (2013). The chi-square test of independence. *Biochemia Medica, 23*(2), 143-149. https://doi.org/10.11613/BM.2013.018

National Center for Educational Statistics. (2022). *Fast facts: Undergraduate graduation rates*. Retrieved from https://nces.ed.gov/fastfacts/display.asp?id=40

Ness, E. C., Rubin, P. G., & Hammond, L. (2021). Becoming a "game changer": Complete College America's role in U.S. higher education policy. *Higher Education, 82*(1), 1-17. https://doi.org/10.1007/s10734-020-00619-x

Orr, D., & Usher, A. (2018). Revisiting student performance as a cornerstone of higher education: how is student performance reflected in performance-based funding? *Research Handbook on Quality, Performance and Accountability in Higher Education,* 290-304. https://doi.org/10.4337/9781785369759.00032

Rodriguez, A., & Albort-Morant, G. (2019). Promoting innovative experiential learning practices to improve academic performance: Empirical evidence from a Spanish Business School. *Journal of Innovation and Knowledge,* (4), 98. https://doi.org/10.1016/j.jik.2017.12.001

Roldan, M., Kothari, T., & Dunn-Jensen, L. M. (2020). Direct effects of high-impact practices on the success of business majors in large, mostly nonresidential public universities. *Journal of Management Education, 44*(1), 39-65. https://doi.org/10.1177/1052562919869384

Rost, J.K., Swayze, A.C., & McCormick, J. (2023). Effect of an experiential learning curriculum on college student graduation. *Experiential Learning and Teaching in Higher Education, 6*(2), 30-48. https://doi.org/10.46787/elthe.v6i2.3561

Wekullo, C. (2022). Relationship between alternative revenue strategies and graduation rates for U.S. public higher education. *Higher Education Politics and Economics, 8*(1), 2. https://doi.org/10.32674/hepe.v8i1.4497

Whitford, E. (2021). Report: State funding closely linked to student success. *Inside Higher Education*. Retrieved from https://www.insidehighered.com/quicktakes/2021/05/19/report-state-funding-closely-linked-student-success

Williams, S. (2010). Federated search and the library website: A study of association libraries member websites. *Journal of Web Librarianship, 4*(1), 3-18. https://doi.org/10.1080/19322900903496273

Yang, N., & Li, T. (2020). How stakeholders' data literacy contributes to student success in higher education: a goal-oriented analysis. *International Journal of Educational Technology in Higher Education, 17*(1), 41. https://doi.org/10.1186/s41239-020-00220-3