

Article

Changes in Biology Self-Efficacy during a First-Year University Course

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Academic self-efficacy encompasses judgments regarding one's ability to perform academic tasks and is correlated with achievement and persistence. This study describes changes in biology self-efficacy during a first-year course. Students ($n = 614$) were given the Biology Self-Efficacy Scale at the beginning and end of the semester. The instrument consisted of 21 questions ranking confidence in performing biology-related tasks on a scale from 1 (not at all confident) to 5 (totally confident). The results demonstrated that students increased in self-efficacy during the semester. High school biology and chemistry contributed to self-efficacy at the beginning of the semester; however, this relationship was lost by the end of the semester, when experience within the course became a significant contributing factor. A proportion of high- and low-achieving (24 and 40%, respectively) students had inaccurate self-efficacy judgments of their ability to perform well in the course. In addition, female students were significantly less confident than males overall, and high-achieving female students were more likely than males to underestimate their academic ability. These results suggest that the Biology Self-Efficacy Scale may be a valuable resource for tracking changes in self-efficacy in first-year students and for identifying students with poorly calibrated self-efficacy perceptions.

INTRODUCTION

The transition from school to university creates a multitude of new experiences and challenges for students (Kantanis, 2000; van der Meer *et al.*, 2010; van der Meer, 2012). University education is self-directed, with the expectation that students will drive their own learning. At the same time, students experience additional freedom along with increased social and economic demands as they progress into adulthood. Although all students enrolled at university have demonstrated their

academic capabilities, some students lack the self-efficacy to apply themselves in this new and academically challenging role (Willcoxson, 2010). As a consequence, such students are vulnerable to academic failure and attrition (Robbins *et al.*, 2004; Davidson and Beck, 2006).

The concept of self-efficacy, first introduced by Bandura (1986) as an aspect of social cognitive theory, is described as being the strength of one's belief in one's ability to perform a given task or achieve a certain outcome. Self-efficacy falls between knowledge and action. An individual may have the skills to perform a task; however, a lack of confidence regarding ability can decrease performance or result in task avoidance (Pajares, 1996; Schunk and Pajares, 2002). Bandura (1986) proposed four factors that influence self-efficacy: "mastery experiences," which provide prior experience of the same or a similar task; "social modeling," or observing another person successfully perform the task; "social persuasion," or being encouraged by others; and "physiological responses" such as fear or anxiety. Mastery experiences appear to have the most significant impact on self-efficacy in education (Lent *et al.*, 1996; Britner and Pajares, 2006; Usher and Pajares, 2006; van Dinther *et al.*, 2011). However,

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effective mastery experience must be both authentic and relevant to the skill level of the individual (van Dinther *et al.*, 2011). Other factors influencing self-efficacy include gender, ethnicity, and a variety of motivational constructs (Schunk and Pajares, 2002; Robbins *et al.*, 2004). For example, most studies evaluating gender differences in self-efficacy report that males are more confident than females (Pajares and Miller, 1994; Cavallo *et al.*, 2004; Larose *et al.*, 2006). Gender differences can persist even when there are no differences in actual ability (Debacker and Nelson, 2000). Motivational constructs that correlate with self-efficacy include goal orientation, implicit theories of intelligence, attributional feedback, and self-concept (Schunk, 1991; Robbins *et al.*, 2004; Hsieh *et al.*, 2007; Komarraju and Nadler, 2013).

In academia, it is well established that self-efficacy is correlated with academic achievement, task persistence, motivation, and resilience (Schunk, 1984; Bandura, 1986; Multon *et al.*, 1991; Pajares, 1996; Andrew, 1998; Komarraju and Nadler, 2013). Self-efficacy is particularly important for first-year students as they navigate the university learning environment for the first time. McKenzie and Schweitzer (2001) found that self-efficacy was the second-strongest predictor of academic performance in first-year science and information technology students after prior academic performance. In addition, Chemers *et al.* (2001) reported that academic self-efficacy related to academic performance in first-year students both directly and indirectly through academic and coping expectations. Academic self-efficacy has also been associated with academic retention in the first year at university, with a study of 401 first-year undergraduates demonstrating that high academic self-efficacy at the end of the semester increases the odds of continuing with study in the subsequent semester (Wright *et al.*, 2013). However, first-year students may also be susceptible to inaccurate self-efficacy judgments, as they are less aware of academic expectations at university level (Gore, 2006). The accuracy of one's self-efficacy is important in academia, as both low self-efficacy and disproportionately high self-efficacy can adversely affect performance (Multon *et al.*, 1991; Pajares, 1996). Previous research has shown that most students overestimate their ability to perform academic tasks (Klassen, 2002; Lawson *et al.*, 2007; Zimmerman and Moylan, 2009; Zimmerman *et al.*, 2011). Moderate overconfidence can be beneficial to students by increasing motivation, effort, and persistence with study (Pajares, 1996; Chen, 2002). However, a gross overestimation of one's abilities can lead students to pursue challenges beyond their capabilities, potentially resulting in failure (Multon *et al.*, 1991) or persistence with ineffective study strategies (Boekaerts and Rozendaal, 2010). Underconfidence may also be detrimental to students by reducing motivation to persist with study or pursue challenging goals (Boekaerts and Rozendaal, 2010). For these reasons, calibration or accuracy of self-efficacy beliefs may play an important role in learning.

Self-efficacy is both task and domain specific (Bandura, 2012). Therefore, students are likely to form differing self-efficacy perceptions for different educational disciplines. This is particularly important within the sciences, where students often approach these disciplines with fear or anxiety (Udo *et al.*, 2004). Self-efficacy in science education has been explored in a variety of scientific disciplines, such as chemistry, physics, mathematics, and geoscience (Hackett and Betz, 1989; Pajares and Miller, 1994; Pajares and Kranzler, 1995;

Pajares and Graham, 1999; Fencil and Scheel, 2005; Dalgety and Coll, 2006; Kurbanoglu and Akim, 2010; Trujillo and Tanner, 2014). The relationship between self-efficacy and academic achievement is particularly striking in mathematics, where the direct effect of self-efficacy on performance was found to be as strong as the effect of general mental ability (Pajares and Kranzler, 1995). In chemistry, Kurbanoglu and Akim (2010) have used path analysis to demonstrate that low chemistry self-efficacy predicted chemistry laboratory anxiety and negatively impacted on chemistry attitudes in first-year students. In biology, however, there are very few studies on self-efficacy (Trujillo and Tanner, 2014). Burgoon *et al.* (2012) discovered that self-efficacy partially predicted academic performance in anatomy, whereas Lawson *et al.* (2007) found that reasoning ability was a stronger predictor of achievement than self-efficacy in first-year biology students. Given the inconsistent nature of these results in relation to previous studies, there is a need to further explore the role of self-efficacy in biology education.

As self-efficacy is a key motivational factor that can affect student performance, it is important to better understand the factors that may influence the development of academic self-efficacy in first-year university students and to explore how discipline-specific self-efficacy develops over time. Therefore, the aim of the current study is to measure changes in biology self-efficacy in a large first-year undergraduate biology course and determine some of the factors that influence self-efficacy in this cohort.

METHODS

Course Background and Student Demographics

The University of Queensland (UQ) is a research-intensive Australian university with 36,000 undergraduate and 12,000 postgraduate students. The students participating in this study were enrolled in the first-year biology course BIOL1040, Cells to Organisms, in Spring 2012. Approximately 850 students were enrolled, 55% were female and ~15% were international. Students completing BIOL1040 came from a variety of undergraduate degree programs, including science and science-related degrees (20%), dentistry (7%), human movement studies (40%), and pharmacy (33%). Students from each degree differed somewhat in terms of the entrance requirements for their programs and their backgrounds, with students requiring high entrance scores to enter dentistry, medium to high scores to enter science or science-related degrees, and medium scores to enter pharmacy or human movement studies. Students in science and dentistry were likely to have completed high school chemistry, with greater than 95% having done so, but only ~50% had completed biology at the high school level. Almost all pharmacy students had completed high school chemistry, with 66% also having completed high school biology. However, fewer human movement studies students (47%) had completed high school chemistry, but approximately three quarters (73%) had completed biology at high school.

Contact hours for BIOL1040 included three 50-min lectures per week and five 3-h practical laboratory classes completed fortnightly throughout the 13-wk-long semester. Topics covered included cellular function, the nervous system, biochemistry, support and movement, circulation and gas

exchange, and the endocrine system. Students completed a variety of assessment tasks covering four areas of competency. The “knowledge” competency consisted of three online multiple-choice quizzes completed during the semester and a final exam. The “communication” competency consisted of two written assignments, a PowerPoint presentation, and an online discussion (Moni *et al.*, 2007). “Practical core competencies” involved mastery of four laboratory skills assessed during classes. The final competency, “practical assessment,” involved four laboratory reports due within 48 h of completion of the related laboratory classes. Marks and feedback for each assessment task were released to students as they progressed through the semester. Students received an overall course grade on a scale of 1–7 (1–3 = fail, 4 = pass, 5 = credit, 6 = distinction; 7 = high distinction).

The Biology Self-Efficacy Scale

Self-efficacy was measured using the published Biology Self-Efficacy Scale (Baldwin *et al.*, 1999), which is a 23-item instrument measuring levels of confidence in a broad range of biology-related activities. The scale was originally developed for biology nonmajors, whereas the students in the current study included both biology majors and nonmajors, who may have various degrees of familiarity and interest in biology. The scale was still deemed suitable for the current study, as the majority of participants were in their first semester of study and therefore unfamiliar with university-taught biology (~97%). The Biology Self-Efficacy Scale consists of three subscales: 1) Methods of Biology (8 questions), 2) Generalization to Other Biology/Science Courses and Analyzing Data (9 questions), and 3) Application of Biological Concepts and Skills (6 questions). The instrument was modified in the current study by removing two questions from the second subscale (item 14: “How confident are you that you would be successful in an ecology course?” and item 17: “How confident are you that you would be successful in a human physiology course?”) and refining item 8, “How confident are you that you will be successful in this biology course,” by defining successful as achieving a grade of 6 or higher. These changes were made to the scale as part of a larger study and did not appear to change the Cronbach’s alpha coefficients for the subscale. Students rated their level of confidence on a Likert scale from 1 to 5 (1 = not at all confident; 2 = only a little confident; 3 = fairly confident; 4 = very confident; 5 = totally confident). Where total self-efficacy scores were used in the data analysis, students’ total self-efficacy was defined as the sum of these scores across all 21 questions, with a minimum possible score of 21 and a maximum of 105.

The Biology Self-Efficacy Scale was provided to students for voluntary completion in their first practical (either week 2 or 3 of the semester) and final practical (week 12 or 13). Students had not completed any assessment before completing the survey at the beginning of the semester. In contrast, by the time students completed the survey at the end of the semester, they had completed and received feedback on all assessment items other than one online quiz, the final practical report, and the final exam. Eighty-nine percent of students completed the survey at the beginning of the semester, and 83% at the end of the semester. Complete responses for both surveys were provided by 614 students (73%). Ethical clearance

for this project was obtained through the UQ Behavioral and Social Sciences Ethical Review Committee (2011001341).

Normalized Change Scores

Raw pre- and postsurvey scores for each subscale of the Biology Self-Efficacy Scale were converted into percentages to calculate normalized change scores (Marx and Cummings, 2007). The formulas provided by Marx and Cummings (2007) allow investigators to calculate change scores for each student derived from pre- and postsurvey scores, thereby taking into account that students with low prescores have more to gain than students with high prescores. For example, a student with a prescore of 20% and a postscore of 60% will have the same normalized change score (0.5) as a student with a prescore of 80% and a postscore of 90%, as both students improved by 50% of their possible gain. Normalized change scores range from –1 to +1. Ten students with presurvey scores of 100% were dropped from the analysis, as recommended by Marx and Cummings (2007).

Multiple Linear Regression

Multiple linear regression analyses were conducted to determine the variability in self-efficacy scores or final exam mark explained by demographic and performance variables. Individual analyses included 1) the variability in self-efficacy at the beginning of the semester explained by gender, degree, high school biology, and high school chemistry; 2) the variability in self-efficacy at the end of the semester explained by gender, degree, high school biology, high school chemistry, progressive grade, and self-efficacy at the beginning of the semester; and 3) the variability in final exam mark explained by gender, high school biology, high school chemistry, progressive grade, and self-efficacy at the end of the semester. Progressive grade was calculated from all assessment items that students had completed and received feedback on by the time of the final survey. All regression analyses met the assumptions for linearity, homoscedasticity, multicollinearity, and normality.

Calibration of Self-Efficacy Scores

High-achieving (grade 6 or 7) and low-achieving (grades 1–3) students were categorized into “confident” or “not confident” in response to item 8 on the Biology Self-Efficacy Scale “How confident are you that you will achieve a high grade (6 or above) in this biology course?” “Confident” students selected 3–5 on the Likert scale (fairly confident to totally confident) for item 8 at the end of the semester, whereas “not confident” students selected 1 or 2 on the Likert scale (not at all or only a little confident). Well-calibrated students were those who were high achieving and confident or were low achieving and not confident. Poorly calibrated students were either “underconfident” (high achieving, not confident) or “overconfident” (low achieving, confident). Differences in target demographic variables within all groups were analyzed using a binomial test.

Statistical Analysis

Statistical analyses were conducted with either GraphPad Prism, version 6 (San Diego, CA) or IBM SPSS Statistics, version 22 (Somers, NY). Results were expressed as mean \pm SEM with statistical significance identified as $p < 0.05$.

Table 1. Cronbach's alpha coefficients for the Biology Self-Efficacy Scale

Self-efficacy subscale	Baldwin <i>et al.</i> (1999)	Current study	
		Beginning of the semester	End of the semester
Methods of Biology	0.88	0.89	0.88
Generalization to Other Biology/ Science Courses and Analyzing Data	0.88	0.86	0.87
Application of Biological Concepts and Skills	0.89	0.89	0.92

The reliability of the three self-efficacy subscales was calculated using Cronbach's alpha. The Cronbach's alpha coefficients for subscales in both surveys in this study were equivalent to those published by Baldwin *et al.* (1999; Table 1).

RESULTS

Self-Efficacy Scores at the Beginning and End of the Semester

Students ($n = 614$) completed the Biology Self-Efficacy Scale at the beginning and end of the semester during a first-year biology course. Descriptive statistics for the cohort, including self-efficacy scores and final exam marks, are presented in Table 2. A paired t test indicated that the cohort overall

Table 2. Descriptive statistics for students ($n = 614$) enrolled in BIOL1040 who completed the Biology Self-Efficacy Scale (Baldwin *et al.*, 1999) at the beginning and end of the semester

	Beginning self-efficacy	End self-efficacy	Final exam mark (%)
	Mean \pm SEM	Mean \pm SEM	Mean \pm SEM
All participants ($n = 614$)	65.71 \pm 0.51	75.87 \pm 0.5	60.52 \pm 0.71
Gender			
Female ($n = 354$)	64.54 \pm 0.67	74.06 \pm 0.65	60.58 \pm 0.97
Male ($n = 260$)	67.31 \pm 0.78	78.35 \pm 0.78	60.44 \pm 1.05
Degree			
Science and science related ($n = 141$)	69.52 \pm 0.99	80.29 \pm 1.00	75.30 \pm 1.01
Dentistry ($n = 44$)	63.14 \pm 1.76	75.66 \pm 1.67	75.38 \pm 1.89
Human movement studies ($n = 244$)	62.01 \pm 0.78	72.52 \pm 0.76	50.73 \pm 0.96
Pharmacy ($n = 185$)	68.31 \pm 0.92	76.99 \pm 0.94	58.34 \pm 1.16
High school biology ^a			
Yes ($n = 381$)	66.51 \pm 0.65	76.18 \pm 0.62	59.32 \pm 0.91
No ($n = 221$)	64.67 \pm 0.83	75.48 \pm 0.88	62.36 \pm 1.19
High school chemistry ^a			
Yes ($n = 468$)	67.15 \pm 0.58	76.92 \pm 0.57	63.39 \pm 0.79
No ($n = 139$)	60.52 \pm 0.96	71.94 \pm 1.02	50.46 \pm 1.36

^aSome students did not indicate their prior high school biology ($n = 12$) or chemistry ($n = 7$) experience.

Table 3. Percentage of students ($n = 614$) who increased, decreased, or had no change in overall and subscale self-efficacy scores from the beginning to the end of the semester

Change in self-efficacy score	Overall self-efficacy (%)	Generalization/analyzing (%)	Methods of Biology (%)	Application (%)
Increase	81.1	69.4	81.1	72.8
Decrease	16.1	22.5	13.4	16.1
No change	2.8	8.1	5.5	11.1

had a significant increase in self-efficacy from the beginning to the end of the semester ($p < 0.05$), with an average biology self-efficacy score of 65.71 ± 0.51 at the beginning of the semester and 75.87 ± 0.5 at the end of the semester. The overall cohort had an average normalized change score of 0.26 ± 0.01 , indicating that, on average, the end-of-semester self-efficacy scores improved by 26% of the maximum possible increase in self-efficacy scores. Eighty-one percent of students demonstrated an increase in overall self-efficacy scores during the semester, whereas only 16% of students demonstrated decreased scores, with just 3% remaining unchanged (Table 3).

Changes in Self-Efficacy for the Subscales of the Biology Self-Efficacy Scale

Normalized change scores were calculated for each student from the beginning- and end-of-semester self-efficacy scores for each of the Biology Self-Efficacy subscales (Figure 1). The average change score was 0.29 ± 0.01 for Methods of Biology,

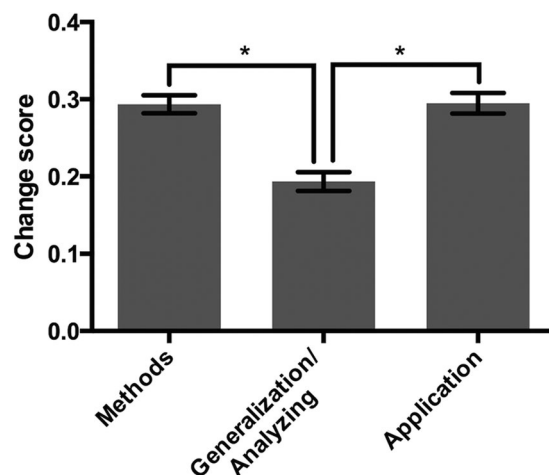


Figure 1. Change scores for the subscales within the Biology Self-Efficacy Scale. Consenting students ($n = 614$) completed the Biology Self-Efficacy Scale (Baldwin *et al.*, 1999) at the beginning of the semester and the end of the semester. Change scores were calculated for individual students using the formulas outlined by Marx and Cummings (2007). Ten students with a maximum score on one or more of the subscales at the beginning of the semester were excluded from analysis. A one-way repeated-measure analysis of variance demonstrated a significant difference ($p < 0.05$) between Generalization to Other Biology/Science Courses and Analyzing Data and the other two subscales. Bars represent mean \pm SEM.

0.19 ± 0.01 for Generalization to Other Biology/Science Courses and Analyzing Data, and 0.29 ± 0.01 for Application of Biological Concepts and Skills. The average change score for Generalization to Other Biology/Science Courses and Analyzing Data was significantly lower than the change scores for the other two subscales ($p < 0.05$, Figure 1). Students with a change score of 1 were included in this analysis; however, as these students received the highest possible score for the end-of-semester self-efficacy subscale, these students may have experienced a ceiling effect within that subscale. Only 38 students had change scores of 1 on one or more subscales, with the majority (33 students) being on the Application of Biological Concepts and Skills subscale. A higher percentage of students demonstrated improved self-efficacy scores at the end of the semester for Methods of Biology (81%), followed by Application of Biological Concepts and Skills (72.8%), and then Generalization to Other Biology/Science Courses and Analyzing Data (69.4%; Table 3).

Factors Contributing to Self-Efficacy at the Beginning of the Semester

A multiple linear regression analysis was performed to determine whether gender, degree, high school biology, and high school chemistry predicted self-efficacy at the beginning of the semester (Table 4). All variables contributed significantly to the model, which accounted for 12% of the variability in self-efficacy at the beginning of the semester ($R^2 = 0.119$). When holding all other variables constant, male students had significantly higher self-efficacy scores by 3.5 points on average compared with female students. In addition, students who had completed high school biology or chemistry were also more self-efficacious than students who had not. When holding all other variables constant, students with prior biology experience reported average self-efficacy scores that were 3.7 points higher on average than students without prior biology, and students with prior chemistry experience reported scores that were 4 points higher on average than students without prior chemistry. Students enrolled in dentistry and human movement studies had significantly lower self-efficacy scores at the beginning of the semester on average compared with students enrolled in science and science-related degrees, whereas pharmacy students had self-efficacy scores that were not significantly different from those of science students.

Table 4. Multiple linear regression analysis of factors affecting self-efficacy at the beginning of the semester^a

	B	SE	<i>p</i> Value
Intercept	62.625	1.864	<0.0005
Gender (male)	3.526	0.989	<0.0005
Degree (dentistry)	-6.802	2.084	0.001
Degree (human movement studies)	-6.928	1.442	<0.0005
Degree (pharmacy)	-1.778	1.364	0.193
High school biology	3.710	1.046	<0.0005
High school chemistry	3.988	1.426	0.005

^aB = unstandardized regression coefficient; SE = SE of the coefficient. $F(6590) = 13.244$, $p < 0.0005$. $R = 0.345$; $R^2 = 0.119$.

Table 5. Multiple linear regression analysis of factors affecting self-efficacy at the end of the semester^a

Model	B	SE	<i>p</i> Value
Intercept	15.762	4.633	0.001
Gender (male)	3.034	0.833	<0.0005
Progressive grade	0.289	0.051	<0.0005
Beginning self-efficacy	0.527	0.033	<0.0005

^aB = unstandardized regression coefficient; SE = SE of the coefficient. $F(3610) = 115.393$, $p < 0.0005$. $R = 0.602$; $R^2 = 0.362$.

Factors Contributing to Self-Efficacy at the End of the Semester

A multiple linear regression was performed to test the model that gender, degree, high school biology, high school chemistry, progressive grade, and beginning-of-semester self-efficacy could predict end-of-semester self-efficacy. The progressive grade was calculated from the scores students received from assessment items that had been marked (with feedback) and provided to students by the time they completed the end-of-semester survey. Although high school biology and chemistry contributed to self-efficacy at the beginning of the semester, these variables did not contribute to self-efficacy at the end of the semester ($p = 0.284$ and $p = 0.801$, respectively). Degree ($p = 0.852$) also did not contribute significantly to the model. After these nonsignificant factors were removed, the final model accounted for 36.2% of the variability in end-of-semester self-efficacy (Table 5). Gender was the only factor that contributed to the variability in self-efficacy scores at both the beginning and end of the semester, with males reporting higher self-efficacy scores by 3 points on average compared with female students at the end of the semester. For every unit increase in progressive grade, end-of-semester self-efficacy scores increased by 0.29 points on average. For every point increase in beginning-of-semester self-efficacy score, the end-of-semester self-efficacy score increased by 0.527 points on average. The Pearson correlation coefficient for the relationship between beginning- and end-of-semester self-efficacy was 0.568 (Figure 2).

Relationship between Self-Efficacy and Academic Performance

A multiple linear regression was performed to test the model that final exam mark could be predicted by gender, degree, high school biology, high school chemistry, progressive grade, and end-of-semester self-efficacy. We chose end-of-semester self-efficacy as opposed to beginning-of-semester self-efficacy, because prior research has indicated that self-efficacy scores more strongly predict academic performance when measured at the end of the semester for first-semester university students (Gore, 2006). Gender ($p = 0.719$) and end-of-semester self-efficacy ($p = 0.590$) did not contribute significantly to the variability in final exam mark. Figure 3 shows a scatter plot of the relationship between end-of-semester self-efficacy and final grade separated by gender. After the nonsignificant variables were removed, the final model accounted for 55.3% of the variability in final exam mark (Table 6). Students enrolled in human movement



Figure 2. Scatter plot of the relationship between students’ self-efficacy scores at the beginning of the semester and the end of the semester. Consenting students ($n = 614$) completed the Biology Self-Efficacy Scale (Baldwin *et al.*, 1999) at the beginning of the semester and the end of the semester. Possible self-efficacy scores ranged from 21 to 105. Data points above the reference line ($x = y$) indicate students who have increased in self-efficacy during the semester, whereas data points below the line represent students who have decreased in self-efficacy during the semester.

studies and pharmacy received significantly lower marks on average compared with students enrolled in science and science-related degrees. Students with high school biology or chemistry performed significantly better on the end-of-semester exam compared with students without prior high school experience in these disciplines. Finally, for each point

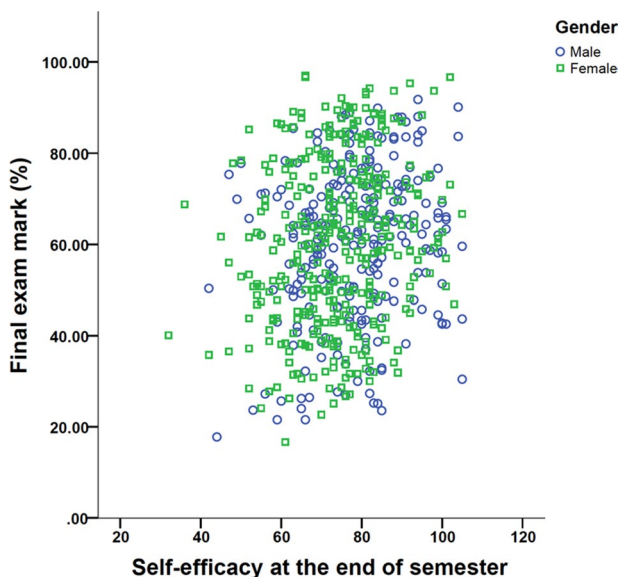


Figure 3. Scatter plot of the relationship between students’ self-efficacy scores at the end of the semester and their final exam grades. Consenting students ($n = 614$) completed the Biology Self-Efficacy Scale (Baldwin *et al.*, 1999) at the end of the semester ~2–3 wk before completing the final exam. Possible self-efficacy scores ranged from 21 to 105.

Table 6. Multiple linear regression analysis of factors affecting final exam performance^a

Model	B	SE	p Value
Intercept	-37.717	6.924	<0.0005
Degree (dentistry)	-3.588	2.101	0.088
Degree (human movement studies)	-11.319	1.645	<0.0005
Degree (pharmacy)	-9.750	1.460	<0.0005
High school biology	2.182	1.052	0.038
High school chemistry	3.654	1.445	0.012
Progressive grade	1.210	0.075	<0.0005

^aB = unstandardized regression coefficient; SE = SE of the coefficient. $F(6583) = 120.046$, $p < 0.0005$. $R = 0.743$; $R^2 = 0.553$.

increase in progressive grade, there was a 1.2% increase in final exam mark on average.

As the correlation between progressive grade and final exam performance was high ($R^2 = 0.49$), the linear regression analysis was repeated without progressive grade as a variable to ensure that the effect of end-of-semester self-efficacy was not being masked by progressive grade. However, the results from this linear regression still indicated a nonsignificant effect of self-efficacy ($p = 0.118$) at the end of the semester. In addition, self-efficacy was still not a significant predictor of final exam grade when the linear regression was performed with normalized self-efficacy change scores ($p = 0.302$) or beginning-of-semester self-efficacy ($p = 0.973$) instead of end-of-semester self-efficacy scores. The disconnect between perceived self-efficacy and academic performance discovered here contradicts previous literature (Multon *et al.*, 1991; Robbins *et al.*, 2004; Brown *et al.*, 2008) and suggests that the Biology Self-Efficacy Scale may be too broad to predict exam performance. One question on the scale related specifically to course performance and was therefore examined in more detail. Students were asked specifically how confident they were that they could achieve a high grade (6 or above) in the course (item 8, Figure 4). Student responses to this question at the beginning and end of the semester were separated into groups by final course grade. At the beginning of the semester, students who went on to receive a grade of 6 or 7 were significantly ($p < 0.05$) more confident on average than students who received grades of 1, 2, or 4. By the end of the semester, those students who went on to receive a grade of 6 or 7 were significantly ($p < 0.05$) more confident on average than students of all other grades.

Students were grouped as either high achievers (receiving grades of 6 or 7) or low achievers (receiving failing grades of 1, 2, or 3) to examine the distribution of overconfident and underconfident students in the course (Table 7). When asked on item 8 about their confidence in achieving a grade of 6 or 7 at the end of the semester, 24% of high achievers indicated that they were not confident (underconfident), whereas 40% of low achievers indicated that they were confident (overconfident). While mean progressive grades in high-achieving students differed slightly but significantly ($p < 0.05$) between confident ($91.9\% \pm 0.4$) and not confident ($89.5\% \pm 0.8$) groups, both groups had progressive grades that were tracking toward a final grade of 6 or 7. In the

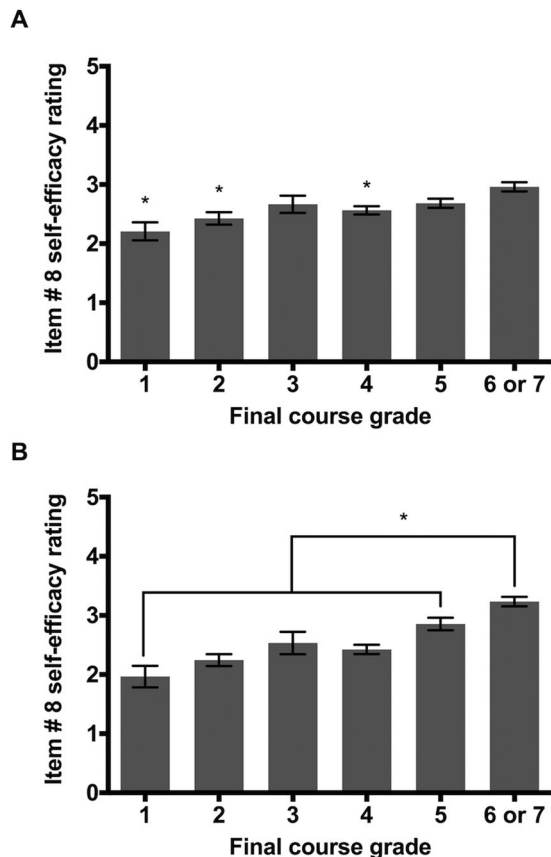


Figure 4. Biology self-efficacy when asked “How confident are you that you will achieve a high grade (6 or above) in this biology course?” Consenting students ($n = 614$) completed the Biology Self-Efficacy Scale (Baldwin *et al.*, 1999) at (A) the beginning of the semester and (B) the end of the semester. Student self-efficacy scores for the question were categorized by final course grade, where grades 1 ($n = 29$), 2 ($n = 82$), and 3 ($n = 30$) are failing grades; 4 ($n = 172$) is a pass; 5 ($n = 123$) is a credit; 6 ($n = 112$) is a distinction; and 7 ($n = 67$) is a high distinction. Responses to this question were on a Likert scale of 1 = not at all confident to 5 = totally confident; therefore, possible self-efficacy scores ranged from 1 to 5. Differences in biology self-efficacy based on final course grades were analyzed using a Kruskal-Wallis test with Dunn’s multiple comparisons. Bars represent mean \pm SEM. Asterisk indicates a significant difference from students receiving a final grade of 6 or 7.

low-achieving groups, progressive grades for low-achieving confident ($75.8\% \pm 1$) and not confident ($75.8\% \pm 0.9$) groups did not differ, but more notably, their progressive grades were well below the requirement for a final grade of 6 (83.8%). The groups were also compared across each measured demographic variable (gender, degree, high school biology, and high school chemistry) to determine whether any differences were present in the distribution of confident and not confident students (see Supplemental Material). Gender was the only variable that demonstrated a difference from the expected ratio. Binomial tests for gender demonstrated a significant shift from the expected ratio (39:61 male:female) in the high-achieving not confident group, with a higher than expected percentage (79%) of these students being female ($p < 0.05$; Table 7). This difference in gender distribution was not apparent in any other group.

DISCUSSION

This study evaluated the development of biology self-efficacy in first-year undergraduate university students enrolled in a large first-year biology course using the Biology Self-Efficacy Scale developed by Baldwin *et al.* (1999). Overall, our results indicate that self-efficacy improved from the beginning to the end of the semester. At both the beginning and the end of the semester, males reported higher self-efficacy than females. Prior experience in high school biology and chemistry significantly explained a small part of the variability in beginning-of-semester self-efficacy scores. However, this relationship was lost by the end of the semester, when experience within the course became a significant factor, explaining substantially more of the variability in self-efficacy. Interestingly, self-efficacy did not significantly contribute to the variability in final exam mark; however, students’ responses to a specific item asking about confidence in achieving a high grade did relate significantly to their final grades.

The Biology Self-Efficacy Scale and Changes in Self-Efficacy over Time

In the current study, self-efficacy was measured using the published Biology Self-Efficacy Scale developed for nonmajors by Baldwin *et al.* (1999). Our results indicate that the instrument may also be applicable for majors, as our participants were from a mix of science and non-science degrees. Although more than two thirds of our participants had prior experience in biology and/or chemistry, only 10 students (1.6%) reported maximum scores for one or more of the subscales at the beginning of the semester, and only 38 students (6.2%) reached the ceiling for a subscale at the end of the semester. This indicates the Biology Self-Efficacy Scale is suitable for both nonmajors and majors in the early stages of their tertiary education.

The average change score for biology self-efficacy was 0.26%, indicating that by the end of the semester our cohort increased their self-efficacy score on average by 26% of the maximum possible increase in beginning-of-semester self-efficacy scores. This result is consistent with other studies showing increases in self-efficacy from the beginning to the end of the semester using either the Biology Self-Efficacy Scale (Gormally *et al.*, 2009) or other discipline-specific measures of self-efficacy (Dalgety and Coll, 2006). Furthermore, in a longitudinal study in Quebec, Larose *et al.* (2006) found that most students had consistently high, or increasing, levels of science self-efficacy during their transition from high school to the first year of science higher education. Broadly, this demonstrates that students strengthen their self-efficacy in a particular discipline as they gain educational experience in that discipline.

In our study, students improved across all three Biology Self-Efficacy subscales during semester, but developed more confidence in the Methods of Biology and Application of Biological Concepts and Skills subscales than the Generalization to Other Biology/Science Courses and Analyzing Data subscale (Figure 1 and Table 3). Previous studies using the Biology Self-Efficacy Scale have found variations in self-efficacy scores across the subscales between majors and nonmajors (Ekici *et al.*, 2012), across university year levels (Ekici *et al.*, 2012), and between students exposed to differing

Table 7. Students who were not confident or confident when responding to item 8 in the Biology Self-Efficacy Scale “How confident are you that you will achieve a high grade (6 or above) in this biology course?” were separated by gender^a

	High achieving			Low achieving		
	All high achieving % (n)	Confident ^b % (n)	Not confident ^c % (n)	All low achieving % (n)	Confident ^b % (n)	Not confident ^c % (n)
All students		76 (135)	24 (43)		40 (57)	60 (84)
Gender						
Male	39 (69)	44 (60)	21 (9)*	40 (56)	47 (27)	35 (29)
Female	61 (109)	56 (75)	79 (34)*	60 (85)	53 (30)	65 (55)

^aHigh achievers received a grade of 6 or 7 and low achievers received a failing grade (grade 1, 2, or 3). Asterisk indicates a significant deviation from the expected ratio of males:females in the relevant achievement group as determined by a binomial test.

^bConfident students responded as fairly confident (3), very confident (4), or totally confident (5) on the Likert scale in response to item 8 on the Biology Self-Efficacy Scale.

^cNot confident students responded as not at all confident (1) or only a little confident (2) on the Likert scale in response to item 8 on the Biology Self-Efficacy Scale.

curricula (Gormally *et al.*, 2009). Therefore, it is likely that changes in perceived strengths and weaknesses on the Biology Self-Efficacy subscales will vary depending on the learning activities students experience within a specific biology course. As such, curriculum designers may find changes in student self-efficacy on particular subscales to be valuable feedback on how students are experiencing a series of educational activities.

The differences in change scores across the three subscales may also reflect differences in the cognitive complexity of the tasks assessed in the Biology Self-Efficacy Scale. All questions in the Application of Biological Concepts and Skills subscale required students to rate their confidence in summarizing and explaining the main points of various scientific genres. These questions would all be classified within Bloom’s taxonomy as “comprehension” (Bloom *et al.*, 1956; Allen and Tanner, 2002), which is a lower-order cognitive skill than Bloom’s “application” (Crowe *et al.*, 2008). The Methods of Biology subscale included both “application” questions (e.g., “Write the methods of a laboratory report”) and “evaluation” questions (e.g., “Critique an experiment described in a biology textbook”), with both considered higher-order cognitive skills. Finally, the Generalization to Other Biology/Science Courses and Analyzing Data subscale included a variety of higher-order cognitive skills, including “analysis” (e.g., “Analyze a set of data”), and “synthesis” (e.g., “Ask a meaningful question that can be answered experimentally”). The difficulty of particular cognitive skills may, therefore, impact on the rate at which students report gains in self-efficacy on the Biology Self-Efficacy subscales.

Factors Influencing Self-Efficacy at the Beginning and End of the Semester

Gender was one of the most persistent factors influencing self-efficacy in our study, contributing significantly to the variability in self-efficacy scores at both the beginning and the end of the semester (Tables 4 and 5). Although most studies at secondary and tertiary education levels support the notion that males have higher science self-efficacy than females (Pajares and Miller, 1994; Debacker and Nelson, 2000; Cavallo *et al.*, 2004; Larose *et al.*, 2006), there have

been reports of either no gender effect (O’Brien *et al.*, 1999) or higher levels of science self-efficacy in females (Britner and Pajares, 2001, 2006). That female students report lower biology self-efficacy scores in the current study is a cause for concern. Although there was no effect of gender on final exam performance (Table 6), perceived differences in self-efficacy may influence other parameters not measured in the current study, such as intention to remain in science and career choice (O’Brien *et al.*, 1999; Davidson and Beck, 2006; Larose *et al.*, 2006). Ehrlinger and Dunning (2003) reported that female students rate their ability to reason about science lower than male students, despite a lack of difference in their performance, and postulated that this may result in females having a lack of interest in pursuing scientific activities. Therefore, although the lack of gender differences in academic performance reported here is positive, this finding needs to be viewed with caution and the longer-term impacts of the persistent gender difference in biology self-efficacy should be further investigated.

This study found a substantial shift in the prior experience factors that contributed to biology self-efficacy across the semester. While both high school biology and high school chemistry significantly predicted variability in self-efficacy scores at the beginning of the semester (Table 4), it is important to note that this model only accounted for 11.9% of the variability in self-efficacy scores. There are a number of possible reasons for this. First, mastery experiences with a task, or within a discipline area, have been shown to be a dominant factor influencing self-efficacy (Lent *et al.*, 1996; Britner and Pajares, 2006; Usher and Pajares, 2006; van Dinther *et al.*, 2011). Our study did not distinguish between positive and negative high school biology and chemistry experiences, and although prior success in biology and chemistry is likely to enhance self-efficacy, failure experiences are likely to reduce self-efficacy (Bandura, 2012). It is possible that the association between prior high school experience and beginning-of-semester biology self-efficacy would be stronger if high school achievement in these disciplines was included in the analysis. Second, many unmeasured factors would be reasonable candidates for contributing to the remaining variability in self-efficacy at the beginning of the semester. For example, goal orientation, attributional feedback, self-concept, and implicit

theories of intelligence have all correlated with self-efficacy in previous studies (Schunk, 1991; Robbins *et al.*, 2004; Hsieh *et al.*, 2007; Komarraju and Nadler, 2013). Therefore, although our findings suggest that a solid foundation in biology and chemistry increases students' self-efficacy when they first attempt university study in biology, this is likely to be an oversimplification, and much richer data are required to develop a more nuanced understanding of the biology self-efficacy students bring when they enter university.

Perhaps more importantly, high school biology and chemistry did not predict any of the variability in self-efficacy by the end of the semester. Instead, progressive grade became a significant predictor (Table 5), suggesting that students were using the experience and feedback gained within the course to determine their biology self-efficacy. It must be noted that the course examined in this study provided a wide range of assessment tasks covering practical experience, communication with lay and scientific audiences, and knowledge tests (Moni *et al.*, 2007; Zimbardi *et al.*, 2013). Therefore, many aspects of the Biology Self-Efficacy Scale were addressed in the course, providing regular, explicit indications of performance on these tasks. This perhaps highlights the importance of feedback from regular and diverse assessment tasks to provide students with tangible evidence of their developing efficacy in a given discipline.

Interestingly, in the current study, there were differences in self-efficacy at the beginning of the semester between groups of students enrolled in different degrees (Table 4). Dentistry students had low self-efficacy at the beginning of the semester on average compared with science students, despite having very high entry requirements. In contrast, pharmacy students were just as self-efficacious as science students, despite going on to obtain a lower final exam mark at the end of the semester. One possible explanation for this discrepancy is the ambiguous nature of academic achievement standards for students who are new to university. Previous research has indicated that social comparison with peers can influence self-efficacy when standards are ambiguous or in the absence of previous experience (Bandura, 1977; Bong and Clark, 1999; Bong and Skaalvik, 2003). The majority of participants in the current study were in their first semester at university, when academic expectations at the university level are still fairly unknown. At the beginning of the semester, students may judge their ability to perform biology tasks at university level by comparing their achievements with those of other students enrolled in the same degree. For example, a dentistry student may base his or her biology self-efficacy on the perceived ability of other high-achieving dentistry students and conclude that he or she is less able than his or her peers. As the semester progresses, students' current experience with biology and the feedback they receive should take over as the primary influence on self-efficacy (Bandura, 1986). This notion is supported in the current study, where degree no longer significantly contributed to the variability in self-efficacy scores at the end of the semester, whereas progressive grade became a strong predictor variable (Table 5).

Finally, self-efficacy at the beginning of the semester accounted for a significant proportion of the variability in self-efficacy at the end of the semester (Table 5 and Figure 2). Our results suggest that, while the cohort on average reported a gain in biology self-efficacy, students who started with lower self-efficacy also finished the course with lower

self-efficacy than their peers. Given the lack of relationship between end-of-semester self-efficacy and performance on the final exam, this calls into question the degree to which the intrasemester assessment feedback was helping students make accurate assessments of their biology efficacy. We therefore now turn our attention from factors contributing to biology self-efficacy to factors contributing to academic performance.

Relationship between Self-Efficacy and Academic Performance

Multiple linear regression analysis indicated that progressive grade accounted for a significant proportion of the variability in final exam performance in our model (Table 6). Other significant factors included degree and high school chemistry and biology experience, but not beginning- or end-of-semester biology self-efficacy. The importance of progressive grade in explaining variation in exam performance may be due to a strong alignment between assessment tasks within the course, or to high-achieving students doing well on multiple forms of assessment compared with lower-achieving students. It is well established that prior academic performance is a strong predictor of future academic performance across multiple contexts (for a review, see Hattie, 2013). Indeed, this relationship may also underlie the apparent link between degree and exam performance in our results (Table 6). In our context, high entrance scores were required for entry into dentistry and some of the science-related degrees (particularly the bachelor of medicine/bachelor of surgery degree), whereas medium-level entrance scores were required for both pharmacy and human movement studies. Thus, it is not surprising that students enrolled in dentistry or science and science-related degrees achieved a higher final exam grade on average compared with pharmacy and human movement studies students (Table 2).

High school biology and chemistry also significantly explained the variation in final exam scores. The biology course in this study had a strong focus on molecular and biochemical processes, which might explain why students lacking high school chemistry did not perform as well on the final exam, as prior chemistry knowledge is likely to impact their ability to understand the course content. From an educational design perspective, it is important to note that students without chemistry enrolled in this course received additional readings and remedial chemistry workshops during the first week of the semester. It would seem that this support is insufficient, suggesting that ongoing chemistry support may be necessary to provide such students with an equal opportunity to succeed.

Interestingly, self-efficacy did not significantly contribute to the variation in final exam performance (Figure 3), which contradicts a wide range of self-efficacy studies across multiple educational areas (Multon *et al.*, 1991; Pajares and Miller, 1994; Andrew, 1998; Chemers *et al.*, 2001; Robbins *et al.*, 2004; Brown *et al.*, 2008; Burgoon *et al.*, 2012). First, we acknowledge that performance on a single exam paper will be influenced by many mitigating factors ranging from effort, motivation, and strategic approaches to studying in the longer term, to situational factors that impact performance on a single point in time. We specifically chose the final exam as our academic performance indicator in this study so that we could

evaluate the temporal relationship between self-efficacy and subsequent academic performance. Both progressive grade and final course grade were deemed inappropriate for the academic performance linear regression analysis, as both of these measures of academic performance included assessment items that were completed before the measurement of end-of-semester self-efficacy. While exam performance is not a measure of academic capacity, the strong relationship with progressive grade from 11 assessment tasks spanning the semester in this study suggests the final exam score is likely to be a reasonable indicator of academic performance in this course and that assessment performance was reasonably stable both across the semester and across different assessment tasks. Given the significant contribution of progressive grade to both final exam score and end-of-semester self-efficacy, it is surprising that end-of-semester self-efficacy was not related to final exam score.

The progressive grade was drawn from multiple tasks assessing a diverse range of skills and knowledge application. As such, the contrasting lack of association between biology self-efficacy scores and final exam mark may reflect a discordance between the tasks measured in the Biology Self-Efficacy Scale and the skills or knowledge assessed on the exam. Bandura (2012) argues that, although measures of self-efficacy can be broad, alignment between the measure of self-efficacy and the performance outcome measure is important. A meta-analysis conducted by Multon *et al.* (1991) found that the strongest effect sizes between self-efficacy and performance were reported when measures of self-efficacy closely aligned with measures of academic performance. For example, a student answers a long division question and then receives a question about his or her self-efficacy in completing long division. Lower effect sizes were reported in studies using general achievement measures, such as course grades or standardized achievement tests. In support of this argument, our results showed that student responses to a specific item on the Biology Self-Efficacy instrument asking specifically about their confidence in achieving a grade of 6 or above for the course were strongly related to final course grade (Figure 4B). Taken together with the variations in gains students reported on subscales of the Biology Self-Efficacy instrument, these results suggest that the instrument may be useful in both macro- and microlevel analyses of biology self-efficacy.

When examining the match between students' performance and self-efficacy, we found a considerable proportion of both low- and high-achieving students displayed a mismatch between their confidence and performance (Table 7). This suggests that some students have difficulty using performance feedback to accurately judge their ability. Similar inaccuracies in calibration between perceived ability and performance have been well documented in a variety of disciplines (Kruger and Dunning, 1999; Hacker *et al.*, 2000; Bell and Volckmann, 2011; Pazicni and Bauer, 2014; Zell and Krizan, 2014). In education, low-achieving students have been shown to overestimate their ability, whereas high-achieving students often underestimate their ability (Hacker *et al.*, 2000; Bell and Volckmann, 2011; Pazicni and Bauer, 2014). The current study demonstrates similar findings, with nearly a quarter of high achievers not being confident in their ability to achieve well in the course and 40% of low achievers erroneously being confident of high achievement. More

notably, though, this study has shown a gender effect in the inaccuracies of calibration, particularly among high-achieving students, with a significantly greater than expected proportion of females among the high-achieving students who were not confident in their ability to achieve well in the course (Table 7). This suggests that high-achieving females are much more likely than their male counterparts to underestimate their potential for achievement in biology.

The prevalence of overconfidence among low achievers is often referred to as the Dunning-Kruger effect and is explained by a lack of metacognitive awareness in individuals who perform poorly (Ehrlinger *et al.*, 2008; Boekaerts and Rozendaal, 2010; Dunning, 2011). In a 4-yr study of chemistry students, Pazicni and Bauer (2014) demonstrated that low-achieving students consistently overestimated their ability on exams, and this trend persisted over the duration of the semester. Research into the Dunning-Kruger effect often focuses specifically on the accuracy of individual ability judgments *after* the completion of an ability task such as an exam (Zimmerman and Moylan, 2009). However, there is recent evidence to suggest that students who overestimate their ability after a performance task also have inflated self-efficacy beliefs before undertaking these tasks (Ramdass and Zimmerman, 2008; Zimmerman *et al.*, 2011). In essence, these students are failing to *calibrate* their self-efficacy or ability judgments in response to performance feedback (Zimmerman and Moylan, 2009). Importantly, Zimmerman and colleagues (Ramdass and Zimmerman, 2008; Zimmerman *et al.*, 2011) have demonstrated that self-regulated learning interventions can improve the accuracy of students' self-efficacy perceptions, ability perceptions, and performance in both school and college-level math. The interventions provided students with an opportunity to explicitly reflect on their performance and the accuracy of their self-efficacy judgments, while providing instruction on using feedback to improve mathematical performance. These promising results suggest that similar self-regulatory interventions could be beneficial in biology and may target students with inaccurate self-efficacy beliefs. However, it is important to consider the negative impact of lowering biology self-efficacy (Pajares, 1996). Therefore, any intervention designed to target self-efficacy calibration should be paired with strategies for improving performance (Ramdass and Zimmerman, 2008; Zimmerman *et al.*, 2011) and encouraging an incremental belief in intelligence in which intelligence is seen as malleable and can be changed with effort and experience (Dweck, 2000; Komaraju and Nadler, 2013). Interestingly, belief in the incremental theory of intelligence has been associated with high self-efficacy, while the converse belief in the entity theory of intelligence (that intelligence is fixed and independent of effort) is associated with low self-efficacy (Dweck, 2000). Therefore, self-regulatory interventions prompting students to assess the accuracy of their biology self-efficacy and fostering an incremental theory of intelligence might also be beneficial for students with low self-efficacy and low performance, potentially providing these vulnerable students with tools to confidently face academic challenges at university.

In conclusion, the Biology Self-Efficacy Scale may be a useful tool for assessing confidence in biology skills in both majors and nonmajors; particularly in first-year students, who may be unaware of university expectations and may start

with inaccurate or inflated self-efficacy judgments. The scale may also be a valuable resource for identifying students with persistent self-efficacy inaccuracies despite receiving performance feedback. Further research is required to determine the most effective intervention to encourage accurate self-efficacy evaluations without hindering motivation in struggling students. One possible option would be to combine interventions that focus on self-regulation and implicit theories of intelligence. Such interventions would also be valuable for high-achieving female science students, who, in our study, were more likely than males to underestimate their ability. This is particularly pertinent at a time when women continue to leave the sciences at almost every stage of the science career pathway (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies, 2007).

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