## Title

Using writing in science class to understand and activate student engagement and self-efficacy



**Authors**

Camfield, Eileen
Beaster-Jones, Laura
Miller, Alex
et al.

**Publication Date**

2020-05-13

Peer reviewed

Chapter 8

# Using Writing in Science Class to Understand and Activate Student Engagement and Self-Efficacy

Eileen Kogl Camfield, Laura Beaster-Jones, Alex D. Miller, and Kirkwood M. Land

**Abstract** Writing is an active learning strategy strongly linked to student engagement. Student-authored learning narratives can reveal powerful self-beliefs that can either activate or inhibit success. In this targeted study of the aspect of student engagement most associated with self-beliefs (i.e., self-efficacy), students in separate sections of an introductory college biology course taught by the same professor were divided into experimental and control groups. The experimental group participated in an additional 1-unit required study skills component featuring writing-to-learn and self-efficacy development strategies. 140 "pre" and "post" student self-efficacy narratives written in both cohorts were scored and also thematically coded. Scoring revealed a Cohen's effect size $d = 0.63$ for the experimental group, but only $d = 0.28$ for control. Thus, writing appears to activate student self-efficacy most if it is part of a deliberate and sustained campaign. Gains seemed particularly impactful for struggling students, as the experimental group also saw significantly fewer students, with unmet fundamental skills earning Ds and Fs in the course than those in the control group. Subsequent student interviews were also analyzed and informed recommendations for future research and pedagogical practice.

## Introduction: Why Writing in Science Class?

Consider these written statements made by several first-semester freshmen on the first day of their introductory biology course:

> "*I'm honestly pretty nervous about this class because I am not that great at science. My strengths are that I can follow directions and work well in groups. My weaknesses are solving hard math problems and being independent*."

> "*I've heard this class is really hard*, *and I am always much slower than my classmates.*"

> "*I'm really scared about this class because I failed it once before. If I don't pass this time, I'll have to change majors and maybe withdraw from this university*."

> "*In high school I had a biology teacher that barely taught and everyone passed by doing nothing.*"

What sorts of self-beliefs did these students have about their abilities before they even walked in the college classroom? How might these beliefs influence their abilities to bounce back from set-backs they may encounter over the course of the semester? Now imagine yourself their professor. How might you adjust your pedagogy to respond to these students' concerns? How might you change their inner-narratives? Is that even possible?

These were the questions this interdisciplinary research team asked as we refined our ongoing efforts to improve success rates in our introductory college biology courses. Given that "the relationship between the amount of writing for a course and students' level of engagement…is stronger than the relationship between students' engagement and any other course characteristic" (Light, 2001, p. 5), early on we believed writing to be an essential – but all-too-often missing – ingredient in biology courses. Indeed, the fact that writing is identified as a high-impact practice (Kuh, 2008), simultaneously creating more authentic and inviting occasions for learning (Bain, 2004, p. 62-63) and serving as "the most intensive and demanding tool for eliciting sustained critical thought" (Bean, 2001, xiii), makes it even more indispensable. Thus, our past work has examined the impact of using writing as both an active learning strategy and method of assessment (Camfield, McFall, & Land, 2015) and has demonstrated a strong connection between writing in biology classes and student engagement (Camfield & Land, 2017).

Because the student narratives collected for these previous studies revealed powerful self-beliefs that seemed to either activate or inhibit success, we wanted to know more and believed that a targeted study of the aspect of student engagement most associated with self-beliefs (i.e., self-efficacy) was indicated. Building on methods from our past work, we planned to use writing as both an assessment tool (to evaluate student levels of self-efficacy and to note any changes over time) and as an activator of self-efficacy (to stimulate student engagement in ways that might change self-perceptions). As this chapter will develop in detail, self-efficacy scores improved most dramatically for those students in our experimental group, who were required to write more; however, common themes emerging from the 140 self-efficacy narratives gathered from both the experimental and control groups underscore the self-efficacy struggles shared by many students.

*Why Self-Efficacy Matters in Science Class*

Self-efficacy was a natural focus for our project. Bandura (1994) demonstrated that self-efficacy enhances human accomplishment and personal well-being in many ways. His work, and the work of many others, has shown that those with strong senses of self-efficacy are open to new challenges, have greater intrinsic interest in learning tasks, and persist even after facing set-backs. They are more likely to have agency and to take pro-active responsibility for negative outcomes, as opposed to feeling personally threatened or overwhelmed by failure. Conversely, those with low levels of self-efficacy conflate performance with basic aptitude, can engage in self-blame, catastrophize, and suffer from high levels of stress and depression. They sometimes give up before they have even begun a task because they believe themselves fundamentally unsuited to difficult work, which they perceive as a personal threat. In these ways self-efficacy seems related to mindset (Dweck, 2006), resilience (Werner, 1989; Masten, 2001; Smith, Tooley, Christopher & Kay, 2010), and grit (Duckworth, 2007). Further, self-efficacy and resilience are both associated with positive emotions (Fredrickson, 2001; Tugade & Fredrickson, 2004), which can be predictive of student success (Gibbons, Blanton, Gerrard, Buunk & Eggelston, 2000; Pritchard & Wilson, 2003; Kerr, Johnson, Gans & Krumrine, 2004).

In terms of first-year college students, "academic self-efficacy and optimism were strongly related to performance and adjustment, both directly on academic performance and indirectly through expectations and coping perceptions (challenge-threat evaluations) on classroom performance, stress, health, and overall satisfaction and commitment to remain in school" (Chemers, Hu, & Garcia, 2001). Moreover, Tolman and Kremling (2017) remind us that "motivation and learning require interaction between students and instructors…Whereas positive experiences enhance learning, negative experiences affect students in a way that hinders learning and graduation" (p. 129). Given this background, we believed understanding something about the foundations for and levels of our students' self-efficacy beliefs could help us more intentionally interact with students to foster their resilience and motivation to persist in our introductory biology courses.

We are not alone in our belief that science student self-beliefs are connected to engagement, are critical to predicting student success, and may be the key to understanding why half of those students who enter STEM fields fail to persist (Hanauer & Bauerle, 2012). "Self-efficacy predicts initial engagement and task performance; in turn, success leads to greater intrinsic interest and a greater likelihood of engaging in that task in the future, often at a more challenging level" (Rittmayer & Bayer, 2008). Unfortunately, there are few comprehensive studies that look specifically at student self-efficacy in introductory college biology courses. Some that exist suggest that one might expect to see a drop in first-year *Biology Self-Efficacy (BSE)* levels, perhaps owing to the fact that students enter having an "inflated" sense of their skills based on their high school course experiences and must calibrate to the more challenging demands of college biology courses (Lawson, Banks, & Logvin, 2007). Others document increases in student self-efficacy development but also note poorly calibrated initial self-perceptions (Ainscough et al, 2016). After observing similar self-perception inflation, Mann and Golubski (2013) recommend development of student metacognitive skills to help with the transition from high school to college-level biology course demands as a key part of targeted retention efforts. Beyond these and studies of student self-efficacy in other disciplines, little is empirically known.

Given this, Trujillo and Tanner (2014) assert the importance of investigating how students *feel* in college biology classrooms and call for "more research and development of self-efficacy assessment tools specifically for the undergraduate biology classroom" (p. 10). Their article delineates the various methods previously used to measure student self-beliefs and attitudes, revealing that most involve standardized questionnaires and scales, noting that "there is not yet a well-established self-efficacy assessment tool tailored to biology learning contexts" (p. 8). Our intention was to take up their call for more empirical research into *BSE* but not to develop a questionnaire because we feared asking closed-ended questions could prime and skew student responses. Instead we chose to honor fully the lived experiences of students in their biology classrooms. Thus, in our investigation we used short student-written narratives composed on the first and last days of the semester to create portraits of the ways students' identities changed over time and the factors that influenced that change. These narratives were later augmented with student interviews. This method aligns with the work first-author Camfield (2015, 2016) has previously published on the development of writing self-efficacy. Moreover, it allowed us to examine the as-yet-unexplored ways the "affective aspects of learning are interrelated" (Trujullio & Tanner, 2014) and ultimately to recommend using writing to influence multiple affective vectors.

## Context: Our Students and Our Biology Course

As indicated in the previous section, for the past several years collaborators at the University of the Pacific, a mid-sized comprehensive university in the Central Valley of California, have attempted to understand and improve student persistence rates in our introductory biology classes, which mirror the national average of D/W/F rates that hover around 50%. The more we studied the phenomenon, the more we supported the National Research Council's (2012) call to include the affective domain of the student experience as an essential element of understanding and improving learning in undergraduate science. This call seemed particularly salient for Pacific's student population that carries nationally-recognized attrition risk factors associated with ethnicity (23.3% of Pacific students identify as white, non-Hispanic) and socio-economic status (33% of Pacific students are Pell eligible). Additionally, the approximately 3,500 undergraduates at Pacific rate their academic self-concept (i.e., ability, confidence, and drive to achieve) lower than their peers at other comparable institutions (CIRP Freshman Survey), and only a 47.1% of incoming students report a strong sense of belonging at the end of the first year (CIRP-YFYC Survey). Add to this the record-low mental and emotional health rates reported by incoming college students in general (Klein, 2010), and we have all the ingredients for profound academic vulnerability. Further, 46.2% of Pacific's student population are pursuing a career in medical or health professions, as compared to only 22.5% of students at peer institutions (CIRP Freshman Survey). This means Pacific has a proportionately high number of at-risk students who will need to pass through the introductory biology course gateway in order to pursue their desired professional path. Unfortunately, many Pacific students seem averse to help-seeking in the form of utilizing faculty office hours.

Principles of Biology (BIO 061) is the first semester of a two-semester introductory biology course sequence. Approximately 500 students enroll in the 5-unit course per semester, and it is divided into 6-8 lecture sections, with maximum enrollments of 80 students, taught by Biology Department faculty. Lectures meet three times a week for 75-minutes. Twenty-five sections of an additional one-unit 3-hour weekly lab (with enrollment capped at 20 students) are run by graduate students. Course topics covered include cellular and molecular biology, cellular energetics, biochemistry, genetics and physiology.

## Interventions for Enhancing Self-Efficacy

In fall 2017, Land taught two sections of the introductory biology class. Students were randomly selected to be placed either in an experimental cohort (N=59) or in a control group (N=53). Both groups received the same lectures (which also included study tips), the same three exams, each including a required take-home essay, and were populated across a number of lab sections.

Those in the experimental cohort, dubbed BIO "Plus," received an additional, one-unit, required, on-line hour of academic coaching (dubbed "studio") from Land each week. Intended as a robust student-success-oriented intervention, the Plus portion connected academic support to all students in the class, rather than relying on optional office hours or tutoring that only a few students might voluntarily use. One goal was to follow the recommendation to build student metacognitive skills in order to ease the transition from high school biology into the college-level course (Mann & Golubski, 2013). To pursue this objective and also to build student self-efficacy, BIO "Plus" studio time was primarily designed around a variety of writing-to-learn activities. These included daily writing "lecture wraps" where students identified the most salient "take-away" points from class. After a few weeks, students were challenged to create a thesis that synthesized these salient points and subsequently to peer review each other's ideas. When students encountered ideas that differed from their own, they were encouraged to consider the source of the discontinuity and examine the validity of alternative perspectives. Thus, we hoped writing would deepen their learning by encouraging reflection and metacognition, as is established in the literature about effective learning habits (Brown, Roediger & Mc Daniel, 2014). We also hoped emphasizing what was learned would develop a sense of *mastery* and the peer review would provide valuable *modeling* – both key elements in fostering student biology self-efficacy (Bandura, 1994).

Moreover, affective concepts like self-efficacy, grit, and resilience were explicitly discussed in the on-line coaching sessions.

*Student-Written Self-Efficacy Narratives*

Our primary intention was to use these two distinct data sets to examine the effects, if any, of minimal (control group) and robust (experimental group) use of writing-to-learn strategies on student biology self-efficacy. Regarding sample configuration, the nature of Pacific's competitive pre-dentistry program selects students who are generally efficacious and high-achieving. As no pre-dentistry majors happened to be enrolled in the experimental group, pre-dentistry majors were removed from the control group in an attempt to create more similar groupings for purposes of comparison. The experimental sample size (n=39 of N=59) was projected to provide a 0.95 confidence level with an allowable acceptable error rate of +/-0.085.

Our methodology aligned with the protocols established by Camfield (2016) in her work on writing self-efficacy. Students in both cohorts completed pre- and post- self-efficacy narrative surveys where they responded freely, in writing, to the prompt: *Describe your strengths and weaknesses as a biology student, drawing on your past experiences to illustrate your claim*. Most students wrote 3-to-5-sentence responses; post-surveys were generally longer than pre-surveys. The open-ended nature of these surveys allowed students to express their lived experiences without the limitation of a more structured instrument.

## Results

*Self-Efficacy Score Changes*

Surveys were evaluated in two ways: (1) pre- and post- surveys scored by three independent raters according to a self-efficacy rubric (see Appendix A), created and published by Camfield (2016), and modified for biology, and (2) thematic coding revealing salient motifs and core categories that characterized aspects of the students' self-efficacy (Charmaz, 2000). Each student's self-efficacy narrative was scored for evidence of *efficacy, mastery, modeling, affect,* and *social agency* on a scale of -1 to 3. The average of the five scores was calculated to give a self-efficacy mean score for each student and each course/time period. The student average self-efficacy scores were, in turn, averaged to create aggregated course self-efficacy mean scores.

Table 8.1 Student Reported Self-Efficacy Scores Compared

| BIO Plus "Pre" (n = 39)* | BIO Plus "Post (n=39)* | | BIO Control "Pre" (n=31)* | BIO Control "Post (n-31)* |
|---|---|---|---|---|
| Mean (μ) = 0.89<br>SD = 0.91<br><br>Very weak evidence of efficacy | Mean (μ) = 1.44<br>SD 0.84<br><br>Approaching moderate evidence of efficacy<br><br>*Effect size Cohen's d = 0.63 (med.+)* | | Mean (μ) = 1.09<br>SD = 0.89<br><br>Weak evidence of efficacy | Mean (μ) = 1.35<br>SD = 0.95<br><br>Approaching moderate evidence of efficacy<br><br>*Effect size Cohen's d = 0.28 (small)* |

* Note: Not all students turned in both pre- and post- narratives, thus subsequent analysis reflects sub-populations of the two cohorts [Bio Plus N=59 and Bio Control N=52].

The students in the Plus section began the semester with 22.47% *lower* overall *BSE* than those in the control group, but by the end of the semester *they had surpassed the control by* 6.25%. This suggests that the extra unit of writing-based support helped them close the *BSE* gap.

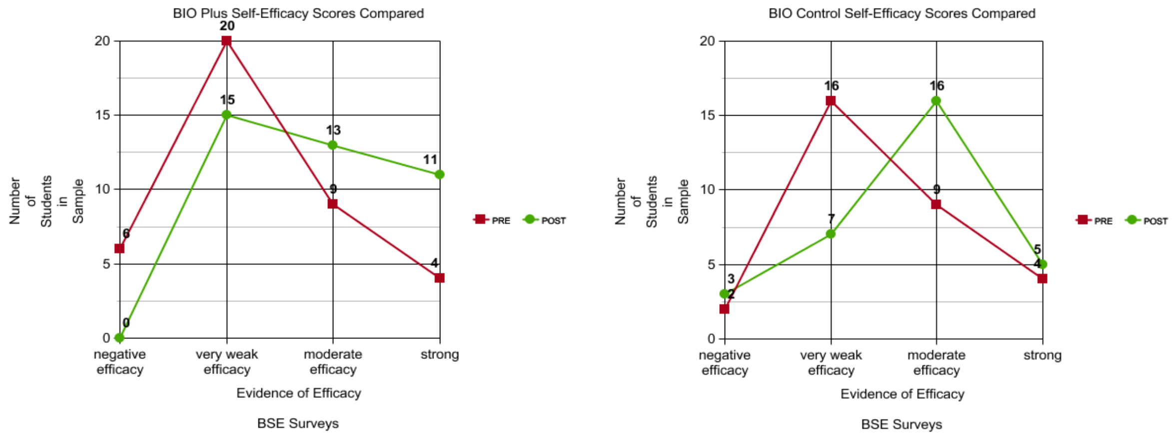


Figure 8.1. Changes in Self-Efficacy Scores Compared

Unfortunately, improvement in self-efficacy did not cause improvement in course performance. In fact, students in the control group on average earned higher grades in the class than those in the experimental group. However, it is widely recognized that building biology self-efficacy is not about improving short-term grades but is more related to improving reasoning abilities, including the ability to accurately recognize what you do not know (Lawson, Banks, & Logvin, 2007) and activating the motivation to persist beyond setbacks. As we examined final course grades in the experimental group, we noted that even those students who did not earn high grades in the class felt greater confidence in their capabilities as biology students by the end of the semester. Moreover, some of the grade differences between our two cohorts can be accounted for by the fact that the experimental group was less academically prepared than the control group. Once students' SAT/ACT scores, which determine "college readiness" and placement into fundamental or basic skills courses, are factored into the equation, the differential performances begin to make more sense.

Table 8.2 Course Performance Compared to Academic Risk Factors

| | Rate of students earning D or F or Incomplete | Percentage of students entering with unmet fundamental skills in math, writing, or both. | Percentage of students with unmet fundamental skills earning grades of D, F, W, or Inc. |
|---|---|---|---|
| BIO Plus Experimental *Sub-Group*, included in *BSE* study (n=39) | 46% D/F (18 students) | 41% of cohort (16 of 39 students) | 69% (11 of 16 students) |
| BIO Reg. Control Sub-Group, included in *BSE* study (n= 31) | 26% D/W/F/I (8 students) | 19% of cohort (6 of 31students) | 83% (5 of 6 students) |

Table 8.2 demonstrates that the experimental sub-group contained proportionately more than twice as many students with unmet fundamental skills than the control group. From this, we might also conclude those students who enter Pacific with unmet fundamental skills in writing and/or math

appear to be at a significantly higher risk of earning a D or F in introductory biology. So, it is encouraging to see that students in the experimental group made such dramatic improvement in their self-efficacy. Table 8.2 also indicates that the at-risk students in the experimental group fared better than their counterparts in the control group, only 69% earning a D or F as opposed to 83% in control.

Further, when improvements in individual self-efficacy scores were compared, we noted that 33% of the students in the experimental group made a big (a full rubric point or more) self-efficacy gain by semester's end, whereas only 23% of students in the control group achieved similar improvements. Additionally, despite the fact that the experimental groups contained weaker students, no students withdrew from the course (as opposed to three who withdrew from the control group), suggesting self-efficacy may have been a factor in persistence.

So far, comparing the two data sets reveals divergent results, confirming our hypothesis that robust writing-to-learn strategies positively impacts student self-efficacy development. Whereas minimal use of writing-to-learn strategies (i.e., control group) has little positive effect on overall student biology self-efficacy development.

*Thematic Analysis of BSE Narrative Surveys*

Nevertheless, when we began digging into the students' narratives and coding for *BSE* themes, parallels in student descriptions were striking. While much of the data shared in the previous sections could have been captured through a closed-ended survey questionnaire, part of the beauty of using open-ended narrative surveys is that they allow for thematic coding of salient themes pertaining to the specific experiences of students in our classes, allowing us to track the self-beliefs and affective states they began the semester with, ended the semester with, and the factors that leveraged change. Using grounded theory methodology (Charmaz, 2000), two readers began with open coding, highlighting and labeling key phrases in the 140 student narratives collected from the experimental and control groups. Categories were generated from the key phrase codes. Discussed here are those that emerged as most salient. Identified as *core categories*, these two thematic elements were shared by students within and often across the two cohorts.

*Incoming Attitudes: Past (Un)mastery Experiences and Their Fallout*

In their initial narratives**,** many students expressed negative past experiences with a science course. Previous biology self-efficacy research has demonstrated that "high school biology and chemistry contributed to self-efficacy at the beginning of the semester" (Ainscough et al, 2016), and our work confirms this finding. Student narratives described having high school teachers who ran the gamut from those who "*taught us nothing*" to those that "*made me love science*." When those experiences were negative, they contributed to high levels of anxiety, often compounded by negative social comparison to others in class (e.g., "*Everyone else took AP Biology in high school, so I am behind.*"), inappropriate expectations (e.g., "*I should be able to learn things more quickly*."), and fixed/categorical self-conceptualization about oneself as biology student (e.g., "*I've always sucked at science*."). Observe what happens when anxiety is correlated with grades earned in the course.

Table 8.3 Final Course Grade Distributions and Incoming Anxiety

| BIO Plus (n=39, those who completed *BSE* survey) | BIO Control (n=31, with pre-dentistry majors removed and reflecting those who completed the *BSE* survey) |
|---|---|
| A = zero<br>B = 6 [50% of students earning this grade reported incoming anxiety]<br>C = 12 [50% of students earning this grade reported incoming anxiety]<br>D = 16 [63% of students earning this grade reported incoming anxiety]<br>F = 4 [25% of students earning this grade reported incoming anxiety] | A = 1 [no academic anxiety expressed]<br>B = 9 [no academic anxiety expressed]<br>C = 13 [13% of students earning this grade reported incoming anxiety]<br>D = 7 [29% of students earning this grade reported incoming anxiety]<br>F = zero<br>INC = 1 [100% expressed anxiety] |

Based on this we postulate that levels of student anxiety help account for why the control cohort out-performed the experimental "plus" group, ie. because students with weaker academic preparation (manifested in lower SAT scores) experience more anxiety than those with higher scores. What is unknown is the extent to which initial/incoming anxiety and fixed mindset are actually predictive of course performance.

*Self-Regulation Issues*

These were described as time management problems (often compounded by course load that included other challenging classes, like chemistry) and lack of help-seeking. One student, who earned an F in the experimental group, wrote: "*My feeling after this semester is not the best because small changes could have helped me succeed way more… I don't know what questions to ask when I don't understand*." Self-regulation problems were exacerbated by disengagement with learning that felt like "*regurgitation*," where success was determined by "*feats of memorization*." Students also associated feeling disengaged with poor course performance but tended to blame themselves for their lack of intrinsic motivation: "*I just couldn't bring myself to memorize all those amino acids, so it was no wonder I did badly on the mid-term."* Students expressed other notable self-regulation problems relating to getting overwhelmed: "*I tend to second guess myself and doubt when situations get hard*," from a student who earned an F in the experimental group, and not knowing how to connect material or "*attack*" a task. This latter was an especially frequent comment in the control group's responses, which perhaps is not surprising as they did not engage in daily writing to reinforce study skills strategies shared in class. A student who earned a D+ observed: "*I feel that I half know things that I learned…stuff makes sense in lecture but on multiple choice it no longer makes sense*." However, the news is not all bad. A different student, from the experimental group, commented that "*Discipline from this course helped me mature my mindset and also become more patient with my weaknesses*."

*Observations from Student Interviews*

Another way we collected information about the "invisible" experiences of the students in the two class cohorts was through formal interviews. With the professor absent from the room, Camfield and Miller questioned the students about their experiences, asking specifically about advice they would give to themselves if they could travel back in time to the first day of class; about any changes in their confidence levels since the first day of class; about one thing the professor did to optimize their learning, and about their proudest moment in the class. Interviews were recorded, transcribed, and coded. Here are the salient motifs.

*"Micro-investments"*

Small gestures from the professor, which require little effort, can have *huge* positive effects on all students. Spontaneously and specifically identified by students in both cohorts, these seem likely to be related to the concept of mediated-efficacy discussed elsewhere by Camfield (2016), which postulates that self-efficacy may actually be a misnomer because it "relies on a conceptualization of independence and individuality that contradicts what students report" (p. 8). In contrast to *self*-efficacy, *mediated*-efficacy is forged in the relationship between student and professor. In essence everything depends on getting that relationship right – too adversarial and students collapse under the burden of adversity; too distant and students feel uncared for; too lenient and students do not feel challenged. In the context of mediated efficacy, course content serves as a tool with which a student can build a new science identity.

The micro-investments our biology students identified included that Land learned all students' names, was responsive to e-mail and accessible outside of class, and often dropped into lab to "visit" for a couple of minutes. Students felt these things established community, showed that he cared, and built connections and accountability across elements of the course. They appreciated that he would call on a *small group* of students to confer and collaboratively answer a question during lecture (rather than "pick on" individuals), provided copies of PowerPoint slides to assist with note-taking, developed real-life analogies to illustrate course concepts, offered practice tests to review prior to exams, allowed them to keep their graded mid-term exams to use as study tools for the final exam, forced them to correct missed test answers, and wove study tips and time management advice into lectures. The effect of these actions might increase engagement and support self-regulation in ways that reduce anxiety, build study skills, prime recall, model how to synthesize ideas, create trust, and foster reflection and metacognition.

*Writing*

More than half of the students in the experimental group, who experienced *more* writing (daily writing wraps with peer review in addition to the essays on exams required of both groups), recognized the value of writing and associated it with their "*proudest moment*" of the semester at a significantly higher rate than the control group (55% vs. 22%). Overwhelmingly, their pride was due to their senses of having improved as writers, and they were clear who they were performing for. One student described how it "*made my day when Dr. Land said he enjoyed reading my essay*." Another commented: "*I know I still have a lot to work on, but writing the essays gave me a great way of showing Dr. Land what I know, even if I messed up on my multiple choice sections*."

Moreover, prizing writing signals students'valuing of higher-order thinking (see Bloom, 1956), as opposed to the lower-order "*feats of memorization*." That said, 66% of students in the control group also identified "*being able to write better*" about biology/science and "*writing helping me remember and retain information*" as aspects of the course that "*built their confidence."* One was particularly pleased that he "*took a risk*" in one of his essays and "*it paid off*." The abilities to synthesize material and take intellectual risks are laudable learning outcomes for any course, and they require both brain-power and trust.

Assigning writing also helped students self-regulate: "*Writing wraps forced me to study in advance and not wait until the day before a test*." It may also have activated additional help-seeking by uncovering what students did not know. Notably, students in the experimental cohort used peer-based supplemental instruction support (a form of group tutoring) at a higher rate than students from any other sections of the course and at a 78.85% increased rate compared to Land's control section.

## Key Take-Aways

Initially, we set out to see if we could use writing as both an assessment tool (to evaluate student levels of self-efficacy and to note any changes over time) and as an activator of self-efficacy. So, did our experiment work? The answer is a qualified yes. Clearly, as an assessment tool, writing provides a rich portrait of the lived student experience in a science course. Further, in terms of activating biology self-efficacy, the students in the Pacific experimental group who experienced significant amounts of writing *and* were directly exposed to the concepts of self-efficacy, grit, and resilience made the greatest self-efficacy gains (Table 8.1). These gains seemed particularly impactful for struggling students, as the experimental group also saw significantly fewer students with unmet fundamental skills earning Ds and Fs in the course than those in the control group (Table 8.2). However, based on the evidence from the control group, it is clear that merely adding writing (e.g., a required essay on a mid-term) to a science course does not *automatically* increase student self-efficacy but can do so *if* it is part of a deliberate and sustained self-efficacy development campaign.

From these data, we have developed the working hypothesis that writing can help build a learning narrative for students (i.e., an integrated conceptual framework), which not only aids information recall/retention but also can further increase student mediated-efficacy and gratification in their learning. Writing also appears to empower student success by giving students space to digest course material, raise questions, and formulate opinions in ways that honor their agency (Gottschalk & Hjortshoj, 2004). In terms of self-efficacy (Bandura, 1994), giving students the agency to write about what *they believed* were the key take-aways from lectures provided *mastery experiences*. Viewing peers' work provided *modeling*. Receiving collaborative feedback from peers, as opposed to grades from the professor, activated a *positive learning environment*. Further, students who engaged in daily writing accompanied with peer review also developed a science identity within a *connected community*. Advocates have long argued that writing in the disciplines "brings students into a community of scholars by helping the students learn to speak that community's language" (Bahls, 2012). "In practicing writing like a scientist, a student learns to think like a scientist and to recognize the different kinds of thinking a scientist must engage in to describe, explain, predict, apply, and clarify phenomena to various audiences" (Camfield, McFall & Land, 2016). Moreover, instructor micro-investments can activate mediated-efficacy, engagement, and optimize student success regarding study skills. They build trust, community, and student sense of "belonging."

What is less clear was whether the *on-line* nature of the extra unit experienced by the experimental group activated or impeded student efficacy and identity development, or if other factors (e.g., study skill tips provided in class or the daily writing) were equally or more impactful. We certainly recognize that on-line delivery may be less effective for at-risk students (Bettinger & Loeb, 2017), and given what emerged in the student narratives about the value of their relationships with the professors, we suspect face-to-face delivery of supplemental "success" sessions might be even more impactful.

## Limitations and Directions for Future Research

Given the possible limitations of on-line delivery, our future work will compare outcomes for students receiving required face-to-face support sessions with those receiving no additional outside support, other than that which is available to them on a voluntary basis. We also experienced the challenge of comparing unlike groups of students. Having a greater number of academically underprepared students in the experimental cohort compared to the control group created an unintentional imbalance. This is the downside of random selection; therefore, when we next run this experiment, we will purposively build our sample groups.

Of additional concern is the fact that the sub-samples we used to calculate changes in *BSE* scores were relatively small (i.e., experimental n=39 vs. control n=31) and confined to a single semester. So, our results may lack statistical power and not be generalizable to other students at other institutions. Despite these challenges, 140 student self-efficacy narratives is a larger data set from which to derive potentially more reliable theme-based conclusions. However, the use of student narrative analysis, although compelling, may be unmanageable for those teaching very large classes because the coding task can be daunting. Determining other ways of uncovering "invisible" themes that pre-determined survey questions might miss is another avenue worth further exploration. Interviews and student focus groups might prove promising. Other areas for future work could involve tracking students longitudinally to see if early engagement and self-efficacy development leads to increased persistence in the major or in the university.

We also aim to expand our research to include other institutions with different student demographics and course delivery systems. Preliminary work with neighboring campus UC Merced has revealed the challenges of coordinating multiple course stakeholders in student success initiatives (two instructors trading off for 250 students in lecture, with nine graduate assistants teaching 24 discussion sections); however, similar themes are emerging from student self-efficacy narrative data.

## Recommendations

In response to recent calls to "assess intangibles" (Shaw, 2017), increased attention should be paid to understanding the "invisible risk factors" students may bring into college biology classrooms. These can include low self-efficacy and anxiety – all pre-existing the first day of the first semester. Brief written narratives can reveal unexpected facets of student experience that closed-ended numeric questionnaires might fail to illuminate. Writing also appears to activate students' senses of self-efficacy, gratification in their learning, and engagement with the course.

Moreover, students' personal stories seem more likely to elicit instructor empathy, an essential ingredient in constructing and sustaining the positive learning environment necessary for self-efficacy development.

Additionally, other important considerations emerged from our study as well, suggesting that in order to compensate against risk-factors, STEM departments and professors should build student resilience by investing in protective elements. This could entail direct self-efficacy cultivation at the course-level: providing mastery experiences, offering modeling for how students can "attack" problems and bounce back from adversity, constructing a learning environment that reduces stress and anxiety, providing students with positive messages that empower rather than weaken their self-beliefs. As José Bowen (2018) reminds us, "Finding a faculty member who believes in you is the single most important thing that can happen for a student during their undergraduate experience." Building community through cohorting and faculty mentoring could also activate student resilience. Departments could also work to integrate curriculum and/or academic support across first-year science courses [see for example Grinnell College's FOCUS Program (https://www.grinnell.edu/academics/centers/csla/focus) and Carleton College's Science Education Resource Center (https://serc.carleton.edu/index.html)].

Given the frustration expressed in so many student narratives about being required to "*regurgitate*" "*meaningless information,*" re-examining traditional curriculum and pedagogy practices is essential. For too many students, science education is something done *to* them, not done *with* them. Programs should ask "Why is memorization a prized skill in the 21st century?" or "Are high-stakes, content-loaded exams the best way to measure student understanding?" Consider instead Bowen's (2017) idea of 21st Century professors as "cognitive coaches," rather than gatekeepers. Professors should also teach transparently: Dispel rumors and avoid "*bad surprises*" where students see a disconnect between what they are being graded on and what they have studied; scaffold assignments in introductory courses to encourage self-regulation; mobilize micro-investments, and use writing to activate not only student engagement but to deepen learning and build science identity.

Finally, proceed with caution and intention. Self-efficacy and other mindset constructs appear quite malleable in a very short amount of time (Camfield, 2015) – this means that significant progress in dismantling negative constructs can happen in a single semester. However, the reverse is also true; progress can be undone quickly if subsequent courses are not aligned to support these goals.

## References

Ainscough, L., Foulis, E., Colthorpe, K., Zimbardi, K., Robertson-Dean, M., Chunduri, and Lluka, L. (2016). Changes in biology self-efficacy during a first-year university course. *CBE—Life Sciences Education, 15*(2). doi: 10.1187/cbe.15-04-0092

Bahls, P. (2012). *Student writing in the quantitative disciplines: A guide to college faculty*. San Francisco, CA: Jossey-Bass.

Bain, K. (2004). *What the best college teachers do*. Cambrdieg, MA: Harvard UP.

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopedia of human behavior* (vol. 4, pp. 71-81). New York: Academic Press. (Reprinted in H. Friedman [Ed.], *Encyclopedia of mental health*. San Diego: Academic Press, 1998).

Bean, J. C. (2001) *Engaging ideas: The faculty's guide to integrating writing, critical thinking,* *and active learning in the classroom*. San Francisco, CA: Jossey-Bass.

Bettinger, E. & Loeb, S. (2017). Promises and pitfalls of online education. *Brookings Institute Evidence Speaks Reports 2*(15). https://www.brookings.edu/wpcontent/uploads/2017/06/ ccf_20170609_loeb_evidence_speaks1.pdf.

Bloom, B., Englehart, M. Furst, E., Hill, W., & Krathwohl, D. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain*. New York: Longman.

Bowen, J.A. & Watson, C.E. (2017) *Teaching naked techniques*. San Francisco, CA: Jossey-Bass.

Bowen, J.A. (2018). “Technology, the Liberal Arts and the New Learning Economy.” Ernest L. Boyer Award Acceptance Speech. Association of American Colleges and Universities, National Convention, Washington, D.C.

Brown, P. C., Roediger, H. L., & M. McDaniel. (2014). *Make it stick: The science of successful learning*. Cambridge, MA: Harvard UP.

Camfield, E. K. (2015). Fast and fruitful: Effective writing assessment for determining the success of new initiatives. *Assessment Update 28*(6), 5-14. doi:10.1002/au.30039

Camfield, E K. (2016). Mediated-efficacy: Hope for “helpless” writers. *Journal of Developmental Education, 39*(3), *2-11*.

Camfield, E.K., McFall, E.E., & Land, K.W. (2016). Leveraging innovation in science education: Using writing and assessment to decode the class size conundrum. *Liberal Education*, *101*(4)/*102*(1), 64-71.

Camfield, E.K. & Land, K. M. (2017). The evolution of student engagement: Writing improves teaching in introductory biology courses. *Bioscene: Journal of College Biology Teaching, 43*(1), 20-26. ISSN 1539-2422

Charmaz, K. (2000). Grounded theory: Objectivist and constructivist methods. In N.K. Denzin & Y.S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 509–535). Thousand Oaks, CA: Sage.

Chemers, M. M., Hu, L. T., & Garcia, B. F. (2001). Academic self-efficacy and first year college student performance and adjustment. *Journal of Educational Psychology*, *93*(1), 55.

CIRP Freshman Survey at University of the Pacific (2016), Higher Education Research Institute, UCLA.

CIRP-YFYC Survey at University of the Pacific (2016), Higher Education Research Institute, UCLA.

Dasgupta, N. (2011). Ingroup experts and peers as social vaccines who inoculate the self-concept: The stereotypes inoculation model. *Psychological Inquiry*, 22(4), 231-246.

Duckworth, A.L., Peterson, C., Matthews, M.D., Kelly, D.R. (2007). "Grit: Perseverance and passion for long-term goals." *Journal of Personality and Social Psychology, 92* (6): 11087–1101. doi:10.1037/00223514.92.6.1087.

Dweck, C. S. (2006). *Mindset: The new psychology of success*. New York, NY: Random House.

Fredrickson, B. L. (2001). The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions. *American Psychologist*, *56*(3), 218.

Gibbons, F. X., Blanton, H., Gerrard, M., Buunk, B., & Eggleston, T. (2000). Does social comparison make a difference? Optimism as a moderator of the relation between comparison level and academic performance. *Personality and Social Psychology Bulletin*, *26*(5), 637-648.

Gottschalk, K., & K. Hjortshoj. (2004). *The elements of teaching writing: A resource for instructors in all disciplines*. New York, NY: Bedford/St. Martins.

Hanauer, D. & Bauerle, C. (2012). Facilitating innovation in science education through assessment reform. *Liberal Education 98*(3), 34.

Kerr, S., Johnson, V. K., Gans, S. E., & Krumrine, J. (2004). Predicting adjustment during the transition to college: Alexithymia, perceived stress, and Psychological symptoms. *Journal of College Student Development*, *45*(6), 593-611.

Klein, A. (2010). Incoming college students rate emotional health at record low, annual survey finds. *Higher Education Research Institute*.

Kuh, G. (2008). *High-impact educational practices: What they are, who has access to them, and why they matter*. Association of American Colleges and Universities, Washington, D.C.

Lawson, A.E., Banks, D.L., Logvin, M. (2007). Self-efficacy, reasoning ability, and achievement in college biology. *Journal of Research in Science Teaching 44*, 706-724.

Light, R. J. (2001). *Making the most of college: Students speak their minds*. Cambridge, MA: Harvard UP.

Mann, M.J. & Golubski, C. (2013). *Self-efficacy and first year biology majors*. Presentation at NABT Biology Education Research Symposium, Atlanta, GA.

Masten, A. S. (2001). Ordinary magic: Resilience processes in development. *American Psychologist*, *56*(3), 227.

National Research Council (2012). Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering, Washington DC: National Academies Press.

Pritchard, M. E., & Wilson, G. S. (2003). Using emotional and social factors to predict student success. *Journal of College Student Development*, *44*(1), 18-28.

Reivich, K., & Shatté, A. (2002). *The resilience factor: 7 essential skills for overcoming life's inevitable obstacles*. New York: Broadway Books.

Shaw, R.J. (2017). Assessing the intangible in our students. *Chronicle of Higher Education.* July 27, 2017. https://www.chronicle.com/article/Assessing-the-Intangible-in/240744

Smith, B. W., Tooley, E. M., Christopher, P. J., & Kay, V. S. (2010). Resilience as the ability to bounce back from stress: A neglected personal resource?. *The Journal of Positive Psychology*, *5*(3), 166-176.

Rittmayer, A.D. & Beier, M.E. (2008). SWE-AWE-CASEE ARP Resources – Self-Efficacy in STEM. *SWE-AWE CASEE Overviews*. Retrieved 2 October 2018 from http://www.AWEonline.org.

Tinto, V. (1993). *Leaving College: Rethinking the Causes and Cures of Student Attrition*, 2nd ed., Chicago: University of Chicago Press.

Tolman, A. O. & Kremling, J. (2017). *Why students resist learning: A practical model for understanding and helping students*. Sterling, VA: Stylus Publishing.

Trujillo, G. & Tanner, K.D. (2014). Considering the role of affect in learning: Monitoring students' self-efficacy, sense of belonging, and science identity. *CBE—Life Sciences Education 13*, 6-15.

Tugade, M. M. & Fredrickson, B. L. (2004). "Resilient individuals use positive emotions to bounce back from negative emotional experiences". *Journal of Personality and Social Psychology 86***,** (2): 320–33. doi:10.1037/0022-3514.86.2.320.

University of the Pacific Institutional Research. *Fast Facts 2017.* http://www.pacific.edu/about-pacific/administrationoffices/institutional-research/official-information/fast-facts-2017.html

Werner, E. E. (1989). *Vulnerable but invincible: a longitudinal study of resilient children and youth*. New York: McGraw-Hill.

# APPENDIX A: Self-Efficacy Scoring Rubric (Pre and Post Instruction)

**BIOLOGY "Plus" Self-Efficacy Scoring Rubric -- Pre**

In the first studio sessions of this semester, students wrote Efficacy Statements describing their perceived strengths and weaknesses as biology students and providing some personal experiences *form past science classes* to support their claims. In reviewing these "pre" diagnostics, please score each sample using the following scale.

**Evidence of Belief in Ability:** The student is able to identify elements of being a successful biology student AND *demonstrates belief in his/her ability to use these elements successfully*. If the student identifies problems or learning challenges, he/she offers possible solutions to these problems. The student may demonstrate awareness of learning as a process (or of "growth mindset") and is able to prioritize specific future tasks. The student may comment on effective management of time to effectively fulfill an assignment.

| | | | | |
|---|---|---|---|---|
| -1 | 0 | 1 | 2 | 3 |
| negative evidence | lack of evidence | very weak evidence | moderate evidence | strong evidence |

**Evidence of Mastery Experiences**: The student describes having had successful experiences in past science classes at some point in the process (i.e. student does not have to have "mastered" the entire subject to have had mastery experiences).

| | | | | |
|---|---|---|---|---|
| -1 | 0 | 1 | 2 | 3 |
| negative evidence | lack of evidence | very weak evidence | moderate evidence | strong evidence |

**Evidence of Use of Positive Modeling:** The student refers to course materials and/or key figures as aspirational models used when approaching her/his own work. The student might also talk about the utility of peer and/or instructor feedback. The student might refer to his/her own successful work as models as well.

| | | | | |
|---|---|---|---|---|
| -1 | 0 | 1 | 2 | 3 |
| negative evidence | lack of evidence | very weak evidence | moderate evidence | strong evidence |

**Evidence of Low Anxiety and/or High Positive Affect:** The student uses positive or affirming adjectives to describe her/himself as a biology/science student. Student may even express confidence and/or enjoyment of the subject. Problems are accurately attributed but seen as specific and manageable (e.g. "I need to work on time management."), as opposed to global and catastrophic (e.g. "I am stupid.").

| | | | | |
|---|---|---|---|---|
| -1 | 0 | 1 | 2 | 3 |
| negative evidence | lack of evidence | very weak evidence | moderate evidence | strong evidence |

**Evidence of Empowerment or Positive Social Agency:** The student takes responsibility for his/her own outcomes, as opposed to blaming other factors for poor results. The student may express willingness to "keep trying" and attributes success to improved understanding of the subject rather than luck or external forces. The student may express "ownership" of the subject or of his/her learning. The student may describe proactively seeking help form others (e.g., forming a study group) and/or actively utilizing available support systems (e.g., tutoring center and/or office hours).

| | | | | |
|---|---|---|---|---|
| -1 | 0 | 1 | 2 | 3 |
| negative evidence | lack of evidence | very weak evidence | moderate evidence | strong evidence |

---

**Student ID or Name:** **Score Pre-Diagnostic _______/15**