Predicting Success in a Statistics Course Geared toward Allied Health Students

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Article Info	Abstract
	Statistics education is an important component of allied health education. Although success in statistics courses has been reported for students in fields such as business, nursing and psychology, there is a dearth of literature in students of other allied health science disciplines. As statistics is a gatekeeper course for many of these disciplines, understanding and addressing demographic predictors of success is a crucial step in helping to maintain a diverse healthcare workforce. In this study, ethnicity, gender, their interaction, age, and class format were used to predict 953 success outcomes in a retrospective dataset, with major being used as a random effect. Ethnicity alone predicted success, with students of other ethnicities having 0.6 times the odds of success as their Caucasian counterparts. As statistics is a potential gatekeeper course for success in health professions programs, academic instructors, administrators and other stakeholders should take steps to ascertain the incidence and nature of disparities in their settings, as it may play a role in maintaining a diverse healthcare workforce.

Introduction

Statistics is defined as "a branch of mathematics dealing with the collection, analysis, interpretation, and presentation of masses of numerical data" (Merriam-Webster Dictionary, 2020). The use of statistical methods to analyze and interpret data is an important goal for many professions and is considered to be a highly demanded skill for employers. In fact, jobs that require statistical competence (e.g., data science, business analytics, machine learning) have been cited as being in the top hard skills in highest demand for the job landscape in the 2010's and beyond (Anderson, 2020; Bowley, 2018). In undergraduate curricula, statistics courses are important for other disciplines as these classes provide formal exposure to research design (Mji & Onwuegbuzie, 2004). Statistics is highly important in fields such as medicine, as humans are biological systems that react differently to treatments (Aggarwal, 2018). In the context of evidence-based practice, it is important for health care professionals to understand and evaluate client or patient data, and to analyze existing research. For example, lack of understanding of statistics has been cited is a barrier for the integration of research into clinical practice in areas such fields as nursing (Epstein, Santa Mina, Gaudet, Singh & Gula, 2011; Hanoch & Pachur, 2004) and athletic training (Riemann & Lininger, 2015). The importance of understanding, and use, of statistical concepts has also been underscored in fields such as exercise science (Beck, 2013; Hopkins, Marshall,

Batterham & Hanin, 2008), and the public health professions (Hayat, Powell, Johnson, & Caldwell, 2017). Other analytical methods such as geospatial information systems (GIS) are used to model incidence of health-related outcomes (Fradelos et al, 2014), and require a fundamental understanding of statistics and its applications. From an interprofessional point of view, statistics is a common denominator across the health professions and plays a crucial role in the understanding of research. Its understanding is essential to the design and understanding of studies within and across disciplines, and also in the scope of practice across the health professions. Hence, the understanding of statistics as well as its applications are important parts of undergraduate health professions education.

Background

Statistics coursework continues to be a challenge for undergraduate students for several reasons. Students who choose human interest majors (e.g., psychology & medicine) generally prefer to learn the relevant human interest content, and prefer to stay away from methodological courses (Aggarwal, 2018; Rajecki, Appleby, Williams, Johnson, & Jeschke, 2005). Such findings suggest poor attitudes toward statistics. Moreover, the construct of anxiety is widely reported as a barrier to success in statistics courses (Mji & Onwuegbuzie, 2004). For example, Kohli and colleagues (2011) found statistics anxiety to be a predictor of success in a business statistics course, while it was reported that students felt less anxiety in a psychological statistics course using a collaborative approach (Gorvine & Smith, 2015). Results are mixed as some studies do not find an association between statistics anxiety and course performance (Lester, 2016). However, statistics attitudes and anxiety are so widely studied that several instruments exist in order to measure it (Cruise, Cash, & Bolton, 1985; Vigil-Colet, Lorenzo-Seva & Condon, 2008).

Demographic variables have been shown to predict success at STEM content, including statistics. Race and ethnicity have been cited to predict STEM achievement, with Asian and Caucasian students reported to have more success than their Black, Hispanic/Latinx, and Native American counterparts (American Psychological Association, 2020). For example, Caucasian students were found to find more success than their ethnic minority counterparts in an introductory (first-year) mathematics course (Wolfle, 2012), and Asians have been reported to have higher achievement than their Caucasian, African-American and Latinx counterparts (van Es & Weaver, 2018). This is not unanimous, as Caucasians were reported to have lower achievement than all other groups in a business statistics course (Kohli, Peng & Mittal, 2011). Others have found no relationship (Rochelle & Dotterweich, 2007). Hence the relationship with race/ethnicity with successful statistics outcomes appears to be complex.

The effect of gender upon performance is apparent, but also complex. Schram (1996) reported that males performed better than females in examination scores, yet females surpassed males in statistics course performance, as well as in business courses. Females were also reported to also perform better than males in a psychological statistics course (Lester, 2016). Conversely, there are reports of males performing better than females (van Es & Weaver, 2018), and even no difference between genders (Rochelle & Dotterweich, 2007). Similarly, the effect of age upon success seems to vary. While it has been shown to be a predictor in similar

courses such as introductory mathematics (Wolfle, 2012), it has not been a predictor in other classes (Kohli, Peng & Mittal, 2011; Rochelle & Dotterweich, 2007).

Stereotype threat is the perception of stigmatized groups that their behavior may confirm negative stereotypes, and has been implicated in the representation of women and minorities in the STEM fields. The anxiety results from negative stereotypes of women and minorities (Beasley & Fischer, 2012; Inzlicht & Ben-Zeev, 2000) being intellectually inferior, and has been reported to have ethnicity/gender interaction effects (Beasley & Fischer, 2012; Brown, 2000). However, some findings (Kohli, Peng & Mittal, 2011; Rochelle & Dotterweich, 2007) have contradicted this trend. In summary, the associations of ethnicity, gender, and age with success in statistics courses are complex and unclear, but may involve factors that are not currently understood. The goal of this study is to add to the literature on statistics achievement, specifically for allied health majors.

Predictors (Fixed Effects)

Since it has been shown that age, ethnicity and gender can predict performance in statistics courses, which are possible gatekeeper courses for allied health disciplines, it is important to understand the incidence and nature of this disparity in pertinent students. Disparities in statistics success within the context of health professions education could have potential downstream public health implications; specifically, such disparities could adversely affect the presence of a diverse health professions workforce, and thus decisions concerning health care policy. As a diverse healthcare workforce is crucial in maintaining the quality of healthcare for underserved populations (Cohen, Gabriel & Terrell, 2002), teaching and administrative personnel should preemptively employ necessary interventions to address any existing disparities in success of statistics outcomes.

Finally, it has been shown that students prefer to take difficult courses in a traditional format (Jaggars, 2014), and are more likely to be unsuccessful in online courses (Jaggars, Edgecombe & Stacey 2013). Statistics is a typically considered to be a difficult course, and the course described in this instance was offered in both traditional and online formats. Hence the format offered was used as a predictor in the study described here. In total, ethnicity, gender, their interaction, age and the format offered were used to predict successful course completion in this study.

Random Effects

Random effects are used to describe correlated groups that may explain variation in success. Semester of attendance was initially going to be used as a random effect. However, this null model effectively explained no variance, and was therefore removed in order to preserve degrees of freedom for the analysis. Nursing programs also accept students as cohorts in which they generally remain until graduating, and are more rigidly structured than the other programs represented in this study (described later). Therefore, the student's major was used as a random effect. This variable was categorized as follows: bachelor of health care sciences (BHCS), bachelor of science in nursing (BSN), pre-health scare sciences, pre-nursing, and other. These categories will be further described below.

Success (Outcome Variable)

In the study, the grades of A, B, and C were defined as success, and all other grades (D, F, W) were defined as unsuccessful. While withdrawal is not the same as failure, it was included in the unsuccessful group for several reasons. Withdrawal is an adverse outcome for the student as it has been shown to prolong time taken to graduate (Nicholls & Gaede, 2014). It is also adverse to the institution as it results in misallocated class spaces, which results in a delay of enrollment for other students. These effects are exacerbated for online classes, as it has been reported that students are more likely to withdraw from online courses (Jaggars, Edgecombe & Stacey 2013).

Method

Data and Participant Characteristics

The data used in this study were blinded with fake ID numbers by the institution's office of data management prior to sharing with the researcher, and there was a total of 953 rows of data. There were 926 unique ID numbers, with 27 students enrolling more than once. Hence the 953 rows describe attempts, specifically successful and unsuccessful outcomes. Of these, 805 were successful, and 148 were unsuccessful. The majority of the students were allied health majors. The course was offered by a health sciences department that housed concentrations in nutrition, exercise science, health promotion, athletic training, and a general baccalaureate degree for allied health professionals who already held an associate's degree in a health related profession (BHCS). However, the course was also taken by pre-nursing students, as well as students who were in the professional phase of a bachelor of science nursing program (BSN). There were 57 pre health care science students, 512 HCSC students, 176 nursing prep students and 131 BSN students (i.e., in the professional phase of the program). Given student anxiety surrounding statistics, it seems likely that the rest of the students (n = 50) who represented other majors took the class as a substitution for a mandatory course within their own department, rather than as an elective.

The course in this study was a sophomore level statistics class in which students were enrolled between Spring 2012 and Summer 2016, for a total of 14 semesters. The statistics course covered the following topics: sampling, experimental design, measures of central tendency and variation, probability distributions, hypothesis testing methods such as correlation, regression, the t-tests, analysis of variance (ANOVA), and non-parametric testing. The course was offered in a health sciences college at a public institution that, as of 2019 is described as having an undergraduate student body with the following demographics: 34% minority, and 53% female. Except for gender, course demographics appear to be comparable to those of the institution. The course was offered in traditional and online formats.

Table 1 below describes the participants by ethnicity, gender, age, and format. Because of the relatively small numbers of self-identified Hispanics, Native Americans, Asians, African Americans, and Pacific Islanders, they were collapsed into one group for analysis. While this results in a loss of information, it has been done in other studies (Kohli, Peng & Mittal, 2011; Rochelle & Dotterweich, 2007).

Table 1. Frequencies

Fixed Effects	Successful	% Successful	Unsuccessful	% Unsuccessful
Ethnicity				
Caucasian	594	62.3 %	93	9.7 %
Hispanic[*]	117	12.3 %	22	2.3 %
Native American[*]	12	1.2 %	8	0.8 %
Asian[*]	38	4.0 %	7	0.7 %
African American[*]	37	3.9 %	12	1.3 %
Pacific Islander[*]	7	0.7 %	6	0.6 %
Gender				
Female	599	62.8 %	106	11.1 %
Male	206	21.6 %	42	4.4 %
Age				
17-25	574	60.2 %	102	10.7 %
25-30	124	13.0 %	25	2.6 %
Older than 30	107	11.2 %	21	2.2%
Format				
Face-to-face	406	42.6 %	68	7.1 %
Online	399	41.9 %	80	8.4 %
Random Effects				
Major				
BHCS	452	47.4 %	79	8.3 %
BSN	124	13.0 %	9	0.9 %
Pre-health care sciences	49	3.7 %	9	1.5 %
Pre-nursing	144	5.1 %	37	0.9 %
Other	14	15.1 %	36	3.8 %

[*]collapsed into one group; n = 211 (22.1 %) for successful students, n = 55 (5.7 %) for unsuccessful students. BHCS = Bachelor of health care sciences; BSN =Bachelor of Science in nursing

The study was granted ethical approval by the local Institutional Review Board (18-102-CNV). The data were retrieved from the institution's Office of Data management. Data were analyzed using R version 3.4.1 (R Core Team, 2017). Visual inspection of the data revealed duplicate cases taking the course in the same semester. Therefore, the *unique* function of the base package (R Core Team, 2017) was used to remove duplicate cases from the dataset. There were 921 participants (representing 953 rows of data) left in the dataset after cleaning.

The method used to analyze the data was multilevel binary logistic regression (MBLR). Caucasian males aged 18-25 years old were used as the baseline demographic. This method is suitable, as students who are unsuccessful often repeat the course in order to be successful. This violates the assumption of independent observations to which multilevel methods such as MBLR are robust (Field, Miles & Field, 2012). The *describe* function of the *psych* package (Revelle, 2017) was used to determine how many students repeated the course; 32

were found. The *glmer* command in the *lme4* package (Bates, Maecheler, Bolker, & Walker 2015) was used for this analysis. A model was created using random intercepts for the semester offered (later removed as it explained no variance), and the student's major. The following variables were then added to create three other models: ethnicity, gender, age, and format (i.e, face-to-face vs online). The *anova* function in the base package was then used to compare all models. The effect sizes (conditional & marginal pseudo R^2) were obtained using the *MuMin* package (Barton, 2018).

Results and Discussion

As shown in Table 2 below, ethnicity predicted success in this study. Non-Caucasian students were 0.6 times as likely to be successful as their Caucasian counterparts, and the marginal pseudo R^2 described a small effect (marginal pseudo R^2 in Table 3). No other variables predicted success in this study. The details may be found in Tables 2 and 3 below.

Table 2. Model Summary

Model	DF	AIC	BIC	LL	Deviance	Chisq	Chi DF	p-value
M	2	818.6	828.3	-407.3	814.6			
M + E**	3	813.2	827.7	-403.6	807.2	7.5	1	0.006
M + E + G	4	815.0	834.5	-403.5	807.0	0.1	1	1.0
M + E + G + E*G	5	817.0	841.3	-403.5	807.0	0.0	1	0.9
M + E + G + E*G + A	7	820.3	854.4	-403.2	806.3	0.6	2	0.8
M + E + G + E*G + A + F	8	820.6	859.5	-402.3	804.6	1.7	1	0.2

Note: M = Major, E = Ethnicity, G = Gender, A = Age, DF = degrees of freedom; AIC = Akaike's Information Criterion; BIC = Bayesian Information Criterion; LL = Log Likelihood; Chisq = Chi square; Chi DF = Chi square degrees of freedom; **indicates significance at the *p* = .01 level.

Table 3. Measures of effect

	Exp(B)*	95% CI	Conditional Pseudo R^2	Marginal Pseudo R^2
Intercept	0.2	0.1-0.3	.067	.015
Other Ethnicity	0.6	1.2-2.5		

*Shows comparison to Caucasian students; ICC = intraclass correlation coefficient

Fixed Effects

In this study, race/ethnicity predicted success in a statistics course geared toward allied health students, with Caucasian students being more likely to succeed than students of other ethnicities. Race/ethnicity has been a predictor of success in other studies, though with different outcomes. For example, one study found that Asian students performed significantly better than all other ethnicities in an introductory statistics course (van Es & Weaver, 2018). Kohli and colleagues (2011) also found that race/ethnicity was one of several variables that predicted success in a sample of students in a business statistics course. However, unlike the present study,

students of other ethnicities performed better than Caucasian students. Hence the relationship of race/ethnicity to statistics achievement appears to be a complex one, and may be dependent upon other factors that are not currently understood. It is worthy to note however, that in this study, non-Caucasians were pooled because of their relatively small numbers. In this situation, statistical interpretation should be approached with practical consideration. For example, the Table 1 shows that there is a near 1:1 ratio of successful to unsuccessful outcomes for Pacific Islander and Native American students, whereas Hispanic students had a 5:1 ratio. This limitation is discussed in the penultimate section of this paper. A positive outcome of this study was that neither age, gender, their interaction, nor format of the class predicted success in a statistics class geared toward students in the applied health sciences. This contradicts previous reports that find one or more of these variables are predictors of success in statistics, and similar courses, and is an overall positive finding.

Teaching Strategies

Statistics instructors may use several strategies in order to maximize student success in statistics. For example, Miller (2019) recommends an instructional method using Robert Steinberg's theory of triarchic intelligence. This method emphasizes the use of analytic abilities to solve abstract problems; creative abilities to apply knowledge to idiosyncratic situations; and practical abilities to apply statistical content to everyday situations. Gorvine and Smith (2015) found that students who worked collaboratively have improved learning outcomes, and reported lower anxiety in learning in a psychological statistics course. Others have used collaborative teaching methods in tandem with technology. For example, positive feedback has been reported for use of projects in a simulated environment by Australian students, where the students conduct studies on a virtual population (Bulmer, 2010). This simulated environment has also been used has used for American students who are required to serve as statistical consultants on projects as part of their statistics course requirements (Schwab-McCoy, 2017). Briefly, students proposed a project and "collected" data from the virtual population. They then exchanged datasets and served as statistical consultants for the data they received, and as clients for those whom they lent their data to be analyzed. The instructor reported anecdotal benefits such as increased group accountability, heightened curiosity, motivation to learn and practice statistics, heightened communication between student groups, and exposure to different approaches to analysis. Reported drawbacks included increased time commitment for the instructor for efficient project planning, and observation of students; increased time commitment for students in their roles as consultants and clients, and student pushback for inadequately explained objectives. For online teaching in statistics, it is reported that a statistics course design with a consistent structure, focused content, and varied learning activities and resources to be effective, alongside strategies such as the use of case studies, instructor notes, mini-projects, and an online discussion forum (Yang, 2017). Methods such as supplemental instruction (SI) have been shown to be effective in improving learning outcomes in STEM courses (Hurley, Jacobs & Gilbert, 2006), with benefits that include increased socialization of students of varying backgrounds. However, disadvantages of SI include its logistic and financial costs (Dawson, van de Meer, Skalicky and Cowley, 2014) and may therefore be unattractive from that standpoint. However, creative instructors may apply the socializing and collaborative aspects of SI in the classroom (Gorvine and Smith, 2015). Hence, instructors may help to improve the odds of success for students by diversifying content, creating various cognitive opportunities for students to solve problems, and

encouraging a collaborative classroom environment.

Introductory Statistics Courses are not monolithic

The above section is not meant to communicate to the reader that all methods will work for all classes, or all instructors, at all times. It is noted by the American Statistical Association (ASA, 2016) that introductory statistics content is not taught the same across classes; for example, some classes focus on literacy while others focus on methodology. They also have varying student audiences, found at different institutions ranging from community colleges to four-year universities. Across institutions, differing budgetary allocations may affect the quality and quantity of available technology. Content may also differ between different majors; i.e., content may differ between statistics classes offered in a life sciences department vs. mathematics vs. business, etc. Allied health students could attend schools where they are required to take a statistics course offered in their own department, are allowed to take coursework in another department, or must take the service course offered by the mathematics department, and may end up taking courses that have differing foci based upon literacy vs. application. Even within each focus, it is likely that different instructors have different pedagogical strategies. However, the aforementioned examples show that methods of instruction may be flexible while still conforming to the ASA GAISE guidelines for undergraduate student instruction (ASA, 2016). It is also worthy to note that many of the strategies are not conceptually exclusive.

Random Effect of the Student's Major

Conditional pseudo R^2 describes the combined variance of the random and fixed effects explained about 7% of variance in success. Hence the student's major explained about 5% of the variation in success (i.e., the difference between conditional and marginal pseudo R^2 values. Note that there appeared to be a wide discrepancy between nursing and other majors; BSN had an approximate 1:14 ratio of unsuccessful to successful outcomes. This was followed respectively followed by BHCS (~1:6), pre-health care sciences (~1:5), pre-nursing (~1:4), and other majors (~1:3). Certain undergraduate health professions programs (e.g., nursing) have a fundamental difference from undergraduate programs such as business and psychology. Many undergraduate health professions prepare students for immediate certification and/or licensure after graduation to work in the field, and competition is fierce to fill spaces within these programs. Conversely, certification of practice, licensure, and competition for spaces are traits that are not as commonly found in undergraduate liberal arts, the natural sciences, or business.

Student competition to fill and keep spaces in these programs, may serve as a potential external motivator for students to succeed, regardless of their demographic characteristics. Hence students in the allied health professions, especially those competing for a limited number of spaces in a baccalaureate and professional degree program may differ in this regard from students in other areas of study. As statistics is a potential gatekeeper course in many allied health baccalaureate & professional programs, the drive to enter/complete these programs may serve to offset statistics anxiety while enrolled in statistics courses. Although not looked at presently, this hypothesis is open for further study as described below.

Conclusion

Non-Caucasian students had 0.6 times the odds of Caucasian students in passing a sophomore level statistics course geared toward allied health majors. Age, gender, and format did not predict success. As a potential gatekeeper course, the use of multiple teaching methodologies to address statistics anxiety and poor attitudes in order to maximize student success is crucial.

Limitations and Recommendations for Future Study

A major limitation of this study is its retrospective nature. Participants were not chosen at random, which could produce a possible biased outcome. Moreover, this study included a heterogenous sample that contained health science students, nurses, and nursing prep students from one school in the Southwestern United States. However, the students in this sample belonged to programs that were not large enough to require their own statistical courses, and were combined for pragmatic reasons (i.e., budget, space allocations, etc.). Many of the students taking these classes often find themselves applying to competitive and vigorous programs that have a limited number of spaces (e.g., athletic training, nutrition, occupational therapy, physical therapy, etc.). Hence the competition to enter or retain a space in these programs may serve as an external motivator that offsets anxiety and poor attitudes toward statistics. Moreover, given the aforementioned discussions that the relationship of success with several of these variables is complex, further investigation using different samples is warranted. In order to verify or refute these findings, this study should be replicated with similar samples of pre-professional health science undergraduate classes found at other institutions. Another limitation of this study is that because the Caucasian group was so much larger than the other groups, the latter were all collapsed into one group for analysis. Although this was necessary, the loss of information in doing so is acknowledged, as well as the subsequent effect upon the outcome. Note the disparate ratios of successful to unsuccessful outcomes for race/ethnicity in Table 1.

Similarly, this study should be repeated with more homogenous samples from similar programs with students such as kinesiology, health studies, nutrition, and other programs with students that compete for professional graduate programs such as those found in pre-physical therapy programs. It may be hypothesized that these populations of students also have poor attitudes and high anxiety toward statistics courses. These constructs should also be further studied within these populations in order to add to the literature of student attitudes and anxiety in statistics across disciplines. As aforementioned, undergraduate nursing programs differ from many other majors due to its more rigorous nature. It may be worthwhile to do similar studies comparing statistics achievement of nursing students to those of a control group of students enrolled in less structured majors/programs. Qualitative approaches may also be useful in order to shed further light on the nature of statistics anxiety in students of the health professions. Examples may include the use of interviews to ascertain the interaction between statistics anxiety and the drive to succeed in nursing and non-nursing students.

Other variables known to predict statistics performance, such as anxiety and mathematical aptitude (Lester 2016; Rochelle & Dotterweich, 2007) were not measured in this study. For example, Lester (2016) reported that

proficiency in algebra was associated with success in a psychological statistics course, whereas anxiety was not. As this was a retrospective dataset, neither mathematical aptitude nor anxiety data were available for inclusion into this study.

Acknowledgements

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