Educational Review

ISSN: 0013-1911 (Print) 1465-3397 (Online) Journal homepage: http://www.tandfonline.com/loi/cedr20

A review of the application of logistic regression in educational research: common issues, implications, and suggestions

Lian Niu

EDUCATIONAL REVIEW
https://doi.org/10.1080/00131911.2018.1483892

A review of the application of logistic regression in educational research: common issues, implications, and suggestions

Lian Niu

Graduate School, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

ABSTRACT

This study reviews the international literature of empirical educational research to examine the application of logistic regression. The aim is to examine common practices of the report and interpretation of logistic regression results, and to discuss the implications for educational research. A review of 130 studies suggests that: (a) the majority of studies report statistical significance and sign of predictors but do not interpret relationship magnitude in terms of probabilities; (b) odds ratio is the most commonly reported effect size, and it tends to be incorrectly interpreted as relative risk, which leads to significant exaggeration of the association magnitude and misleading conclusions; and (c) marginal effects and predicted probabilities are reported by only 10.7% of reviewed studies, and the specification of independent variables' values is frequently missing. It is suggested that marginal effects and predicted probabilities be reported more frequently to fully utilise the information provided by logistic regression results.

ARTICLE HISTORY
Received 13 December 2017
Accepted 30 May 2018

KEYWORDS
Logistic regression; odds ratio; relative risk; marginal effects; effect size exaggeration

Introduction

Logistic regression is the commonly used statistical method in empirical studies involving categorical dependent variables. As Allison (1999) demonstrates, a dichotomous-dependent variable violates the assumptions of homoscedasticity and normality of the error term for linear regression model. Consequently, the estimates of the standard error will not be consistent estimates of the true standard errors, and the coefficient estimates will no longer be efficient. In addition, estimating a linear probability model with the ordinary least squares technique will lead to predicted values that are outside the plausible range of the probability (0,1). For these reasons, the logistic regression model is used when the dependent variable is dichotomous. This model transforms probability to odds and then takes the logarithm of the odds. By doing so, both the lower and upper bound of the probability is removed. The logistic regression model takes the following form (Allison 1999, 13):

CONTACT Lian Niu Lian.niu09@gmail.com University of North Carolina, 207 Bynum Hall, Chapel Hill, NC 27599, USA

$$log\left[\frac{p_i}{1-p_i}\right] = \alpha + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik} \qquad 1\text{–}1$$

where *i* denotes individual, p_i represents the probability of the event occurring, 1- p_i represents the probability of the event not occurring, the ratio of the two represents the odds of the event, and the left-hand side expression represents the log-odds, or the logit. On the right-hand side of the equation, α represents the intercept, β represents the regression coefficient, and x represents the independent variable (for more detailed background of logistic regression, see also Kleinbaum et al. 1998; McCulloch and Searle 2001; Menard 2010; Pedhazur 1997; Rencher 2000; Tabachnick and Fidell 2001).

As can be seen from the right-hand side of equation 1–1, the specification of the logistic regression model is very similar to that of the linear regression model in terms of independent variables. Like linear regression, logistic regression can handle both continuous and categorical independent variables. Major statistical softwares include easy-to-use procedures for logistic regression models. Although it is relatively straightforward to specify and estimate logistic regression models, the interpretation of the results is more complicated and less intuitive compared to linear regression. This is due to the fact that in the logistic regression model, the relationship between the probabilities and the set of independent variables is not linear; instead, it is the relationship between the *logit* and the set of independent variables that is assumed to be linear. As a result, the estimates of the coefficients represent the change in the *log of odds* corresponding to a certain amount of change in the independent variable. Acknowledging the difficulty of interpreting the log of odds, the common practice is to exponentiate the estimates of the coefficients to obtain the odds ratio. This step eliminates the complication of interpreting the log, and the odds ratio becomes the standard effect size output by statistical softwares. Nevertheless, the concept and proper interpretation of the odds ratio still leave many researchers confused. A browse of the current educational research literature shows that different approaches to interpreting logistic regression results have been adopted. For example, the odds ratio is interpreted as a relative risk in some studies (Chiang et al. 2012; Sullivan and Cosden 2015) but not in others (Jaeger and Eagan 2011). Some studies do not interpret the odds ratio at all but report and interpret marginal effects and predicted probabilities instead (King 2015; Ko and Jun 2015). Which approach is most commonly adopted in educational research? Is the most common approach the best? What are the implications of taking various approaches?

The aim of this study is to review current literature in educational research where logistic regression is used to examine the application of logistic regression, focusing on the presentation and interpretation of logistic regression results. The goal is to provide educational researchers and research literature readers with a better understanding of how logistic regression results can be reported and accurately interpreted to better answer educational research questions. Specifically, this study examines the following aspects of the application of logistic regression: (a) the statistics being reported as logistic regression results, and (b) the interpretation of statistical significance level, direction, and magnitude of the association between predictor and event probability. The goals of this study are to reveal any common issues in using logistic regression to explain educational phenomena, to compare different approaches of interpreting logistic regression results, and to provide suggestions of preferred approaches to enhance the quality of the application of this statistical method.

Review method

The first step of the study was to search for relevant literature, namely empirical educational research studies in which logistic regression was used. To obtain a sample size manageable for a review study, the search was limited to studies that were written in English, published in peer-reviewed journals, and published from 2010 to 2016. The online databases searched included Education Source by EBSCO, ERIC, PsycINFO, and Web of Science. The following search terms were used to search anywhere in the document: logistic regression, education. The search was limited to studies published in peer-reviewed journals to include research that had been evaluated through rigorous peer review processes. The search yielded 143 articles. These documents then were reviewed, and studies that did not include empirical analysis using logistic regression model were excluded. This process resulted in a list of 130 empirical research articles. The articles were then coded in terms of the statistics reported and the interpretation (or the lack thereof) of such statistics. The coding was based on contents anywhere in the articles, including tables, figures, texts, and appendices. If the detected statistically significant relationship between the predictor and the event occurrence was interpreted in terms of probabilities, then an article was coded as having interpreted the magnitude of association. If odds ratio was explicitly interpreted as relative risk, namely if the definition of relative risk was used to explain the numeric value of reported odds ratio, then an article was coded as having treated odds ratio as relative risk. Given that this is a single-authored study, no additional coder was involved to check the coding of articles. Instead, the author used Table B1 in Appendix B to double-check the coding and to present a summary of the reviewed studies. Given the straightforward binary (yes/no) nature of all categories of the coding, the author believes that the lack of a second coder should not impact the accuracy of the coding.

Because the inclusion criterion was the application of logistic regression, the included studies demonstrated a wide range of research topics. The most common outcome variables concerned students' choice among two or more options, such as student enrolment pattern (Campbell and Mislevy 2013), students' intention of urban/rural placement (Jones, Bushnell, and Humphreys 2014), college major choice (Ferguson et al. 2012; Pinxten et al. 2015), participation in student organisations (Case 2011), pursuit of financial aid (Radey and Cheatham 2013), and decision to pursue graduate education (d'Aguiar and Harrison 2016). Another common type of dependent variable is student outcome such as degree attainment (Flynn 2014), academic success (Fong, Melguizo, and Prather 2015; Stegers-Jager et al. 2012), and retention (Evans 2013; O'Neill et al. 2011; Pruett and Absher 2015; Santelices et al. 2016). Students' health and social behaviours also were among the examined outcomes (Taliaferro and Muehlenkamp 2015; Titzmann, Brenick, and Silbereisen 2015).

The manuscripts then were analysed to determine the type of statistics being reported, as well as the accuracy and extent of the interpretation of the significance, direction, and magnitude of the association between predictors and event probability. The following section reports the results of the analysis, summarises the frequency and type of statistics being reported as logistic regression results, determines the suitability of reported effect sizes and the accuracy of their interpretation, and analyses the scope of information revealed by the reported effect sizes and the interpretation. A discussion section then follows to compare approaches of interpreting logistic regression results, to identify common issues and their implications, and to make suggestions of how to overcome such issues.

Results

This section examines the application of logistic regression in two aspects. The first examines the statistics being reported as logistic regression results. The second examines how significance level, direction, and magnitude of the association between predictor and event probability are interpreted.

Statistics being reported as logistic regression results

Table 1 presents the frequency of relevant statistics reported as logistic regression results in the reviewed studies. The majority of studies (81.5%) reported the odds ratio (OR) as effect size. The confidence interval of either the coefficient estimate or the odds ratio was reported by less than half (43.1%) of the studies, while the *p* value of the significance test was reported by most studies (86.9%). This suggests that *p* values are more commonly used than confidence intervals as indication of the significance level of independent variables. Given the fact that odds ratio, confidence interval, and *p* value are among the standard output of major statistical packages such as STATA and SAS, it is unsurprising to see that these statistics frequently are reported as logistic regression results.

Compared to the odds ratio, alternative measures of relationship magnitude were much less frequently reported. As can be seen from Table 1, marginal effects and predicted probabilities each were reported by 5.4% of the reviewed studies. This might be because researchers do not find it necessary to report and interpret effect sizes other than odds ratio. It also is plausible that the additional steps such as code writing and specification of independent variable values required to obtain these statistics affect their popularity.

The interpretation of significance and direction of association

Before reviewing the included studies' interpretation of model results, a brief overview of the basics of logistic regression is necessary. The goal of using logistic regression model is to understand the correlational relationship between independent variables (predictors) and the likelihood of the event. As indicated in equation 1–1, the left-hand side of logistic regression model is the log of odds, and coefficient β_k is the change in the log of odds for one-unit change in x_k, holding all other independent variables constant. To eliminate the complication of interpreting β_k in terms of changes in log odds, the common practice is to exponentiate both sides of the equation to obtain the odds ratio, namely the ratio of the odds of an event for two individuals differing by one-unit on x. The odds ratio can be expressed as follows:

Table 1. Frequency and percentage of reported statistics as logistic regression results.

Statistic	Frequency	Percentage
Odds ratio	106	81.5%
Confidence interval of coefficient or odds ratio	56	43.1%
p value of significance test	113	86.9%
Marginal effects	7	5.4%
Predicted probability	7	5.4%

Note: N = 130

$$\text{Odds ratio} = \text{Exp}(\beta) \ = \frac{p(x+1)/(1-p(x+1))}{p(x)/(1-p(x))} \qquad 2\text{–}1$$

where *p* represents the probability of the event occurring, *x* represents independent variable, and *x + 1* represents one-unit change in independent variable. It can be seen that although the odds ratio is related to event probability and it measures a ratio between two individuals differing by one-unit on the independent variable, it does not measure the ratio of probabilities. Instead, it measures the ratio of odds. The ratio of probabilities, also called relative risk or risk ratio, measures the ratio of the probability of an event occurring in one group (exposed to certain treatment/condition) to the probability of the same event occurring in another group (unexposed to such treatment/condition). The difference between the two ratios is easier to understand by comparing the formulae. Relative risk is expressed as follows:

$$\text{Relative risk} \ = \frac{p(x+1)}{p(x)} \qquad 2\text{–}2$$

where *p* represents the probability of the event occurring, *x* represents independent variable, and *x + 1* represents one-unit change in independent variable.

Comparing equations 2–1 and 2–2, the difference between the odds ratio and the relative risk is obvious. This can be demonstrated by a simple example with hypothetical event probabilities. Let the hypothetical probabilities of obtaining college degree be 0.6 and 0.8 for men (reference group) and women (comparison group), respectively. The relative risk of women compared to men therefore is 0.8/0.6 = 1.33. The odds for women are 0.8/(1–0.8) = 4, and the odds for men are 0.6/(1–0.6) = 1.5. The odds ratio of women compared to men equals (0.8/(1–0.8))/(0.6/(1–0.6)) = 4/1.5 = 2.66. It can be seen that for the hypothetical probabilities, the odds ratio between the two genders is much larger than the gender relative risk.

The interpretations of the odds ratio and the relative risk also are different. Relative risk is easier and more intuitive to understand. Using the previous example, the probability of women receiving a college degree is 1.33 times as large as the probability of men, or 33% higher. We can say that women are 33% more likely to receive a college degree compared to men. It is less easy to interpret the odds ratio. An odds ratio of 2.66 does not mean that women are 2.66 times as likely as men, or 1.66 times more likely than men, to receive a college degree. In other words, the ratio of odds does not translate into the ratio of probability automatically. Therefore, it is important that the odds ratio is not mistaken for the ratio of probabilities (namely relative risk). It also is important that the odds ratio not be interpreted as relative risk in wordings such as "n percent more likely to" or "n times as likely to." Doing so would inflate the difference of probabilities between the comparison and reference groups and, therefore, be misleading.

If the odds ratio should not be interpreted as relative risk, how should it be interpreted? Using the same example, we can say that the odds of women receiving a college degree are 2.66 times as large as the odds for men. But what exactly does this statement reveal? In fact, not much can be inferred directly from this statement except that women are more likely than men to receive a college degree (2.66 > 1). It is, however, not clear *how much* more likely women are to receive a college degree than men because the odds ratio does not correspond to one probability ratio but rather to a series of probability ratios. Let the probability of obtaining a college degree for men and women be 0.43 and 0.67, respectively. It can be calculated that the odds ratio of women to men is still 2.66, but the relative risk is 1.56 instead of 1.33 as calculated before with the other pair of probabilities (0.6 and 0.8). The odds ratio reveals the direction of the relationship but not the magnitude in terms of probabilities. Knowing the value of the odds ratio does not indicate how much more or less likely the event is to occur for two individuals differing by one-unit on the independent variable.

As discussed above, *p* value of significance test was reported by most studies, and less than half of the studies reported the confidence interval of the coefficient estimate or the odds ratio. Both statistics were used to interpret whether independent variable was statistically significant in predicting the event likelihood. Also, the direction of the association could be easily determined by examining the value of the effect size statistic. Table 2 presents the frequency and percentage of studies that explicitly interpreted the significance of independent variables and direction of the association.

It can be seen that the majority of the studies explicitly interpreted the significance of predictors and the direction of the associations. Typically, these two interpretations are combined. For example, Mendez and Mendez (2016, 11) made the following statement in their study on college students' perception of faculty and physical appearance: "As we hypothesized, perceived age statistically significantly predicted attractiveness, knowledge and approachability. First, younger faculty members were perceived to be more attractive than older faculty, confirming Hypothesis 1. This result is statistically significant ($p = 0.00$)". Similarly, Pinxten et al. (2015, 1930) reported the association between students' course-taking background and college major choice as follows: "students with a mathematical/science course-taking background were significantly more inclined to opt for an engineering, economics, (para)medical or science major over a major in literature, history, or arts". These interpretations provide complete information on whether a correlational relationship exists, and whether significant independent variables positively or negatively predict event probability.

There are a few studies where either significance or direction was not sufficiently interpreted. For example, in a study that examined students' satisfaction of a training program, Aine et al. (2014, 197) reported the association between students' evaluation of learning and overall satisfaction as follows: "In the GP group, good evaluation of diagnostic skills learning during GP training was predictive of overall training satisfaction". Although this interpretation is correct, it is not complete and does not explain whether good evaluation of diagnostic skills positively or negatively predicts student satisfaction. Similarly, in a study on college students' sexual activities, Burke, Gabhainn, and Young (2015, 41) reported the results regarding the predictor "student status," stating: "Univariate regression models identified student status to be a significant predictor of having four or more sexual partners in their life". This statement combined with the omission of predictor level specification in the text or in the

Table 2. Frequency and percentage of interpretation of independent variable.

Interpretation	Frequency	Percentage
Significance of independent variable	118	90.8%
Direction of association	110	84.6%
Magnitude of association in terms of probabilities	52	40.0%

Note. N = 130

tables makes it unclear whether being a student positively or negatively predicted certain sexual activities. These incomplete and rather vague interpretations decrease the amount of information made available to the readers; impact the readability of the studies; and make it difficult to understand, assess, and adopt the specific findings. Table 2 shows that about 15% of the reviewed studies failed to provide interpretation of the association direction, and about 9% did not discuss the significance of predictors in text. Considering that predictor significance and direction of the association are the primary results of logistic regression and should be discussed sufficiently in text, these percentages suggest that there is room for improvement in educational research in this regard.

The interpretation of magnitude of association

Once individual predictor significance and the direction of association are determined, the crucial question to be answered is: how strong is the detected relationship? Using the habit formed by interpreting linear regression results, one would want to know how much the event probability changes for a certain amount of change in the predictor. However, unlike linear regression, where coefficient estimate measures the change in the dependent variable for certain change in the independent variable, logistic regression does not yield such a measure. Logistic regression does not model the linear relationship between the predictors and the event probability. As previously discussed, the odds ratio, which is a transformation of the logistic regression coefficient estimate, is not a measure in terms of probability. This does not mean, however, that the magnitude of the predictor cannot be properly interpreted to help us better understand educational phenomena. The following sections provide a detailed review of the included studies to examine if the magnitude of the significant predictors was interpreted, what methods were used, and if the methods were appropriate.

Quantification of association magnitude

Fifty-two studies, or 40% of all included studies, attempted to interpret the magnitude of statistically significant relationships in terms of probabilities (Table 2). This percentage is much lower than those that included interpretation of predictor significance and direction of association. The fact that 60% of the studies didn't interpret the strength of the detected relationships in terms of probabilities may be because of various reasons. Researchers may find it sufficient to reveal the direction of the relationship and unnecessary to quantify the strength of the relationship. It also is plausible that some researchers may be uncertain about how to interpret the magnitude in probabilities, and choose to only interpret the direction to avoid errors. A typical example can be found in a study on the relationship between new degree structure and medical students' career considerations (van den Broek et al. 2010), in which it was concluded that:

> In the third year of medical school, pre-BaMa students were significantly more likely to consider a temporary stop than BaMa students. Apparently, those who cannot receive a bachelor degree think more about the opportunity to interrupt the course than those who can receive one. (1000)

Although this conclusion reveals that the new degree structure is related to lower preference for a temporary stop during the program, it is unknown how large the difference in preference is before and after the introduction of the new degree structure. Not only was the difference in probabilities missing, even the meaning of odds ratio values was not interpreted.

Odds ratio

As discussed previously, the odds ratio is easily available because it is part of the standard output for logistic regression by major statistical software packages. Not surprisingly, it is commonly used as a measure of magnitude of detected relationship (Pruett and Absher 2015; Radey and Cheatham 2013; Swecker, Fifolt, and Searby 2013; Wood 2013). This statistic frequently is interpreted in text similar to the following: "The odds that students with visual impairments received accommodations and other disability-specific services at 2-year colleges were more than 7 times those for students with learning disabilities (OR = 7.1, $p < .001$)" (Newman and Madaus 2015, 213). This interpretation is not incorrect; it explains that the odds of receiving accommodations for students with visual impairments are seven times as large as the odds for students with learning disabilities. But what exactly does that mean? This interpretation still does not eliminate the confusion caused by the concept of odds, and therefore is not easy to comprehend. Explaining the odds ratio using this approach *only* is potentially problematic, because the interpretation could be easily misunderstood as a comparison of event *probabilities* by readers confused by the concepts of odds and probability.

Some studies show such confusion on the researcher's part. Besides its ready availability, odds ratio also appears to be appealing as a measure of relationship magnitude because it measures a ratio between the comparison and the reference group corresponding to a certain amount of change in the predictor. It is rather intuitive to interpret this statistic as a ratio of event probabilities. This is shown explicitly by a study on the relationship between higher education and students' entrepreneurial intentions, where it is concluded that "The odds ratio of 1.573 indicates that senior students have ***a probability*** of stating an entrepreneurial intention 1.5 times higher than the freshmen students" (Ertuna and Gurel 2011, 395). Clearly, odds ratio is incorrectly interpreted as ratio of probabilities. A review of the included studies shows that 36 studies interpreted the value of odds ratio as relative risk (ratio of probabilities). That is 69.2% of the 52 studies that attempted to interpret relationship strength in terms of probabilities (see Table 2, row 3). For example, in a study on the relationship between lecture quiz score and final exam performance, Wambuguh and Yonn-Brown (2013) discussed the findings as follows:

> Students attaining combined quizzes scores of at least 70% are approximately ***9 times*** (OR value of 8.78 in Table 2) ***as likely*** to pass the final examination with the same score or better compared to those who got scores below 70% ($\chi^2 = 160.53$, $p < .001$). (3)

In a study on the relationship between usage of student services and college students' experiences of difficulty and distress, Julal (2013, 419, 421) explained the relationship between experiencing personal difficulty and using student services as follows: "The odds ratio of 34.34 showed that students who were faced with personal difficulty were more likely to use one or more of the available support services…. [They] were ***34 times***

more likely to use one or more support services". Similarly, Baker-Eveleth, O'Neill, and Sisodiya (2014, 66) described the association between students' performance in predictor and subsequent courses as follows: "as students perform worse in the [predictor] course [Business Law] they are nearly ***10 times more likely*** to score a D or F in the module rather than an A – Exp(B) = 9.807".

Similar interpretation of odds ratio is abundant (Beran et al. 2012; Lee 2014; Lombardi et al. 2013; Luna and Fowler 2011; Lyons and Akroyd 2014; Munisamy, Jaafar, and Nagaraj 2014). As discussed previously, the odds ratio tends to be larger than relative risk. Interpreting odds ratio as relative risk could lead to an exaggeration of the predictor's relationship with event probability. Table 3 presents overestimation of relative risks calculated based on the odds ratio reported by Julal's (2013) study and hypothetical event probabilities. Using equations 2–1 and 2–2, it can be demonstrated that relative risk can be expressed in odds ratio and event probability using the following formulae:

$$\text{Relative risk } = \frac{\text{Oddsratio}}{1 + (\text{Oddsratio} - 1) * \text{p}(\text{x})} \qquad 2\text{–}3$$

$$\text{Relative risk} = \text{Odds ratio} - (\text{Odds ratio} - 1) \ * \text{p}(\text{x} + 1) \qquad 2\text{–}4$$

where $p(x)$ represents the event probability for the reference group, and $p(x + 1)$ represents the event probability for the comparison group. Hypothetical probabilities of using student services for students without personal difficulty (reference group) are shown in the second column of Table 3. Using equation 2–1 and the odds ratio reported by Julal (2013) comparing students with and without personal difficulty, hypothetical probabilities for students with difficulty are calculated and shown in the first column of Table 3. Using equation 2–3 (or equation 2–2), relative risks are calculated and shown in the third column of Table 3.

Comparison of the calculated relative risks and the reported odds ratio shows that the latter overestimates the former extensively. If students without personal difficulty rarely use student services as suggested by the hypothetical probability of 0.05, the odds ratio would overestimate relative risk by a factor of 2.67. With the increase of the event occurrence for the comparison group, the overestimation becomes stronger. For example, if 40% of students without difficulty use student services, interpreting the odds ratio

Table 3. Relative risk based on hypothetical probabilities and reported odds ratio.

Hypothetical probability of using student service for students with difficulty	Hypothetical probability of using student service for students without difficulty	Hypothetical relative risk, students with difficulty vs. students without difficulty	Reported odds ratio, students with difficulty vs. students without difficulty	Overestimation of relative risk (odds ratio/relative risk)
0.64	0.05	12.88	34.34	2.67
0.79	0.10	7.92	34.34	4.33
0.86	0.15	5.72	34.34	6.00
0.90	0.20	4.48	34.34	7.67
0.92	0.25	3.68	34.34	9.34
0.94	0.30	3.12	34.34	11.00
0.95	0.35	2.71	34.34	12.67
0.96	0.40	2.40	34.34	14.34

Note. Odds ratio reported by Julal (2013).

as relative risk would exaggerate the relationship magnitude by a factor of 14.34. The exact extent of the exaggeration is unknown because the exact event probabilities are unavailable, but it is obvious that the study's (Julal 2013) conclusion is not valid. The calculated relative risks are still large and indicate strong predictive relationship between personal difficulty and usage of student services, but they are not nearly as dramatic as a factor of 34 as suggested by Julal's (2013) conclusion.

Table 4 lists examples of studies that made similar exaggerating conclusions by interpreting odds ratio as relative risk. Hypothetical probabilities are approximated based on descriptive statistics reported in the studies. For example, the overall completion rate of the Free Application for Federal Student Aid (FAFSA) among single mother students is 87% (Radey and Cheatham 2013). Based on this percentage, when the probability of completing FAFSA among single mother students at public universities (reference group) is set at 0.8, the odds ratio would overestimate relative risk by a factor of 8. Single mother students at for-profit institutions (comparison group) would be estimated to be 22% more likely (or 122% as likely) than their counterparts at public universities to complete FAFSA instead of nearly 10 times more likely to do so as claimed by Radey and Cheatham (2013). Looking at the claimed difference of nearly 10 times,

Table 4. Overestimation of relationship magnitude by interpreting odds ratio as relative risk.

Conclusion	Reported odds ratio	Hypothetical probability, comparison group	Hypothetical probability, reference group	Hypothetical relative risk	Over-estimation
Students attaining combined quizzes scores of at least 70% are approximately 9 times (OR value of 8.78 in Table 2) as likely to pass the final examination with the same score or better compared to those who got scores below 70% (χ2 = 160.53, p < .001). (Wambuguh and Yonn-Brown 2013, p.3)	8.78	0.93	0.6	1.55	5.67
The likelihood of entering public university increases by a factor of 6.781 if a student has one sibling and it is significant at the 1 per cent level. (Yusif, Yussof, and Osman 2013, p. 22)	6.781	0.91	0.6	1.52	4.47
Students in the high HSR [high school risk] group were 6.04 times more likely to engage in heavy episodic drinking (p < .001) and 2.51 times more likely to experience a blackout in college (p < .001) than were students in the low HSR group (see Table 7). Students in the high HSR group were also 2.85 times more likely to engage in heavy episodic drinking in college as compared to the moderate HSR group, p < .05. (Sullivan and Cosden 2015, p. 24)	6.04 2.51 2.85	0.92 0.39 0.92	0.65 0.2 0.8	1.41 1.93 1.15	4.28 1.30 2.48
Those attending for-profit institutions were nearly 10 times more likely to complete FAFSAs than aid-eligible women at public universities. (Radey and Cheatham 2013, p. 270)	9.75	0.98	0.8	1.22	8.00

Note. Hypothetical probabilities are approximated based on descriptive statistics reported in respective studies.

readers would conclude that students at for-profit institutions are dramatically more inclined to apply for financial aid, while the actual difference (here calculated based on approximated probabilities) is much less extreme. Similarly, college students with a history of high-risk factors are estimated to be about 41% more likely to engage in heavy drinking and about 93% more likely to experience blackouts compared to students with a history of low-risk factors, not 6.04 times and 2.51 times more likely to do so, respectively; and high-risk factor college students are estimated to be about 15% more likely to drink heavily compared to moderate-risk factor students, not 2.85 times more likely to do so as suggested by Sullivan and Cosden's (2015) conclusion. It can be seen that interpreting odds ratio as relative risk has led to inaccurate understanding of educational phenomena, and the extent of the inaccuracy is too large to be ignored.

Marginal effects and predicted probabilities

Because the odds ratio does not reveal relationship strength in terms of probability, alternative measures are needed to quantitatively interpret logistic regression results. Agresti (2013) acknowledged the fact that it may be difficult to understand odds or odds ratio effects, and suggested the use of instantaneous rate of change in the probability or estimated probabilities at selected values (such as sample means or quartiles) of the independent variables to address such difficulty. The current review shows that marginal effects and predicted probabilities have been used to provide probability-based interpretations of logistic regression results. Marginal effects are partial derivative or instantaneous rates of change for continuous independent variables and discrete changes for categorical independent variables. Marginal effects measure the change in predicted probabilities corresponding to a certain change in the independent variable of interest, holding all other independent variables constant. The interpretation of marginal effects for categorical and continuous variables is different. For categorical variables, marginal effects measure the change in predicted probability as the independent variable of interest changes from 0 to 1, while holding all other independent variables constant. For continuous variables, marginal effects provide good approximation to the amount of change in predicted probability for a one-unit change in the independent variable, while holding all other independent variables constant. The difference lies in that marginal effects for continuous independent variables are approximation because the relationship between the independent variable and predicted probability is not linear (Williams 2016). Predicted probabilities are probabilities calculated using logistic regression coefficient estimates and selected values of independent variables.

Both marginal effects and predicted probabilities are dependent on the values of independent variables, which are selected by researchers based on substantive considerations or following common practices. For example, to avoid the impact of outliers, the upper and lower quartiles could be used instead of the smallest and largest values of the independent variable when calculating estimated probabilities (Agresti 2013). It is important that the selection of independent variable values is described and if possible, justified. It also is important that the implications of the selected values of independent variables be reflected in the interpretation of these two measures, as demonstrated in the examples provided by Agresti (2013). Specifically, marginal effects should not be interpreted as constant effects and should always be interpreted in relation to the selected values of independent variables that are held constant. The same applies to the calculated values of predicted probabilities.

Table 1 shows that seven studies claimed to report marginal effects to interpret the magnitude of relationship strength. Four of these studies used this statistic correctly. Marginal effects at the means were reported by three studies (Fernández-Macías et al. 2013; Jaeger and Eagan 2011; Pursel et al. 2016), where the independent variables other than the one of interest were held constant at their means. Average marginal effect was reported by one study (Bielby et al. 2014), where the marginal effect of the independent variable of interest is calculated for each case holding other independent variables at their respective values and the average of all individual marginal effects is calculated.

Two of the seven studies did not report complete information in relation to marginal effects. Ko and Jun (2015) used a figure to report marginal effects of the independent variable "chance to benefit society" on college students' preference for public sector jobs. The values of the calculated marginal effects were not reported in the figure or in text, and the specification of independent variables' values was not reported. As a result, the readers still were not provided with quantitative measures of the relationship strength. It also is difficult to adopt the finding because the values of the other independent variables are unknown to the readers. Melguizo, Torres, and Jaime's (2011) study also suffered from this issue by omitting the specification of independent variables' values. One of the seven studies used the term marginal effect incorrectly. Santelices et al. (2016) interpreted coefficient estimates as predicted probabilities and incorrectly calculated the marginal effect.

Table 1 also shows that seven studies reported predicted probabilities to quantify the relationship strength. Similar to Ko and Jun's study (2015), four of the seven studies did not report the exact values of predicted probabilities, but instead used figures to visually show differences in predicted probabilities (Flynn 2014; Jowett et al. 2014; King 2015; Pleitz et al. 2015). One study omitted the calculation method of predicted probabilities and specification of independent variables' value (Pleitz et al. 2015).

It can be seen that the reporting of marginal effects and predicted probabilities in the quantitative interpretation of relationship magnitude suffers not only from low quantity, but also from quality issues. The omission of specification of independent variables' values is a common issue, leading to interpretation of predictive relationship magnitude without clearly stated conditions. Another common issue is the omission of exact values of marginal effects or predicted probabilities, providing the readers with only vague information about the relationship strength. Even for the very few studies that reported the selected values of independent variables, the interpretation of the marginal effects tends to lack emphasis on the conditional nature of this statistic. For example, Jaeger and Eagan (2011) interpreted marginal effects at the means (referred to as ME) as follows:

> Black students ($ME = 0.04$, $p < .001$) were significantly more likely to be retained than their White counterparts. In-state students had a significantly higher probability of retention compared to students who resided outside the state of the institution ($ME = 0.08$, $p < .001$). (522)

The interpretation does not make explicit that the marginal effects, or the changes in predicted probabilities, hold only for otherwise average individuals. Marginal effects and predicted probabilities are dependent on the selected values of independent variables. For individuals with values much higher or lower than the average on independent variables, the marginal effect of 0.04 for being Black and the marginal effect of 0.08 for being an in-state student might not hold, and the conclusion might be affected. Emphasising the conditional nature of marginal effects and predicted probabilities could make the interpretation and conclusion more accurate and enable readers to properly adopt the findings.

Discussion

The review of 130 empirical educational studies applying logistic regression reveals three major issues that warrant attention: (a) a common lack of quantitative interpretation of the magnitude of detected predictive relationship (60% of the studies did not attempt to provide such in terms of probabilities); (b) common practice of interpreting odds ratio as relative risk (69.2% of the studies that attempted to interpret strength of predictive relationship in terms of probabilities explained odds ratio value as difference in probability); and (c) omission of specification of independent variables' values in the calculation and interpretation of marginal effects and predicted probabilities.

Lack of quantitative interpretation of relationship magnitude in terms of probabilities

The current review indicates that most educational studies using logistic regression report significance and sign of predictors, but do not quantitatively interpret the predictive relationship strength in terms of probabilities. This issue can be attributed in part to the confusion caused by the concept of the odds ratio, which is the standard output by major statistical software packages used to estimate logistic regression models. In the reviewed studies, the odds ratio is the most commonly reported effect size, and the interpretation of its meaning falls into three categories: no interpretation, interpreted as change in odds, and interpreted as relative risk. It is not incorrect not to interpret odds ratio or to interpret it as the change in odds corresponding to a certain change in the predictor, but the amount of information revealed by these options is low. For some studies, the goal is to detect significant predictor(s) and the direction of the relationship. The magnitude of the association may not be of interest to the researcher. Although in such case it may not be necessary to report quantitative measures such as marginal effects, doing so would better utilise the readily available results to reveal deeper understanding of educational phenomena. Reporting these statistics also could prevent the overestimation of the relationship strength. It is suggested that researchers go beyond the value of the odds ratio and report marginal effects or predicted probabilities. Technically, this could be done easily with the simple commands used by major statistical software packages to calculate such statistics. For example, marginal effects and predicted probabilities can be easily computed using the *margins* command in STATA.

Interpreting odds ratio as relative risk

Interpreting odds ratio as relative risk causes more serious concern than the two previous options because doing so leads to an overestimation of the predictive relationship as demonstrated in Tables 3 and 4. Almost 70% of the studies that attempted to interpret the results in terms of probabilities did so by interpreting the odds ratio as a ratio of probabilities; this indicates a noteworthy weakness on educational researchers' conceptual understanding of logistic regression. Exaggerating relationship magnitude not only undermines the validity and rigour of research studies, but it also could mislead educators, education administrators, and policy-makers. For example, by reading the finding of Radey and Cheatham (2013, 270) that aid-eligible women at for-profit institutions are almost "10 times more likely" to complete an application for financial aid than those at public institutions, a policy maker might draw the conclusion that new policy and/or funding is needed to address this large gap and to urge public institutions to make more efforts to assist students to seek financial aid. In fact, this gap is overestimated extensively, and the actual gap could be in the range of about 22% (Table 4). Empirical studies inform practice, research, and policy making of education. The threat to well-informed decision making posed by overestimating predictive relationship magnitude should not be overlooked. The relatively common presence of this issue in educational research reviewed here reflects a conceptual weakness of both empirical researchers and peer reviewers and warrants attention. Given the similarity of model specification between linear and logistic regression, it is not surprising that researchers tend to interpret logistic regression results in the same way they interpret linear regression results. Educational researchers should carefully distinguish between the two types of regression models, update conceptual understanding of odds ratio and its limitations, and use more caution when interpreting predictive relationship strength detected by logistic regression models. Also, peer reviewers should pay more attention to the statistics used as effect size and how they are interpreted.

Omission of specification of independent variables' values

Marginal effects and predicted probabilities both are dependent on the values of independent variables other than the one of interest. This means that selecting different sets of values for the other independent variables in the model would yield different marginal effects and predicted probabilities. As a result, the calculated values of these statistics are conditional. This review suggests that it is relatively common that the selection of independent variables' values is not reported and/or not incorporated in the interpretation of the calculated statistics. Ignoring the conditional nature of the statistics could make it difficult for readers to understand the educational phenomena of interest, or they even could mistake the conditional values as constant effects. It is suggested that educational researchers be more cautious when reporting marginal effects and predicted probabilities as logistic regression results, and to always discuss their conditions. Table 5 summarises the approaches of interpreting magnitude of predictive relationship revealed by this review.

Recommendations

In summary, this review indicates that there is much room for improvement in the interpretation of logistic regression results in educational research. Researchers and peer reviewers could consider the following recommendations when using logistic regression models.

Table 5. Approaches of interpreting magnitude of relationship revealed by the current review.

Approach	Revealed issue of approach	Suggestion
No quantitative interpretation of relationship magnitude	Does not fully utilise logistic regression results to understand educational phenomena	Report and interpret quantitative measurements of predictive relationship
Interpretation of odds ratio as change in odds corresponding to change in predictor	Difficult to comprehend; causes confusion; might be understood as ratio of probabilities; does not measure prediction in terms of probabilities	Use statistics in terms of probabilities as supplement
Interpretation of odds ratio as ratio of probabilities	Exaggerates predictive relationship; leads to inaccurate conclusion; might mislead readers	Compute statistics in terms of probabilities, such as marginal effects and predicted probabilities
Calculation of marginal effects or predicted probabilities	Omission of the selection of independent variables' values in the calculation and interpretation of these statistics	Report selected values of other independent variables in the model and emphasise the conditional nature of calculated statistics

- Fully utilise the information available from logistic regression results

First, researchers should consider interpreting the magnitude of detected association between predictors and event probabilities to fully utilise the information available from logistic regression results. It is suggested that researchers calculate marginal effects and/or predicted probabilities using methods discussed above in the section Marginal Effects and Predicted Probabilities. Marginal effects and predicted probabilities could be easily computed by major statistical software packages. These statistics provide a good approximation of the change in event probability corresponding to a certain change in individual predictors, and they provide much flexibility for researchers to compare probabilities corresponding to predictor values of substantive interest. Currently, many articles only report and interpret odds ratio and discuss the direction of the association. Doing so does not reveal changes in event probability corresponding to certain change in predictors, and does not shed light on the relative importance of the predictors. Even when relationship magnitude is not of primary interest to the researchers, the readers, especially educational policy makers and practitioners, oftentimes need such information in order to prioritise and allocate scarce resources. Computing and reporting statistics in terms of probability could provide readers with a deeper understanding of the educational phenomena, and be more helpful in informing research, practice, and policy making.

- Enhance conceptual understanding of logistic regression, especially of the definition of the odds ratio

Second, conceptual understanding of logistic regression should be enhanced especially to clarify the definition of the odds ratio. One common error to avoid is that the odds ratio should not be interpreted as relative risk or a ratio of probabilities. Although it is very tempting to do so, treating the odds ratio as relative risk leads to exaggeration of prediction magnitude and misleading conclusions about educational phenomena. Instead, researchers could compute statistics in terms of probability to quantitatively measure the magnitude of the predictive relationship. Researchers should also explicitly remind readers not to confuse odds ratio with relative risk.

- Avoid confusing the interpretation of logistic regression with that of linear regression

Third, more attention should be paid to ensure that the interpretation of logistic regression results is not confused with that of linear regression models. Specifically, calculating marginal effects and/or predicted probabilities would require careful selection of values of independent variables, such specification should always be reported, and the conditional nature of these statistics should be emphasised in their interpretation and in the overall conclusions.

Technical complexity may have been a factor that has kept researchers from moving beyond odds ratio and towards calculated probabilities. However, advanced statistical software packages have made such calculating relatively simple. The main challenge faced by researchers seems to lie in the conceptual understanding of the method of logistic regression. Given its popularity in educational research, it is imperative that researchers revisit the key concepts of this method. Some might argue that the extra burden of calculating and reporting probability-based statistics is not worthwhile because oftentimes knowing the significance and direction of the association is sufficient, and even if not, that odds ratio approximates relative risk. This review, however, suggests that odds ratio could be very misleading as a substitute for relative risk. This review serves as a starting point for educational researchers interested in using logistic regression to revisit previous studies, detect any misleading conclusions drawn, and more importantly, improve accuracy in their own research. It would be helpful for future research to explore whether the issues identified in this review, such as effect size exaggeration, have had any noticeable impact on educational policy making or practices. It would also be interesting to compare the application of logistic regression in educational research and other research fields.

Conclusion

The results of this review reveal several issues in the application of logistic regression models in current educational research publications that warrant attention among researchers. The primary concern is the weakness in conceptual understanding of the method, its difference from linear regression model, and the meaning and limitation of the odds ratio. Although logistic regression is a powerful tool in understanding correlational relationships, this review indicates that some of the results being reported by educational research based on logistic regression results might not be accurate and should be interpreted with caution by readers. It is strongly suggested that educational researchers, including empirical researchers and peer reviewers, properly address the issues discussed in this review to enhance the quality of logistic regression studies. While this review has focused on the reporting and interpretation of logistic regression results, it should be noticed that successful use of logistic regression also relies on aspects such as model selection, suitability of model for data structure, model specification, model testing, and measurement of model fit. Due to the limitation of the scope of this review, these aspects have not been examined or discussed. Future review studies on these topics could further shed light on the adoption of logistic regression in educational research.

Disclosure statement

No potential conflict of interest was reported by the author.

References

* References marked with an asterisk indicate studies included in the review.

Agresti, A. 2013. *Categorical Data Analysis*. Hoboken: John Wiley & Sons.

*Aine, T., M. Sumanen, T. Heikkila, H. Hyppola, H. Halila, J. Vanska, S. Kujala, I. O. Virjo, and K. Mattila. 2014. "Factors Associated with General Practice Specialty Training Satisfaction - Results from the Finnish Physician Study." *Education for Primary Care* 25: 194–201.

Allison, P. D. 1999. *Logistic Regression Using SAS: Theory and Application*. Cary, NC: SAS Institute.

*Baker-Eveleth, L. J., M. O'Neill, and S. R. Sisodiya. 2014. "The Role of Predictor Courses and Teams on Individual Student Success." *Journal of Education for Business* 89 (2): 59–70. doi:10.1080/08832323.2012.757541.

*Beran, T. N., C. Rinaldi, D. S. Bickham, and M. Rich. 2012. "Evidence for the Need to Support Adolescents Dealing with Harassment and Cyber-Harassment: Prevalence, Progression, and Impact." *School Psychology International* 33 (5): 562–576. doi:10.1177/0143034312446976.

*Bielby, R., J. R. Posselt, O. Jaquette, and M. N. Bastedo. 2014. "Why are Women Underrepresented in Elite Colleges and Universities? A Non-Linear Decomposition Analysis." *Research in Higher Education* 55: 735–760. doi:10.1007/s11162-014-9334-y.

*Burke, L., S. N. Gabhainn, and H. Young. 2015. "Student Sex: More or Less Risky than Other Young Adults?" *Sex Education* 15 (1): 31–47. doi:10.1080/14681811.2014.947362.

*Campbell, C. M., and J. Mislevy. 2013. "Student Perceptions Matter: Early Signs of Undergraduate Student Retention/Attrition." *Journal of College Student Retention: Research, Theory & Practice* 14 (4): 467–493. doi:10.2190/CS.14.4.c.

*Case, K. F. 2011. "A Gendered Perspective on Student Involvement in Collegiate Clubs and Organizations in Christian Higher Education." *Christian Higher Education* 10: 166–195. doi:10.1080/15363759.2011.576208.

*Chiang, H. M., Y. K. Cheung, L. Hickson, R. Xiang, and L. Y. Tsai. 2012. "Predictive Factors of Participation in Postsecondary Education for High School Leavers with Autism." *Journal of Autism and Developmental Disorders* 42 (5): 685–696. doi:10.1007/s10803-011-1297-7.

*d'Aguiar, S., and N. Harrison. 2016. "Returning from Earning: UK Graduates Returning to Postgraduate Study, with Particular Respect to STEM Subjects, Gender and Ethnicity." *Journal of Education and Work* 29 (5): 584–613. doi:10.1080/13639080.2014.1001332.

*Ertuna, Z. I., and E. Gurel. 2011. "The Moderating Role of Higher Education on Entrepreneurship." *Education + Training* 53 (5): 387–402. doi:10.1108/00400911111147703.

*Evans, D. B. 2013. "Examining the Influence of Noncognitive Variables on the Intention of Minority Baccalaureate Nursing Students to Complete Their Program of Study." *Journal of Professional Nursing* 29 (3): 148–154. doi:10.1016/j.profnurs.2012.04.016.

*Ferguson, E., D. James, J. Yates, and C. Lawrence. 2012. "Predicting Who Applies to Study Medicine: Implication for Diversity in UK Medical Schools." *Medical Teacher* 34 (5): 382–391. doi:10.3109/0142159X.2012.652237.

*Fernández-Macías, E., J. Antón, F. Braña, and R. M. De Bustillo. 2013. "Early School-Leaving in Spain: Evolution, Intensity and Determinants." *European Journal of Education* 48 (1): 150–164. doi:10.1111/ejed.12000.

*Flynn, D. 2014. "Baccalaureate Attainment of College Students at 4-Year Institutions as a Function of Student Engagement Behaviors: Social and Academic Student Engagement Behaviors Matter." *Research in Higher Education* 55 (5): 467–493. doi:10.1007/s11162-013-9321-8.

*Fong, K. E., T. Melguizo, and G. Prather. 2015. "Increasing Success Rates in Developmental Math: The Complementary Role of Individual and Institutional Characteristics." *Research in Higher Education* 56: 719–749. doi:10.1007/s11162-015-9368-9.

*Jaeger, A. J., and M. K. Eagan. 2011. "Examining Retention and Contingent Faculty Use in a State System of Public Higher Education." *Educational Policy* 25 (3): 507–537. doi:10.1177/0895904810361723.

*Julal, F. S. 2013. "Use of Student Support Services among University Students: Associations with Problem-Focused Coping, Experience of Personal Difficulty and Psychological Distress." *British Journal of Guidance & Counselling* 41 (4): 414–425. doi:10.1080/03069885.2012.741680.

*Jones, M. P., J. A. Bushnell, and J. S. Humphreys. 2014. "Are Rural Placements Positively Associated with Rural Intentions in Medical Graduates?" *Medical Education* 48 (4): 405–416. doi:10.1111/medu.12399.

*Jowett, T., J. Harraway, B. Lovelock, S. Skeaff, L. Slooten, M. Strack, and K. Shephard. 2014. "Multinomial-Regression Modeling of the Environmental Attitudes of Higher Education Students Based on the Revised New Ecological Paradigm Scale." *The Journal of Environmental Education* 45 (1): 1–15. doi:10.1080/00958964.2013.783777.

*King, B. 2015. "Changing College Majors: Does It Happen More in STEM and Do Grades Matter?" *Journal of College Science Teaching* 44 (3): 44–51. doi:10.2505/4/jcst15_044_03_44.

Kleinbaum, D. G., L. L. Kupper, K. E. Muller, and A. Nizam. 1998. *Applied Regression Analysis and Other Multivariable Methods*. 3rd ed. Pacific Grove: Duxbury Press.

*Ko, K., and K.-N. Jun. 2015. "A Comparative Analysis of Job Motivation and Career Preference of Asian Undergraduate Students." *Public Personnel Management* 44 (2): 192–213. doi:10.1177/0091026014559430.

*Lee, A. 2014. "Students with Disabilities Choosing Science Technology Engineering and Math (STEM) Majors in Postsecondary Institutions." *Journal of Postsecondary Education and Disability* 27 (3): 261–272.

*Lombardi, A., B. Doren, J. M. Gau, and L. E. Lindstrom. 2013. "The Influence of Instructional Settings in Reading and Math on Postsecondary Participation." *Journal of Disability Policy Studies* 24 (3): 170–180. doi:10.1177/1044207312468766.

*Luna, G., and M. Fowler. 2011. "Evaluation of Achieving A College Education Plus: A Credit-Based Transition Program." *Community College Journal of Research and Practice* 35 (9): 673–688. doi:10.1080/10668920903527050.

*Lyons, F. W., and D. Akroyd. 2014. "The Impact of Human Capital and Selected Job Rewards on Community College Faculty Job Satisfaction." *Community College Journal of Research and Practice* 38 (2–3): 194–207. doi:10.1080/10668926.2014.851965.

McCulloch, C. E., and S. R. Searle. 2001. *Generalized, Linear, and Mixed Models*. New York: John Wiley & Sons.

*Melguizo, T., F. S. Torres, and H. Jaime. 2011. "The Association between Financial Aid Availability and the College Dropout Rates in Colombia." *Higher Education* 62 (2): 231–247. doi:10.1007/s10734-010-9385-8.

Menard, S. 2010. *Logistic Regression: From Introduction to Advanced Concepts and Applications*. Thousand Oaks, CA: SAGE.

*Mendez, J. M., and J. P. Mendez. 2016. "Student Inferences Based on Facial Appearance." *Higher Education* 71 (1): 1–19. doi:10.1007/s10734-015-9885-7.

*Munisamy, S., N. I. M. Jaafar, and S. Nagaraj. 2014. "Does Reputation Matter? Case Study of Undergraduate Choice at a Premier University." *The Asia-Pacific Education Researcher* 23 (3): 451–462. doi:10.1007/s40299-013-0120-y.

*Newman, L. A., and J. W. Madaus. 2015. "An Analysis of Factors Related to Receipt of Accommodations and Services by Postsecondary Students with Disabilities." *Remedial and Special Education* 36 (4): 208–219. doi:10.1177/0741932515572912.

*O'Neill, L., J. Hartvigsen, B. Wallstedt, L. Korsholm, and B. Eika. 2011. "Medical School Dropout - Testing at Admission versus Selection by Highest Grades as Predictors." *Medical Education* 45 (11): 1111–1120. doi:10.1111/j.1365-2923.2011.04057.x.

Pedhazur, E. J. 1997. *Multiple Regression in Behavioral Research: Explanation and Prediction*. 3rd ed. Fort Worth, TX: Harcourt Brace College Publishers.

*Pinxten, M., B. De Fraine, W. Van Den Noortgate, J. Van Damme, T. Boonen, and G. Vanlaar. 2015. "'I Choose so I Am': A Logistic Analysis of Major Selection in University and Successful

Completion of the First Year." *Studies in Higher Education* 40 (10): 1919–1946. doi:10.1080/03075079.2014.914904.

*Pleitz, J. D., A. E. MacDougall, R. A. Terry, M. R. Buckley, and N. J. Campbell. 2015. "Great Expectations: Examining the Discrepancy between Expectations and Experiences on College Student Retention." *Journal of College Student Retention: Research, Theory & Practice* 17 (1): 88–104. doi:10.1177/1521025115571252.

*Pruett, P. S., and B. Absher. 2015. "Factors Influencing Retention of Developmental Education Students in Community Colleges." *Delta Kappa Gamma Bulletin* 81 (4): 32–40.

*Pursel, B. K., L. Zhang, K. W. Jablokow, G. W. Choi, and D. Velegol. 2016. "Understanding MOOC Students: Motivations and Behaviours Indicative of MOOC Completion." *Journal of Computer Assisted Learning* 32: 202–217. doi:10.1111/jcal.12131.

*Radey, M., and L. P. Cheatham. 2013. "Do Single Mothers Take Their Share?: FAFSA Completion Among Aid-Eligible Female Students." *Journal of Diversity in Higher Education* 6 (4): 261–275. doi:10.1037/a0035089.

Rencher, A. C. 2000. *Linear Models in Statistics*. New York: John Wiley.

*Santelices, M. V., X. Catalán, D. Kruger, and C. Horn. 2016. "Determinants of Persistence and the Role of Financial Aid: Lessons from Chile." *Higher Education* 71: 323–342. doi:10.1007/s10734-015-9906-6.

*Stegers-Jager, K. M., E. W. Steyerberg, J. Cohen-Schotanus, and A. P. N. Themmen. 2012. "Ethnic Disparities in Undergraduate Pre-Clinical and Clinical Performance." *Medical Education* 46 (6): 575–585. doi:10.1111/j.1365-2923.2012.04265.x.

*Sullivan, K., and M. Cosden. 2015. "High School Risk Factors Associated with Alcohol Trajectories and College Alcohol Use." *Journal of Child & Adolescent Substance Abuse* 24: 19–27. doi:10.1080/1067828X.2012.754390.

*Swecker, H. K., M. Fifolt, and L. Searby. 2013. "Academic Advising and First-Generation College Students: A Quantitative Study on Student Retention." *NACADA Journal* 33 (1): 46–53. doi:10.12930/NACADA-13-192.

Tabachnick, B. G., and L. S. Fidell. 2001. *Using Multivariate Statistics*. 4th ed. Boston: Allyn and Bacon.

*Taliaferro, L. A., and J. J. Muehlenkamp. 2015. "Risk Factors Associated with Self-Injurious Behavior among a National Sample of Undergraduate College Students." *Journal of American College Health* 63 (1): 40–48. doi:10.1080/07448481.2014.953166.

*Titzmann, P. F., A. Brenick, and R. K. Silbereisen. 2015. "Friendships Fighting Prejudice: A Longitudinal Perspective on Adolescents' Cross-Group Friendships with Immigrants." *Journal of Youth and Adolescence* 44 (6): 1318–1331. doi:10.1007/s10964-015-0256-6.

*van den Broek, S., B. Muller, N. Dekker, A. Bootsma, and O. T. Cate. 2010. "Effect of the New Bologna Bachelor Degree on Career Considerations of Medical Students in One Medical School." *Medical Teacher* 32 (12): 997–1001. doi:10.3109/0142159X.2010.498487.

*Wambuguh, O., and T. Yonn-Brown. 2013. "Regular Lecture Quizzes Scores as Predictors of Final Examination Performance: A Test of Hypothesis Using Logistic Regression Analysis." *International Journal for the Scholarship of Teaching and Learning* 7 (1): 1–10. doi:10.20429/ijsotl.2013.070107.

Williams, R. 2016. "*Marginal Effects for Continuous Variables*." https://www3.nd.edu/~rwilliam/stats3/Margins02.pdf

*Wood, J. L. 2013. "The Same … But Different: Examining Background Characteristics among Black Males in Public Two-Year Colleges." *The Journal of Negro Education* 82 (1): 47–61. doi:10.7709/jnegroeducation.82.1.0047.

*Yusif, H., I. Yussof, and Z. Osman. 2013. "Public University Entry in Ghana: Is It Equitable?" *International Review of Education* 59 (1): 7–27. doi:10.1007/s11159-013-9331-y.

Appendix A. List of reviewed studies not cited in the text

Abdulghani, H. M., G. Al-Shaikh, A. K. Alhujayri, N. S. Alohaideb, H. A. Alsaeed, I. S. Alshohayeb, M. M. Alyahya, A. I. Alhaqwi, and S. A. Shaik. 2013. "What Determines the Selection of Undergraduate Medical Students to the Specialty of Their Future Careers?" *Medical Teacher* 35: S25–S30. doi:10.3109/0142159x.2013.765548

Aikins, R. D., A. Golub, and A. S. Bennett. 2015. "Readjustment of Urban Veterans: A Mental Health and Substance Use Profile of Iraq and Afghanistan Veterans in Higher Education." *Journal of American College Health* 63 (7): 482–494. doi:10.1080/07448481.2015.1068173

Andersen, L., and T. J. Ward. 2014. "Expectancy-Value Models for the STEM Persistence Plans of Ninth-Grade, High-Ability Students: A Comparison Between Black, Hispanic, and White Students." *Science Education* 98 (2): 216–242. doi:10.1002/sce.21092

Angelin, M., B. Evengård, and H. Palmgren. 2015. "Illness and Risk Behaviour in Health Care Students Studying Abroad." *Medical Education* 49 (7): 684–691. doi:10.1111/medu.12753

Barrett, K. L., W. G. Jennings, and M. J. Lynch. 2012. "The Relation Between Youth Fear and Avoidance of Crime in School and Academic Experiences." *Journal of School Violence*, 11 (1): 1–20. doi:10.1080/15,388,220.2011.630309

Barron, J. S., E. Bragg, D. Cayea, S. C. Durso, and N. S. Fedarko. 2015. "The Short-Term and Long-Term Impact of a Brief Aging Research Training Program for Medical Students." *Gerontology & Geriatrics Education* 36 (1): 96–106. doi:10.1080/02701960.2014.942036

Becerra, D. (2012). "Perceptions of Educational Barriers Affecting the Academic Achievement of Latino K-12 Students." *Children and Schools* 34 (3), 167–177. doi:10.1093/cs/cds001

Bingham, C. R., A. I. Barretto, M. A. Walton, C. M. Bryatn, J. T. Shope, and T. E. Raghunathan. 2011. "Efficacy of a Web-Based, Tailored, Alcohol Prevention/Intervention Program for College Students: 3-month Follow-Up." *Journal of Drug Education* 41 (4): 405–430. doi:10.2190/DE.41.4.e

Blackford, K., and J. Khojasteh. 2013. "Closing the Achievement Gap: Identifying Strand Score Differences." *American Journal of Educational Studies* 6 (2): 5–15.

Boek, S., S. Bianco-Simeral, K. Chan, and K. Goto. 2012. "Gender and Race are Significant Determinants of Students' Food Choices on a College Campus." *Journal of Nutrition Education and Behavior* 44 (4): 372–378. doi:10.1016/j.jneb.2011.12.007

Bouck, E. C., and G. S. Joshi. 2015. "Does Curriculum Matter for Secondary Students with Autism Spectrum Disorders: Analyzing the NLTS2." *Journal of Autism and Developmental Disorders* 45 (5): 1204–1212. doi: 10.1007/s10803-014–2281-9

Champion, J., F. Parker, B. Mendoza-Spencer, and A. Wheeler. 2011. "College Algebra Students' Attitudes Toward Mathematics in Their Careers." *International Journal of Science and Mathematics Education* 9 (5): 1093–1110. doi:10.1007/s10763-010–9246-z

Chandauka, R. E., J. M. Russell, J. Sandars, and P. Vivekananda-Schmidt. 2015. "Differing Perceptions Among Ethnic Minority and Caucasian Medical Students Which May Affect Their Relative Academic Performance." *Education for Primary Care* 26 (1): 11–15.

Cogan, M. F. 2011. "Predicting Success of Academically Dismissed Undergraduate Students Using Quality Point Status." *Journal of College Student Retention: Research, Theory and Practice* 12 (4): 387–406. doi: 10.2190/CS.12.4.a

De Backer, L., H. Van Keer, and M. Valcke. 2015a. "Socially Shared Metacognitive Regulation During Reciprocal Peer Tutoring: Identifying its Relationship with Students' Content Processing and Transactive Discussions." *Instructional Science* 43 (3): 323–344. doi:10.1007/s11251-014–9335-4

De Backer, L., H. Van Keer, and M. Valcke. 2015b. "Exploring Evolutions in Reciprocal Peer Tutoring Groups' Socially Shared Metacognitive Regulation and Identifying its Metacognitive Correlates." *Learning and Instruction 38*: 63–78. doi:0.1016/j.learninstruc.2015.04.001

Eckles, J. E., and E. G. Stradley. 2012. "A Social Network Analysis of Student Retention Using Archival Data." *Social Psychology of Education* 15 (2): 165–180. doi:10.1007/s11218-011–9173-z

England-Siegerdt, C. 2010. "Do Loans Really Expand Opportunities for Community College Students?" *Community College Journal of Research and Practice* 35 (1–2): 88–98. doi:10.1080/10,668,926.2011.525180

Epping, A. S., M. P. Myrvik, R. F. Newby, J. A. Panepinto, A. M. Brandow, and J. P. Scott. 2013. “Academic Attainment Findings in Children with Sickle Cell Disease.” *Journal of School Health* 83 (8): 548–553.

Flannery, K. B., J. L. Frank, and M. M. Kato. 2012. “School Disciplinary Responses to Truancy: Current Practice and Future Directions.” *Journal of School Violence* 11 (2): 118–137. doi:10.1080/15,388,220.2011.653433

Fox, R. S., E. L. Merz, M. T. Solorzano, and S. C. Roesch. 2013. “Further Examining Berry’s Model: The Applicability of Latent Profile Analysis to Acculturation.” *Measurement and Evaluation in Counseling and Development* 46 (4): 270–288. doi:10.1177/0748175613497036

Furlong, M., and M. Quirk. 2011. “The Relative Effects of Chronological Age on Hispanic Students’ School Readiness and Grade 2 Academic Achievement.” *Contemporary School Psychology* 15 (1): 81–92.

Gil-Flores, J., T. M. Padilla-Carmona, and M. Suárez-Ortega. 2011. “Influence of Gender, Educational Attainment and Family Environment on the Educational Aspirations of Secondary School Students.” *Educational Review* 63 (3): 345–363. doi:10.1080/00131911.2011.571763

Gonzalez, L. M. 2012. “College-Level Choice of Latino High School Students: A Social-Cognitive Approach.” *Journal of Multicultural Counseling and Development* 40 (3): 144–155. doi:10.1002/j.2161–1912.2012.00014.x

Greenberg, J. P. 2013. “Determinants of After-School Programming for School-Age Immigrant Children.” *Children and Schools* 35 (2): 101–111. doi: 10.1093/cs/cdt002

Greulich, L., S. Al Otaiba, C. Schatschneider, J. Wanzek, M. Ortiz, and R. Wagner. 2014. “Understanding Inadequate Response to First Grade Multi-Tier Intervention: Nomothetic and Ideographic Perspectives.” *Learning Disability Quarterly: Journal of the Division for Children with Learning Disabilities* 37 (4): 204–217. doi: 10.1177/0731948714526999

Haas, A. L., S. K. Smith, and K. Kagan. 2013. “Getting ‘Game’: Pregaming Changes During the First Weeks of College.” *Journal of American College Health* 61 (2): 95–105. doi:10.1080/07448481.2012.753892

Harrell, I. L., and B. L. Bower. 2011. “Student Characteristics That Predict Persistence in Community College Online Courses.” *American Journal of Distance Education* 25 (3): 178–191. doi: 10.1080/08923647.2011.590107

Hawkins, A., C. R. Graham, R. R. Sudweeks, and M. K. Barbour. 2013. “Academic Performance, Course Completion Rates, and Student Perception of the Quality and Frequency of Interaction in a Virtual High School.” *Distance Education* 34 (1): 64–83. doi:10.1080/01587919.2013.770430

Hayes, J. B., R. A. Price, and R. P. York. 2013. “A Simple Model for Estimating Enrollment Yield From a List of Freshman Prospects.” *Academy of Educational Leadership Journal* 17 (2): 61–68.

Hickman, G. P., and D. Wright. 2011. “Academic and School Behavioral Variables as Predictors of High School Graduation Among at-Risk Adolescents Enrolled in a Youth-Based Mentoring Program.” *The Journal of At-Risk Issues* 16 (1): 25–33.

Hillman, N. W. 2013. “Cohort Default Rates: Predicting the Probability of Federal Sanctions.” *Educational Policy* 29 (4): 559–582. doi: 10.1177/0895904813510772

Honney, K., M. Buszewicz, W. Coppola, and M. Griffin. 2010. “Comparison of Levels of Depression in Medical and Non-Medical Students.” *Clinical Teacher* 7 (3): 180–184. doi:10.1111/j.1743-498X.2010.00384.x

Houser, L. C.-S., and S. An. 2015. “Factors Affecting Minority Students’ College Readiness in Mathematics.” *Urban Education* 50 (8): 938–960. doi: 10.1177/0042085914536998

Hu, S., A. C. McCormick, and R. M. Gonyea. 2012. “Examining the Relationship Between Student Learning and Persistence.” *Innovative Higher Education* 37 (5): 387–395. doi:10.1007/s10755-011–9209-5

Jamali, A., S. Tofangchiha, R. Jamali, S. Nedjat, D. Jan, A. Narimani, and A. Montazeri. 2013. “Medical Students’ Health-Related Quality of Life: Roles of Social and Behavioural Factors.” *Medical Education* 47 (10): 1001–1012. doi: 10.1111/medu.12247

Jelfs, A., and J. T. E. Richardson. 2013. "The Use of Digital Technologies Across the Adult Life Span in Distance Education." *British Journal of Educational Technology* 44 (2): 338–351. doi:10.1111/j.1467–8535.2012.01308.x

Jonesa, L. Ø., T. Mangerb, O.-J. Eikeland, and A. Asbjørnsen. 2013. "Participation in Prison Education: Is it a Question of Reading and Writing Self-Efficacy Rather Than Actual Skills?" *Journal of Correctional Education* 64 (2): 41–62.

Kolenovic, Z., D. Linderman, and M. M. Karp. 2013. "Improving Student Outcomes via Comprehensive Supports: Three-Year Outcomes From CUNY's Accelerated Study in Associate Programs (ASAP)." *Community College Review* 41 (4): 271–291. doi:10.1177/0091552113503709

Kovner, C. T., C. Brewer, C. Katigbak, M. Djukic, and F. Fatehi. 2012. "Charting the Course for Nurses' Achievement of Higher Education Levels." *Journal of Professional Nursing* 28 (6): 333–343. doi:10.1016/j.profnurs.2012.04.021

Kushimoto, T. 2010. "Outcomes Assessment and its Role in Self-Reviews of Undergraduate Education: In the Context of Japanese Higher Education Reforms Since the 1990s." *Higher Education* 59 (5): 589–598. doi:10.1007/s10734-009–9266-1

Kushner, J., and G. M. Szirony. 2014. "School Counselor Involvement and College Degree Attainment: A Quantitative Conundrum." *Online Journal of New Horizons in Education* 4 (1): 75–79.

Kwenda, M. 2011. "Factors Affecting Performance in an Introductory Sociology Course." *College Teaching* 59: 60–65. doi: 10.1080/87,567,550,903,418,578

Larsen, J. K., M. Kleinjan, R. C. M. E. Engels, J. O. Fisher, and R. Hermans. 2014. "Higher Weight, Lower Education: A Longitudinal Association Between Adolescents' Body Mass Index and Their Subsequent Educational Achievement Level?" *Journal of School Health* 84 (12): 769–776. doi: 10.1111/josh.12212

Lauderdale-Littin, S., E. Howell, and J. Blacher. 2013. "Educational Placement for Children with Autism Spectrum Disorders in Public and Non-Public School Settings: The Impact of Social Skills and Behavior Problems." *Education and Training in Autism and Developmental Disabilities* 48 (4): 469–478.

Lee, M., H. Kim, and M. Kim. 2014. "The Effects of Socratic Questioning on Critical Thinking in Web-Based Collaborative Learning." *Education as Change* 18 (2): 285–302. doi:10.1080/16,823,206.2013.849576

Leppo, R. H. T., S. W. Cawthon, and M. P. Bond. 2014. "Including Deaf and Hard-of-Hearing Students with Co-Occurring Disabilities in the Accommodations Discussion." *Journal of Deaf Studies and Deaf Education* 19 (2): 189–202. doi:10.1093/deafed/ent029

Lewis, T. F., and E. Wahesh. 2015. "Perceived Norms and Marijuana Use at Historically Black Colleges and Universities." *Journal of College Counseling* 18 (2): 130–143. doi:10.1002/jocc.12010

Liu, L. 2012. "Factors Influencing Students' Preference to Online Learning: Development of an Initial Propensity Model." *International Journal of Technology in Teaching and Learning* 7 (2): 93–108.

Liu, Z., and Y. Gao. 2015. "Family Capital Social Stratification, and Higher Education Attainment – An Empirical Study Based on Jiangsu Province." *Chinese Education & Society* 48 (3): 218–230. doi:10.1080/10,611,932.2015.1085773

Long, G. L., C. Marchetti, and R. Fasse. 2011. "The Importance of Interaction for Academic Success in Online Courses with Hearing, Deaf, and Hard-of-Hearing Students." *International Review of Research in Open and Distance Learning* 12 (6): 1–19.

Magalhães, E., P. Costa, and M. J. Costa. 2012. "Empathy of Medical Students and Personality: Evidence from the Five-Factor Model." *Medical Teacher* 34 (10): 807–812. doi:10.3109/0142159X.2012.702248

McGinley, M., K. M. Rospenda, L. Liu, and J. A. Richman. 2015. "Chronic Generalized Harassment During College: Influences on Alcohol and Drug use." *Journal of Youth and Adolescence* 44 (10): 1898–1913. doi:10.1007/s10964-015–0313-1

McLaughlin, M. J., K. E. Speirs, and E. D. Shenassa. 2012. "Reading Disability and Adult Attained Education and Income: Evidence from a 30-year Longitudinal Study of a Population-Based Sample." *Journal of Learning Disabilities* 47 (4): 374–386. doi:10.1177/0022219412458323

McVie, S. 2014. "The Impact of Bullying Perpetration and Victimization on Later Violence and Psychological Distress: A Study of Resilience Among a Scottish Youth Cohort." *Journal of School Violence* 13 (1): 39–58. doi:10.1080/15,388,220.2013.841586

Mendoza, P., and J. P. Mendez. 2012. "The Oklahoma's Promise Program: A national model to promote college persistence." *Journal of College Student Retention: Research, Theory and Practice* 14 (3): 397–421. doi:10.2190/CS.14.3.g

Newman, M. D., and J. M. Petrosko. 2011. "Predictors of alumni association membership." *Research in Higher Education* 52 (7): 738–759. doi: 10.1007/s11162-011–9213-8

Novak, H., and L. McKinney. 2011. "The Consequences of Leaving Money on the Table : Examining Persistence Among Students Who Do not File a FAFSA." *Journal of Student Financial Aid* 41 (3): 5–23.

Nunez, A.-M., and G. Crisp. 2012. "Ethnic Diversity and Latino/a College Access: A Comparison of Mexican American and Puerto Rican Beginning College Students." *Journal of Diversity in Higher Education* 5 (2): 78–95. doi: 10.1037/a0026810

Owens, J. 2010. "Foreign Students, Immigrants, Domestic Minorities and Admission to Texas' Selective Flagship Universities Before and After the Ban on Affirmative Action." *Peabody Journal of Education* 85 (4): 486–510. doi:10.1080/0161956X.2010.518046

Pérez, A., T. Rodríguez, M. J. López, X. Continente, M. Nebot. 2016. "Adoption of Preventive Measures and Attitudes Toward the H1N1 Influenza Pandemic in Schools." *Journal of School Health* 86 (7): 534–542. doi: 10.1111/josh.12406

Price, J. H., G. M. Kirchofer, J. Khubchandani, J. Kleinfelder, and M. Bryant. 2013. "Development of a College Student's Mistrust of Health Care Organizations Scale." *American Journal of Health Education* 44 (1): 19–25. doi:10.1080/19,325,037.2012.749705

Prins, E., S. Monnat, C. Clymer, and B. W. Toso. 2015. "How is Health Related to Literacy, Numeracy, and Technological Problem-Solving Skills Among U.S. Adults? Evidence From the Program for the International Assessment of Adult Competencies (PIAAC)." *Journal of Research and Practice for Adult Literacy, Secondary, and Basic Education* 4 (3): 22–42.

Rohr, S. L. 2012. "How Well Does the SAT and GPA Predict the Retention of Science, Technology, Engineering, Mathematics, and Business Students." *Journal of College Student Retention: Research, Theory & Practice* 14 (2): 195–208. doi: 10.2190/CS.14.2.c

Rojas, Y. 2013. "School Performance and Gender Differences in Suicidal Behaviour – A 30-year Follow-Up of a Stockholm Cohort Born in 1953." *Gender and Education* 25 (5): 578–594. doi:10.1080/09540253.2013.797955

Rye, B. J., C. Mashinter, G. J. Meaney, E. Wood, and S. Gentile. 2015. "Satisfaction With Previous Sexual Health Education as a Predictor of Intentions to Pursue Further Sexual Health Education." *Sex Education* 15 (1): 93–107. doi:10.1080/14,681,811.2014.967389

Schripsema, N. R., A. M. van Trigt, J. C. C. Borleffs, and J. Cohen-Schotanus. 2014. "Selection and Study Performance: Comparing Three Admission Processes Within One Medical School." *Medical Education* 48 (12): 1201–1210. doi:10.1111/medu.12537

Schumacher, P., A. Olinsky, J. Quinn, and R. Smith. 2010. "A Comparison of Logistic Regression, Neural Networks, and Classification Trees Predicting Success of Actuarial Students." *Journal of Education for Business* 85 (5): 258–263. doi:10.1080/08832320903449477

Shen, F. C. 2015. "The Role of Internalized Stereotyping, Parental Pressure, and Parental
Support on Asian Americans' Choice of College Major." *Journal of Multicultural Counseling and Development* 43 (1): 58–73. doi:10.1002/j.2161–1912.2015.00064.x

Song, Y., P. Loyalka, and J. Wei. 2013. "Determinants of Tracking Intentions, and Actual Education Choices among Junior High School Students in Rural China." *Chinese Education & Society* 46 (4): 30–42. doi:10.2753/CED1061-1,932,460,403

Stein, C. H., L. A. Osborn, and S. C. Greenberg. 2016. "Understanding Young Adults' Reports of Contact With Their Parents in a Digital World: Psychological and Familial Relationship Factors." *Journal of Child and Family Studies* 25 (6): 1802–1814. doi:10.1007/s10826-016–0366-0

Strayhorn, T. L. 2010. "Money Matters: The Influence of Financial Factors on Graduate Student Persistence." *Journal of Student Financial Aid* 40 (3): 4–25.

Sullivan, A. L., D. A. Klingbeil, and E. R. Van Norman. 2013. "Beyond Behavior: Multilevel Analysis of the Influence of Sociodemographics and School Characteristics on Students' Risk of Suspension." *School Psychology Review* 42 (1): 99–114.

Trant, E. C., K. E. Crabtree, D. J. Ciancio, L. A. Hart, T. B. Watson, and R. L. Williams. 2015. "Why Some HOPE Scholarship Recipients Retain the Scholarship and Others Lose It." *Innovative Higher Education* 40 (3): 201–214. doi:10.1007/s10755-014–9306-3

Turcios-Cotto, V. Y., and S. Milan. 2013. "Racial/Ethnic Differences in the Educational Expectations of Adolescents: Does Pursuing Higher Education Mean Something Different to Latino Students Compared to White and Black Students?" *Journal of Youth and Adolescence* 42 (9): 1399–1412. doi:10.1007/s10964-012–9845-9

Tuttle, L. V., and G. D. Musoba. 2013. "Transfer Student Persistence at a Hispanic-Serving University." *Journal of Latinos and Education* 12 (1): 38–58. doi:10.1080/15,348,431.2013.734248

van Rooij, S. W. 2012. "Open-Source Learning Management Systems: A Predictive Model for Higher Education." *Journal of Computer Assisted Learning* 28 (2): 114–125. doi:10.1111/j.1365–2729.2011.00422.x

Wei, X., E. R. A. Christiano, J. W. Yu, J. Blackorby, P. Shattuck, and L. A. Newman. 2014. "Postsecondary Pathways and Persistence for STEM Versus Non-STEM Majors: Among College Students With an Autism Spectrum Disorder." *Journal of Autism and Developmental Disorders* 44 (5): 1159–1167. doi:10.1007/s10803-013–1978-5

Wells, K., C. Makela, and C. Kennedy. 2014. "Co-Occurring Health-Related Behavior Pairs in College Students: Insights for Prioritized and Targeted Interventions." *American Journal of Health Education* 45 (4): 210–218. doi:10.1080/19,325,037.2014.916637

Whannell, R. 2013. "Predictors of Attrition and Achievement in a Tertiary Bridging Program." *Australian Journal of Adult Learning* 53 (2): 280–301.

Wilkins, S., and M. S. Balakrishnan. 2013. "Assessing Student Satisfaction in Transnational Higher Education." *International Journal of Educational Management* 27 (2): 143–156. doi:10.1108/09513541311297568

Willits, K. A., M. L. Troutman-Jordan, M. A. Nies, E. F. Racine, E. Platonova, and Harris, H. L. 2013. "Presence of Medical Home and School Attendance: An Analysis of the 2005–2006 National Survey of Children with Special Healthcare Needs." *Journal of School Health* 83 (2): 93–98. doi:10.1111/josh.12003

Wilson, I., B. Griffin, L. Lampe, D. Eley, G. Corrigan, B. Kelly, and P. Stagg. 2013. "Variation in Personality Traits of Medical Students Between Schools of Medicine." *Medical Teacher* 35 (11): 944–948. doi:10.3109/0142159X.2013.827331

Wolf, S., J. L. Aber, and P. A. Morris. 2015. "Patterns of Time Use Among Low-Income Urban Minority Adolescents and Associations with Academic Outcomes and Problem Behaviors." *Journal of Youth and Adolescence* 44 (6): 1208–1225. doi:10.1007/s10964-015–0294-0

Zhao, D., and B. Parolin. 2014. "Merged or Unmerged School? School Preferences in the Context of School Mapping Restructure in Rural China." *Asia-Pacific Education Researcher* 23 (3): 547–563. doi:10.1007/s40299-013–0129-2

Appendix B. Summary of the reviewed studies

Table B1. Summary of the reviewed studies.

	Report of Statistics							Interpretation of Statistics			
Author(s) and year	OR	CI	*p*	ME	RR	Est. Probab. Change	Pred. Probab.	Stat. Sig.	Direct. of Assoc.	Magnitude of Assoc.	Treated OR as RR
Abdulghani et al. (2013)	Y	Y	N	N	N	N	N	Y	N	N	N
Aikins, Golub, and Bennett (2015)	Y	Y	N	N	N	N	N	Y	Y	N	N
Aine et al. (2014)	Y	Y	N	N	N	N	N	Y	N	N	N
Andersen and Ward (2014)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
Angelin, Evengård, and Palmgren (2015)	Y	Y	N	N	N	N	N	Y	Y	N	N
Baker-Eveleth, O'Neill, and Sisodiya (2014)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Barrett, Jennings, and Lynch (2012)	Y	N	N	N	N	N	N	Y	Y	N	N
Barron et al. (2015)	Y	Y	Y	N	N	N	N	Y	N	N	N
Becerra (2012)	Y	N	Y	N	N	N	N	Y	Y	N	N
Beran et al. (2012)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
Bielby et al. (2014)	N	N	Y	Y	N	N	N	Y	Y	Y	N
Bingham et al. (2011)	Y	Y	N	N	N	N	N	Y	Y	N	N
Blackford and Khojasteh (2013)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Boek et al. (2012)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Bouck and Joshi (2015)	Y	N	Y	N	N	N	N	Y	Y	N	N
Burke, Gabhainn, and Young (2015)	Y	Y	Y	N	N	N	N	Y	N	N	N
Campbell and Mislevy (2013)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Case (2011)	Y	N	Y	N	N	N	N	Y	N	N	N
Champion et al. (2011)	N	N	N	N	Y	N	N	Y	Y	Y	N
Chandauka et al. (2015)	N	N	Y	N	N	N	N	Y	Y	N	N
Chiang et al. (2012)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
Cogan (2011)	Y	N	Y	N	N	N	N	Y	Y	N	N
d'Aguiar and Harrison (2016)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
De Backer, Van Keer, and Valcke (2015a)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
De Backer, Van Keer, and Valcke (2015b)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
Eckles and Stradley (2012)	Y	N	Y	N	N	N	N	N	N	Y	Y
England-Siegerdt (2010)	N	N	N	N	N	N	N	N	Y	N	N
Epping et al. (2013)	Y	Y	Y	N	N	N	N	Y	N	N	N
Ertuna and Gurel (2011)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Evans (2013)	N	N	N	N	N	N	N	N	Y	N	N
Ferguson et al. (2012)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Fernández-Macías et al. (2013)	N	N	N	Y	N	N	N	Y	Y	Y	N
Flannery, Frank, and Kato (2012)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Flynn (2014)	Y	N	Y	N	N	N	Y	Y	Y	N	N
Fong, Melguizo, and Prather (2015)	Y	N	Y	N	N	N	N	Y	Y	N	N
Fox et al. (2013)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Furlong and Quirk (2011)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Gil-Flores, Padilla-Carmona, and Suárez-Ortega (2011)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Gonzalez (2012)	N	N	Y	N	N	N	N	N	N	N	N
Greenberg (2013)	Y	N	Y	N	N	N	N	Y	Y	N	N
Greulich et al. (2014)	Y	Y	Y	N	N	N	N	Y	N	N	N
Haas, Smith, and Kagan (2013)	Y	Y	Y	N	N	N	N	Y	N	N	N
Harrell and Bower (2011)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Hawkins et al. (2013)	N	N	N	N	N	N	N	N	N	N	N
Hayes, Price, and York (2013)	Y	N	Y	N	N	N	N	N	Y	N	N

(*Continued*)

Table B1. (Continued).

Author(s) and year	Report of Statistics: OR	CI	*p*	ME	RR	Est. Probab. Change	Pred. Probab.	Interpretation of Statistics: Stat. Sig.	Direct. of Assoc.	Magnitude of Assoc.	Treated OR as RR
Hickman and Wright (2011)	Y	N	Y	N	N	N	N	Y	Y	Y	N
Hillman (2013)	Y	N	Y	N	N	N	Y	Y	Y	Y	N
Honney et al. (2010)	N	N	Y	N	N	N	N	N	Y	N	N
Houser and An (2015)	Y	Y	Y	N	N	N	N	N	Y	N	N
Hu, McCormick, and Gonyea (2012)	Y	N	Y	N	N	N	N	Y	Y	N	N
Jaeger and Eagan (2011)	N	N	Y	Y	N	N	N	Y	Y	Y	N
Jamali et al. (2013)	Y	Y	Y	N	N	N	N	N	N	N	N
Jelfs and Richardson (2013)	N	N	N	N	N	N	N	Y	Y	N	N
Jones, Bushnell, and Humphreys (2014)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Jonesa et al. (2013)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Jowett et al. (2014)	Y	Y	N	N	N	N	Y	Y	Y	N	N
Julal (2013)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
King (2015)	Y	N	Y	N	N	N	Y	Y	Y	N	N
Ko and Jun (2015)	Y	N	Y	Y	N	N	N	Y	Y	N	N
Kolenovic, Linderman, and Karp (2013)	Y	N	Y	N	N	N	N	Y	Y	Y	N
Kovner et al. (2012)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Kushimoto (2010)	Y	N	Y	N	N	N	N	Y	Y	N	N
Kushner and Szirony (2014)	N	N	N	N	N	N	N	Y	Y	N	N
Kwenda (2011)	Y	N	Y	N	N	N	N	Y	Y	N	N
Larsen et al. (2014)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Lauderdale-Littin, Howell, and Blacher (2013)	Y	N	Y	N	N	N	N	Y	Y	N	N
Lee (2014)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Lee, Kim, and Kim (2014)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
Leppo, Cawthon, and Bond (2014)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
Lewis and Wahesh (2015)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Liu (2012)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Liu and Gao (2015)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
Lombardi et al. (2013)	Y	Y	Y	N	N	N	N	N	N	Y	Y
Long, Marchetti, and Fasse (2011)	N	N	Y	N	N	N	N	Y	N	N	N
Luna and Fowler (2011)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Lyons and Akroyd (2014)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Magalhães, Costa, and Costa (2012)	Y	Y	Y	N	N	N	N	Y	Y	Y	N
McGinley (2015)	Y	N	Y	N	N	N	N	Y	Y	N	N
McLaughlin, Speirs, and Shenassa (2012)	Y	Y	N	N	N	N	N	Y	Y	Y	Y
McVie (2014)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Melguizo, Torres, and Jaime (2011)	N	N	Y	Y	N	N	N	Y	Y	Y	N
Mendez and Mendez (2016)	N	N	Y	N	N	N	N	Y	Y	N	N
Mendoza and Mendez (2012)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Munisamy, Jaafar, Nagaraj (2014)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Newman and Petrosko (2011)	Y	N	Y	N	N	N	N	N	N	N	N
Newman and Madaus (2015)	Y	Y	Y	N	N	N	N	Y	Y	Y	N
Novak and McKinney (2011)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Nunez and Crisp (2012)	Y	N	Y	N	N	N	N	Y	Y	N	N
O'Neill et al. (2011)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
Owens (2010)	N	N	N	N	N	Y	Y	Y	Y	Y	N
Pérez et al. (2016)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Pinxten et al. (2015)	N	N	Y	N	N	N	N	Y	Y	N	N
Pleitz et al. (2015)	N	N	Y	N	N	Y	Y	Y	Y	Y	N

(*Continued*)

Table B1. (Continued).

	Report of Statistics							Interpretation of Statistics			
Author(s) and year	OR	CI	*p*	ME	RR	Est. Probab. Change	Pred. Probab.	Stat. Sig.	Direct. of Assoc.	Magnitude of Assoc.	Treated OR as RR
Price et al. (2013)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Prins et al. (2015)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Pruett and Absher (2015)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Pursel et al. (2016)	N	N	Y	Y	N	N	N	Y	Y	Y	N
Radey and Cheatham (2013)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
Rohr (2012)	Y	N	Y	N	N	N	N	Y	Y	N	N
Rojas (2013)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
Rye et al. (2015)	Y	N	Y	N	N	N	N	Y	N	N	N
Santelices et al. (2016)	N	N	Y	Y	N	N	N	Y	Y	Y	N
Schripsema et al. (2014)	Y	N	Y	N	N	N	N	Y	N	N	N
Schumacher et al. (2010)	N	N	N	N	N	N	N	N	N	N	N
Shen (2015)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Song, Loyalka, and Wei (2013)	N	N	Y	N	N	N	N	Y	Y	N	N
Stegers-Jager et al. (2012)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Stein, Osborn, and Greenberg (2016)	N	Y	Y	N	N	N	N	Y	Y	Y	N
Strayhorn (2010)	N	N	Y	N	N	N	N	Y	Y	Y	N
Sullivan, Klingbeil, and Van Norman (2013)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Sullivan and Cosden (2015)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Swecker, Fifolt, and Searby (2013)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Taliaferro and Muehlenkamp (2015)	Y	Y	Y	N	N	N	N	Y	N	N	N
Titzmann, Brenick, and Silbereisen (2015)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Trant et al. (2015)	Y	N	Y	N	N	N	N	Y	Y	Y	N
Turcios-Cotto and Milan (2013)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Tuttle and Musoba (2013)	Y	N	Y	N	N	N	N	Y	Y	N	N
van den Broek et al. (2010)	Y	Y	Y	N	N	N	N	Y	Y	N	N
van Rooij (2012)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Wambuguh and Yonn-Brown (2013)	Y	N	Y	N	N	N	Y	Y	Y	Y	Y
Wei et al. (2014)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Wells, Makela, and Kennedy (2014)	Y	N	Y	N	Y	N	N	Y	Y	Y	Y
Whannell (2013)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Wilkins and Balakrishnan (2013)	Y	N	Y	N	N	N	N	Y	N	N	N
Willits et al. (2013)	Y	Y	Y	N	N	N	N	Y	Y	N	N
Wilson et al. (2013)	Y	N	Y	N	N	N	N	Y	Y	N	N
Wolf, Aber, and Morris (2015)	Y	N	Y	N	N	N	N	Y	Y	N	N
Wood (2013)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Yusif, Yussof, and Osman (2013)	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Zhao and Parolin (2014)	Y	N	Y	N	N	N	N	Y	Y	N	Y

Note. OR: odds ratio; CI: confidence interval; *p*: *p* value or significance level; ME: marginal effect; RR: relative risk. This table summarises the statistics reported and the statistics interpreted by each study included in the review. The last column reports whether a study interpreted odds ratio as relative risk. If a statistic is reported or interpreted, a *Y* is noted; otherwise, an *N* is noted.