

Feature

Approaches to Biology Teaching and Learning

Considering the Role of Affect in Learning: Monitoring Students' Self-Efficacy, Sense of Belonging, and Science Identity

Gloriana Trujillo and Kimberly D. Tanner

Department of Biology, SEPAL: The Science Education Partnership and Assessment Laboratory, San Francisco State University, San Francisco, CA 94132

INTRODUCTION

Take a moment to remember what it was like to walk into a biology classroom as an undergraduate student for the first time. What were you thinking or feeling? Were you nervous, anxious, or excited? Did you think about what grade you were expecting or hoping for? Were you trying to recall what you learned in your most recent biology course? Were you wondering where you might sit or whether your friends were enrolled in the class with you? Did you do a quick scan of the students present to see with whom you might have something in common? Were you a committed biology major at this point, or were you just beginning to explore biology?

In addition to their prior conceptual biology knowledge, students bring numerous other factors into their undergraduate biology learning environments. They bring their career goals and their biases about whether the subject is one they are comfortable learning. Students also bring their "lived experience" as it pertains to biology: some knowledge about the academic culture of biology and perceptions about whether they as students will feel comfortable in this culture. Students bring ideas about the subject or about themselves and their role in the sciences based on societal stereotypes. Many lines of research support the notion that students can experience psychological repercussions from negative societal stereotypes that can influence their experiences in academic settings, a phenomenon called *stereotype threat* (Steele

and Aronson, 1995). Substantial data suggest that stereotype threat can affect students' affective experiences in classrooms to the extent that academic performance can suffer (reviewed in Schmader *et al.*, 2008). It is therefore important to consider our students' affective, nonconceptual experiences as they enter our biology courses, how these may impact their experiences in our classrooms, and how we can minimize negative impacts.

As a biology instructor meeting your class for the first time, you most likely have been provided with little background information about your students. You may have registration information that tells you about their choices of major, prior biology courses, and anticipated graduation years. But knowing what their expectations are for the course, and what they want to do when they "grow up" would be even more helpful. How comfortable do your students feel with the subject of biology or in the culture of a biology classroom? Do they have connections within the class, do they want to form study groups? Which students work 30 hours per week, or have significant family responsibilities, while taking a full course load? Getting to know your students can be a challenge. While conversations you have with students one-on-one during office hours can help, systematically collecting this type of information from every student, in the same way, can help you assess the biological conceptual ideas of all of the students at the beginning of a course and can help you be more effective. Fortunately, there are a number of ways to learn more about the affective aspects of the students entering our courses, their beliefs about their biology abilities, whether they feel a part of the biology community and how they are forming their science identity regarding biology.

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Address correspondence to: Kimberly D. Tanner (kdtanner@fsu.edu).

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INVESTIGATING THE STUDENT EXPERIENCE CAN BE IMPORTANT IN BIOLOGY TEACHING AND LEARNING

Increasingly, biology instructors are collecting evidence from students about how they think about biology concepts before,

during, and after instruction. But while enormous emphasis has been placed on getting to know students conceptually through assessments, little emphasis has been placed on investigating affective aspects of students' undergraduate science experiences. Although the information we glean from conceptual assessment data is no doubt critically important, it may not be the only kind of important information to collect about our students. Recently, there has been a national call to incorporate research on the affective domain of the student experience as a key line of inquiry in discipline-based education research (National Research Council, 2012). To begin to understand the affective experiences of students, we as biology educators will need to expand our evidence-collection tool kits to include affective measures.

Educational psychologists divide learning activities into three categories: cognitive, metacognitive, and affective (Vermunt, 1996). We are familiar with cognition as the mental processes associated with learning. Metacognition relates to becoming aware of and influencing those mental processes (Tanner, 2012). Our focus here, affective learning, is described as those activities "directed at coping with the feelings that arise during learning, . . . [leading] to an emotional state that may positively, neutrally or negatively affect the progression of a learning process" (Vermunt, 1996, p. 26). Neuroscientists are also increasingly exploring the symbiotic relationship between cognition and affect and have found that parts of the brain previously thought to function solely in cognition are also important for affect (Pessoa, 2008). How then, do we bring affective evidence collection into the undergraduate biology classroom?

Many instructors strive to take into account students' feelings and emotional responses in planning their undergraduate biology classes. An example would be starting a class session with a real-world problem, using the 5E model to evoke an emotional response to biological ideas with the initial "engage" portion of a class session (Bybee *et al.*, 2006; Tanner, 2010). However, there may be other teaching situations in which the instructor may not consider student affect or experience, and these may be the most critical moments to do so. For example, if assessment results indicate that a group of students are struggling to grasp a concept, some instructors might make the assumption that there is "something wrong" with the students, a view sometimes referred to as the student *deficit model*. This model infers that these students, otherwise equal to their peers, are somehow lacking intellectually. An alternative to the deficit model, the *dynamic model*, calls on instructors to consider those individual characteristics of students that might alter their experience of the learning environment and hinder their conceptual learning (Ford and Grantham, 2003). Instructors shifting from a deficit model to a dynamic model in an undergraduate biology classroom would consider not only cognitive aspects of learning but also affective aspects of learning that may influence students' success. What may be key to understanding and promoting student achievement is to learn more about students' beliefs about their abilities in biology contexts, whether they feel they are part of the biology community, and how they are forming their science identity regarding biology.

While describing the vast landscape of research on the affective domain in learning is beyond the scope of this feature, we present here three key constructs pertaining to the affective domain—*self-efficacy*, *sense of belonging*, and *science*

identity. Additionally, we explore emerging assessment tools that may allow biology educators to monitor this dimension of students' learning in their courses. For each construct, we begin with a definition and then explore assessment questions and tools that have been developed, largely in other disciplines, which instructors may wish to adapt to gain insights into their students' perspectives and experiences in their courses. Just asking students to reflect on one of the ideas presented below as part of an in-class quick-write or a written homework assignment is a simple step instructors can take to begin to explore, understand, and monitor the affective dimension of student learning in classrooms.

SELF-EFFICACY: HOW A PERSON ACQUIRES BELIEFS ABOUT HIS OR HER ABILITY TO DO SOMETHING

Setting up an experiment independently for the first time is a challenge. Ideally, you can watch someone do a similar experiment first to gain confidence that you have the right equipment, have included all the appropriate controls, etc. If the experiment fails that first time (which is likely!), you need to be prepared to try again. You might think about giving up. What makes the difference in your decision to persist or retreat? How many times do you have to set up an experiment before you feel confident in doing so? What might you predict about your students' beliefs in their ability to complete specific tasks in your classroom?

Self-efficacy is an aspect of social cognitive theory defined as "the exercise of human agency through people's beliefs in their capabilities to produce desired effects by their actions" (Bandura, 1997, p. vii), or as in the example above, your belief in your ability to set up an experiment correctly. The literature on self-efficacy originates with Albert Bandura's work in the 1970s, with much of the current knowledge about self-efficacy coming from disciplines such as counseling psychology and career psychology (reviewed in Usher and Pajares, 2008). Many studies have examined self-efficacy in as many domains: occupation functioning and performance, school experience, and programmatic outcomes, for example. Self-efficacy is asserted and documented to be domain specific, meaning one may have high self-efficacy in one discipline, but that level of self-efficacy does not necessarily transfer to a related discipline. Research in self-efficacy strives to answer the question, "To what extent do one's beliefs about oneself affect one's behaviors?"

Many self-efficacy researchers have focused on the hypothesized "sources" of self-efficacy, which are used to build an individual's self-efficacy (reviewed in Usher and Pajares, 2008). Four proposed sources are: *mastery experience*, *emotional/physiological states*, *social persuasion*, and *vicarious experience*. The first of these, mastery experience, relates directly to an individual's previous experiences at completing a related task. The extent to which the individual succeeded or perceived success is thought to impact their self-efficacy with respect to completing the task again. In the classroom, a student may build mastery experience for interpreting graphs after having multiple successful experiences doing so. Emotional or physiological states are those internal feelings experienced in association with successful versus unsuccessful events: joy or frustration, satisfaction or fear, for example.

Students may perceive their success at a particular task by the feelings they experience related to that task. One example may be students who experience relief at answering a difficult exam question correctly. Social persuasion is the external verbal encouragement or support received from peers, instructors, or other community members. Bandura (1997, p. 101) states, “it is easier to sustain a sense of efficacy, especially when struggling with difficulties, if significant others express faith in one’s capabilities than if they convey doubts.” Students in the classroom may benefit from the social persuasion of their friends—“You can ace this class!”—or from instructors’ comments—“Transfer of energy through cell respiration is a difficult idea for everyone, and I know you can understand this!” Finally, vicarious experience occurs when one observes the experiences of others. Individuals perceived to be at the same ability level are often models of vicarious experience, but models can also be identified based on characteristics such as ethnicity, gender, or access to resources. For students, vicarious experience frequently occurs when one compares oneself with another in an attempt to determine what the “norm” is. For example, a student receives a grade on an exam and learns how the grade compares with another student’s grade or the mean achieved by the class. Why should we as instructors aspire to strengthen self-efficacy in our students? While many instructors see self-efficacy as key to general success, many others might question the role of self-efficacy in biology conceptual learning.

Self-efficacy has been shown to mediate a number of factors, such as academic achievement, perseverance, and self-regulated learning. In geosciences, students who had low self-efficacy but strong academic backgrounds received the same grades as those with high self-efficacy and weaker academic backgrounds (McConnell *et al.*, 2010). In introductory psychology, researchers showed that, of three separate factors studied, self-efficacy was the only one that predicted grade point average (GPA; Komarraju and Nadler, 2013). Another factor that correlates with an increase in self-efficacy is perseverance. Students who have higher self-efficacy are more likely to persist in the face of difficulty (reviewed in Zimmerman, 2000; Usher and Pajares, 2008). Others have noticed this effect in studying gender differences in physics self-efficacy (Sawtelle *et al.*, 2012). Perseverance is particularly important for those students who are considering leaving the sciences altogether (Seymour and Hewitt, 1997). “Self-regulated learning” pertains to processes such as goal setting, self-monitoring, and choosing which learning strategies to use (Zimmerman, 2000). Increasing students’ self-efficacy

increases their capacity to self-regulate their learning, and thus their potential to tackle more challenging goals. However, while a large body of research has shown the positive effect self-efficacy has on academic performance, one study in biology education has suggested that efforts at improving self-efficacy to affect course performance may be ineffective in an introductory nonmajors biology course (Lawson *et al.*, 2007). Clearly, more research on the role of self-efficacy in undergraduate biology learning is needed. To conduct this research, and in the process learn more about our students, we need assessment tools to begin to measure self-efficacy in a classroom context.

MONITORING AND MEASURING SELF-EFFICACY AMONG STUDENTS

If self-efficacy is important in biology learning, then instructors may choose to monitor and address self-efficacy alongside monitoring and addressing biological concepts. In this section, we discuss examples of studies evaluating self-efficacy; in each case, we describe the intentions of the researchers, the tools they used, and key findings. While there is not yet a well-established self-efficacy assessment tool tailored to biology learning contexts, multiple tools from other disciplines are available for adaptation.

One of the most often used instruments to measure general self-efficacy is the Motivational Strategies and Learning Questionnaire (MSLQ; Pintrich *et al.*, 1991). The MSLQ has been validated for use in a variety of contexts, with junior high school students to college students, and for course evaluation, individual needs assessment in counseling, and assessment of interventions (Duncan and McKeachie, 2005). It is composed of two major scales: 1) a Motivation Scale and 2) a Learning Strategies Scale. These scales are further subdivided into multiple subscales, with one of the subscales from the Motivation Scale specifically being Self-Efficacy for Learning and Performance. A sample statement from this subscale is, “I’m confident I can do an excellent job on the assignments and tests in this course.” Additional sample statements from this self-efficacy subscale are listed in Table 1. Instructors could choose to administer the entire 81-item MSLQ, individual scales, or just the self-efficacy subscale. One example of using MSLQ in a biology context was to test the impact of active-learning strategies, such as think-pair-share, pause procedure, and minute papers in a physiology course (Wilke, 2003). Using the MSLQ, Wilke found an increase in student self-efficacy

Table 1. Statements from the Self-Efficacy subscale from the Motivated Strategies for Learning Questionnaire^a

Statement
I believe I will receive an excellent grade in this class.
I’m certain I can understand the most difficult material presented in the readings for this course.
I’m confident I can learn the basic concepts taught in this course.
I’m confident I can understand the most complex material presented by the instructor in this course.
I’m confident I can do an excellent job on the assignments and tests in this course.
I expect to do well in this class.
I’m certain I can master the skills being taught in this class.
Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.

^aFrom Pintrich *et al.*, 1991.

Table 2. Sample statements from the SOSESC-P used in physics courses for nonmajors^a

Statement	Source of self-efficacy
When I came across a tough physics question, I worked at it until I solved it.	Performance accomplishments (mastery experience)
I can remember the basic physics concepts taught in this class.	Performance accomplishments (mastery experience)
I enjoyed physics labs/activities.	Emotional arousal
My instructor encouraged me that I could use physics concepts to understand real-life phenomena.	Verbal encouragement/social persuasion
My instructor’s demonstrations and explanations gave me confidence that I could solve physics-related problems.	Vicarious learning
Watching other students in class made me think that I could not succeed in physics. (reverse-scored)	Vicarious learning

^aFrom Fencl and Scheel, 2005.

that was associated with increased academic achievement, as measured by course grades, in the context of the implementation of active-learning strategies.

Discipline-specific measurement tools that probe sources of self-efficacy have been developed and utilized in a variety of disciplines and types of institutions. One such inventory developed in physics is the Sources of Self-Efficacy Science Courses–Physics (SOSESC-P), which examines self-efficacy through the lens of its proposed four sources—mastery experience, vicarious learning, emotional/physiological states, and social persuasion. Examples of statements from the four categories used in the SOSESC-P are listed in Table 2 (development of this instrument is described in Fencl and Scheel, 2004). An example of a statement from mastery experience (referred to as *performance accomplishment* by Fencl and Scheel) is, “When I came across a tough physics question, I worked at it until I solved it.” Vicarious learning is represented in sample statements that include watching either other students or the instructor perform discipline-specific tasks, such as “My instructor’s demonstrations and explanations gave me confidence that I could solve physics-related problems.” A sample statement for the emotional/physiological states is, “I enjoyed physics labs/activities.” Finally, the social persuasion source of self-efficacy is represented by encouragement, such as: “My instructor encouraged me that I could use physics concepts to understand real life phenomena.” In their study, Fencl and Scheel examined the contributions of active-learning strategies to the sources of self-efficacy for students in a nonmajors physics course (Fencl and Scheel, 2005). They found that collaborative learning positively impacted all sources of self-efficacy monitored. While the researchers found that both classroom climate and the sources of self-efficacy correlated with use of active-learning strate-

gies, the social persuasion and vicarious learning categories had the most significant associations. These data suggest that instructors in undergraduate biology classrooms may be able to foster increases in self-efficacy—and subsequently impact conceptual learning—by encouraging students (social persuasion) and by providing role models for students to identify with in biology (vicarious learning).

In addition, there are self-efficacy assessment tools that have been developed specifically for biology (e.g., Kitchen and Reeve, 2007; Lawson *et al.*, 2007). We highlight the Biology Self-Efficacy Scale, which was implemented in an introductory biology course for nonmajors (see Table 3; Baldwin *et al.*, 1999). This scale was validated, and three major themes emerged from factor analysis: 1) methods of biology, 2) generalization to other biology/science courses, including analyzing data, and 3) application of biology concepts and skills. Questions in the methods of biology section of the Biology Self-Efficacy Scale ask about lab reports and experiments, for example: “How confident are you that you could critique a laboratory report written by another student?” The items from the section on generalizing knowledge to other courses relate to students’ confidence in their ability to succeed in other biology courses, in analyzing data, or in explaining biology to another person. One sample statement from this section of the scale is: “How confident are you that you could tutor another student for this biology course?” Finally, in the section on application of biology concepts and skills, the statements relate to one’s confidence in one’s ability to explain the biology ideas in a documentary, research paper, or public lecture to another person: “How confident are you that after reading an article about a biology experiment, you could explain its main ideas to another person?” Baldwin and colleagues did observe an increase in students’ self-efficacy

Table 3. Statements from self-efficacy scales that use biology-specific tasks, administered in biology courses for non-biology majors^a

Statement	Factor subscale
How confident are you that you could critique a laboratory report written by another student?	Methods of biology
How confident are you that you could tutor another student for this biology course?	Generalization to other science courses
How confident are you that after reading an article about a biology experiment, you could explain its main ideas to another person?	Application of biological concepts and skills

^aFrom Baldwin *et al.*, 1999.

at the end of the course, which the authors interpret as an increase in biology literacy. While this tool is an admirable initial foray, there is clearly a need for more research and development of self-efficacy assessment tools specifically for the undergraduate biology classroom.

SENSE OF BELONGING: ACQUIRING A FEELING OF BEING PART OF A COMMUNITY

Everyone has had times when they felt “out of place.” This can be in a new social setting, when you are unfamiliar with unspoken rules, or when visiting a new place, particularly one where you do not speak the local language. It can happen professionally, for example, when attending a conference outside your discipline. What gives us the feeling that we are “out of place,” and how do we cope with and overcome these feelings? What would you predict about whether your students feel “out of place” in your classroom?

The *New Oxford American Dictionary* defines “belonging” in terms of a person who “[fits] in a specified place or environment” or “[has] the right personal or social qualities to be a member of a particular group.” Research on belonging in a generalized sense is prolific in psychology, particularly as it relates to the fundamental human need to belong (Baumeister and Leary, 1995). In the literature, the phrase “sense of belonging” is most prevalent in research on belonging in higher education; therefore, we will follow suit by using this phrase.

Early research on sense of belonging in university settings focused on the integration of students of color into the campus climate (Hurtado and Carter, 1997; Lee and Davis, 2000). The concept of sense of belonging in higher education arose from attempts to understand why students leave college, particularly with Tinto’s proposal that leaving is due to a lack of social integration (Tinto, 1993). In a study that focused on Asian college students, researchers found that multicultural experiences and ethnic group identification positively correlated with Asian students’ sense of campus connectedness (Lee and Davis, 2000). Hurtado and Carter found that student engagement with course content outside the classroom increased students’ sense of belonging. They further proposed that sense of belonging is important for persistence in college, particularly for Latino students. These results further confirmed previous work that suggested student persistence toward degree attainment is related to peer-group connection and student interactions with faculty (Astin, 1993).

Other studies have introduced interventions to attempt to increase sense of belonging in groups that reportedly experience marginalization on college campuses. Walton and Cohen (2011) implemented an intervention to frame perceived adversity, such as social discomfort, as nonthreatening by presenting quotes of academically older students who had had similar experiences initially but subsequently felt an increase in their sense of belonging. The intervention was provided for first-year college students and had a positive impact on both academic and health outcomes among African-American students. The research described above and previous studies examine *social* belonging, or one’s sense of belonging in social settings on college campuses. However, there is another aspect of sense of belonging that may be even more instrumental for success in an undergraduate biology classroom: the sense of belonging within a specific academic community, namely the biology community.

Current research suggests that sense of belonging in an academic context influences individuals in at least three ways: academic motivation, academic achievement, and well-being (reviewed in Anderman and Freeman, 2004). In a study examining sense of belonging in a college classroom among first-year college students from nonmajor sections of biology, psychology, and English, researchers found the perception that an academic activity is valuable, useful, or important was strongly associated with sense of belonging (Freeman *et al.*, 2007). These results confirmed research conducted previously with younger populations of students (e.g., see Goodenow, 1993; Goodenow and Grady, 1993). In terms of academic achievement, one study showed that a sense of belonging in school positively predicted final semester grades (Roeser *et al.*, 1996), as well as predicting GPA after students transitioned to new schools (Gutman and Midgley, 2000). The third factor influenced by students’ sense of belonging in academic contexts is well-being. Students’ well-being is important in classrooms, in that students must be mentally and physically alert and engaged if they are to succeed. One study showed that school connectedness was correlated with an avoidance of risky behavior (Resnick *et al.*, 1997) and an increase in positive affect among students (Anderman, 1999). Additional research is needed to determine whether sense of belonging is a direct mediator of academic achievement, or whether other constructs are involved. While studies show that sense of belonging is no doubt key, more research is needed to understand how our students’ sense of belonging impacts their performance in our classrooms.

Measuring the Sense of Belonging among Biology Students

In this section, we discuss examples of studies evaluating the academic sense of belonging; for each, we describe the intentions of the researchers, the tools they used, and key findings. Although instruments to measure belonging specifically in biology contexts have not yet been published, other studies of academic sense of belonging suggest appropriate strategies. In Table 4, we present sample statements from the four studies explored here; these range from investigating the general academic sense of belonging to studying the discipline-specific sense of belonging.

In a national study of Latino students about the transition to college and campus racial climates, Hurtado and Carter (1997) surveyed sense of belonging among second- and third-year college students. They used the following statements: “I see myself as a part of the campus community,” “I feel that I am a member of the campus community,” and “I feel a sense of belonging to the campus community.” The authors found that frequent discussions of course content outside class was strongly related to sense of belonging, while talking with faculty outside class and acting as tutors were also highly correlated with students’ sense of belonging in their third year as college students (Hurtado and Carter, 1997). The researchers called for additional studies that “might determine whether a high sense of belonging is evident in students with specific college majors or in various fields of study; in classrooms in which faculty require study groups; and in other institutionally based structures, such as living-learning residential programs, that may enhance students’ opportunities to discuss course content outside class” (p. 338).

Table 4. Sample statements from tools developed to monitor students' sense of belonging

Sample statement	Implementation context
I see myself as a part of the campus community. I feel that I am a member of the campus community. I feel a sense of belonging to the campus community.	National survey, Sense of Belonging Scale (Hurtado and Carter, 1997)
When I am in a math setting, I feel a connection with the math community. When I am in a math setting, I feel respected. When I am in a math setting, I feel comfortable. When I am in a math setting, I trust my instructors to be committed to helping me learn. When I am in a math setting, I enjoy being an active participant. When I am in a math setting, I try to say as little as possible. (reverse scored)	Calculus class, Math Sense of Belonging Scale (Good <i>et al.</i> , 2012)
I feel like I belong in physics. People in physics accept me. I feel like an outsider in physics. (reverse scored)	Calculus-based introductory physics, Survey Construct-Belonging (Stout <i>et al.</i> , 2013)
I feel I belong within my department. I am satisfied with my academic experience. I feel comfortable at the [university]. People at the [university] accept me.	First-year STEM graduate students (in Smith <i>et al.</i> , 2013; modified from Walton and Cohen, 2007) and College Satisfaction and Persistence Scale (Cabrera <i>et al.</i> , 1992)

Some researchers have started to investigate these questions of sense of belonging in specific disciplines, and we highlight examples of emerging assessment tools in math, in physics, and among STEM graduate students. In the context of mathematics, psychologists examined sense of belonging to the math academic community among introductory psychology students, using a tool the authors designed called the Math Sense of Belonging Scale (Good *et al.*, 2012). In designing this tool, the group identified a factor structure of the scale with five factors: *membership*, *acceptance*, *affect*, *trust*, and *desire to fade*. A sample statement from the membership factor is, "When I am in a math setting, I feel a connection with the math community." An example of a statement that pertains to acceptance follows: "When I am in a math setting, I feel respected"; this may be interpreted as either acceptance of oneself or of one's ideas. An example statement from the trust category asks about students' perceptions of the classroom: "When I am in a math setting, I trust my instructors to be committed to helping me learn." A sample statement from the affect category is, "When I am in a math setting, I feel comfortable." The desire to fade category is represented by statements such as "When I am in a math setting, I enjoy being an active participant" and the reverse-scored statement "When I am in a math setting, I try to say as little as possible."

Interestingly, the driving research questions behind this effort in mathematics was to understand the gap in gender representation within mathematics. The authors therefore also measured whether the sense of belonging correlated with an endorsement of stereotypes about women in math and a subscription to a "growth" mind-set for intelligence. In this study, Good and colleagues (2012) found a lower sense of belonging for women who perceived a high degree of stereotyping in the math community and embraced a "fixed" mind-set. Further, both women's and men's sense of belonging were predictive of their intent to remain in the math discipline. The authors propose that sense of belonging is important not only for students to feel they belong in

the community but also to feel their ideas are valued and accepted.

A second study by a group of physics education researchers used a tool to survey undergraduates about their sense of belonging in physics in the context of a calculus-based physics course (Stout *et al.*, 2013). The authors were also interested in probing whether a difference in males' and females' sense of belonging existed that might be related to the gender gap in physics representation. The statements used by the physics groups were both about personal feelings of belonging ("I feel like I belong in physics") and about the community ("People in physics accept me"). Reverse-coded statements were used in the instruments designed by both the physics and math groups, an example being "I feel like an outsider in physics." Students surveyed in the physics study were also asked about the extent to which they saw value in physics in their everyday lives (Stout *et al.*, 2013). The physics group also found that in men, belonging is a predictor for seeing the value of physics applications to everyday life and that a sense of belonging is also a good predictor for course grades. The authors found that, similar to Good and colleagues (2012), the endorsement of stereotypes about women in physics correlates with a decrease in a sense of belonging within physics for women.

A third study developed a sense of belonging assessment tool for implementation with first-year STEM graduate students (Smith *et al.*, 2013). The disciplines represented in this study were biochemistry, biology, chemistry, computer science, earth science, environmental science, engineering, mathematics, and physics, sampled at two universities. Statements from this study were modified from previous studies in sense of belonging and persistence in higher education (Cabrera *et al.*, 1992; Walton and Cohen, 2007). Sample statements from this scale include: "I feel I belong within my department," "I feel comfortable at the [university]," and "People at the [university] accept me." While the authors do note that the last two statements refer to the larger university, they predicted that graduate students would respond to the larger

university community in the same way as to the specific department, given the typical graduate student's experience. The researchers were particularly interested in comparing sense of belonging between genders in disciplines in which representation is disproportionate. Following this line of inquiry, an additional measure in this study examined women and their perceptions of effort expenditure compared with their peers. The researchers found there was a perception of greater effort expenditure by women when asked to compare themselves with their peers, but men did not express greater effort expenditure. The effort expenditure perception by women was also negatively related to women's sense of belonging. Interestingly, this study suggests that gender differences in sense of belonging persist into graduate school, despite the choice by women to pursue this path and their acceptance into graduate programs. One statement asked in the graduate student survey relates to this point: "I am confident I made the right decision in choosing my program." Although this research is not directly related to undergraduates, the underlying notion that sense of belonging among women graduate students is disproportionate to that of men continues to raise the question of whether a differential sense of belonging exists for undergraduate students in the sciences with different personal characteristics.

In summary, a number of assessment tools have been developed and modified to measure sense of belonging among college students generally, and a few have been developed specifically for those students engaged in the science disciplines. There is, to our knowledge, no biology-specific sense of belonging scale, suggesting another area of biology education research ripe for development.

SCIENCE IDENTITY: ON SEEING ONESELF AS A SCIENTIST

When we introduce ourselves to someone, we can describe ourselves in many different ways, depending on the context. We can define ourselves in terms of our role at work; for those of us at academic institutions, as a colleague, faculty member, scientist, perhaps biologist. In other contexts we could be defined in terms of our hobbies—athlete, foodie, artist, or traveler; or as a parent, sibling, or other community member. There are likely multiple ways that you describe yourself, depending on to whom you are introducing yourself. In our classrooms, to what extent can we monitor our students' perceptions of their identities with respect to science, or specifically, biology?

We have not sufficiently attended to the more fundamental question of whether students see themselves as the kind of people who would want to understand the world scientifically and thus participate in the kinds of activities that are likely to lead to the appropriation of scientific meanings. (Brickhouse *et al.*, 2000, p. 443)

Identity has been defined generally as the "kind of person" one is recognized as "being" in any given context, either by oneself or with others (Gee, 2000). Another suggested definition of identity refers to a "compilation of level of interest, self-assessment of competency, and how much recognition one feels with regard to it" (Scutt *et al.*, 2013, p. 5). A third definition, which is relevant here, is that identity is defined when "an individual accepts influence from another person

or a group in order to establish or maintain a satisfying self-defining relationship to the other" (Kelman, 2006, p. 3).

A conceptual framework has been developed that aligns with these definitions in order to analyze science identity (Carlone and Johnson, 2007). The framework includes three components: *recognition*, *competence*, and *performance*. The first component, recognition, means that a person is recognized by himself or herself and/or by others as "a science person." Competence is the possession of knowledge about and facility with science content, skills, and practices. And performance is the social performances of science practices in the public arena and culture of science, which likely includes demonstrating competence to other members of the science community. A fourth component suggested to aid in examining science identity is *interest* (Hazari *et al.*, 2010). The addition of interest may be particularly important for students who have not yet committed to a particular major or career, in that they will most likely first exhibit an interest in science before adopting a science identity.

Science identity is hypothesized to be key in student persistence and retention in the sciences. In studies such as *Talking about Leaving* and "They're Not Dumb, They're Different," multiple lines of evidence suggest that students who leave the sciences are no less talented or competent than those who persist in the sciences (Tobias, 1990; Seymour and Hewitt, 1997). Instead, those who leave appear to reject the culture of science, in particular the culture of undergraduate science classrooms, and, as a result, choose not to adopt a professional identity within this scientific culture.

Measuring the Extent to Which Our Students Embrace a Science Identity

Unlike self-efficacy and sense of belonging, research on science identity has not produced initial assessment tools to gauge student adoption of science identity. While there is emerging research, most research methodologies that investigate science identity employ methods such as interviews and case studies, which are not adaptable for use in undergraduate biology classrooms with large numbers of students. In this section, we discuss examples of studies evaluating science identity, and for each, we describe the intentions of the researchers, the tools they used, and interesting findings. While a few of these studies suggest statements that could be adapted into survey-style assessment tools (see Table 5), much more research into whether and how students adopt a science identity is needed in biology education research.

Many of the studies on science identity utilize case studies to collect qualitative data with a specific framework for data interpretation. In one example, researchers interviewed African-American girls about their perceptions of science and aspirations to pursue science-related careers (Brickhouse *et al.*, 2000). The researchers were interested in both how the students think about themselves as people who can do science, as well as how they engage with science in their classroom experiences. In other examples of case studies, research that has focused on high school students persisting in or leaving science has noted the importance of community support in forming science identities (Aschbacher *et al.*, 2009). Another study concluded that women of color in science careers have frequently created their own science identities, using this approach to reject identities otherwise assigned to them

Table 5. Sample statements and questions used to explore students' science identities

Sample statement or question	Implementation context
Do you see yourself as a biology/chemistry/physics person?	National survey, PRiSE (Hazari <i>et al.</i> , 2013)
Being a scientist is an important reflection of who I am. I have come to think of myself as a "scientist." I am a scientist. In general, being a scientist is an important part of my self-image. Having more people with my background in my field makes me feel more like a scientist.	Science support programs (Chemers <i>et al.</i> , 2011)

by individuals in academic or social situations (Johnson *et al.*, 2011).

A few discipline-specific science identity studies employ either mixed-methods or quantitative use of assessment tools. Two studies focused on physics reported on data collected from the Persistence Research in Science and Engineering (PRiSE) project, using a survey administered in first-year college English courses to a randomized, stratified sampling of students. The first study examined the students' high school experiences, outcome expectations, and career choice, in addition to their physics identity (Hazari *et al.*, 2010). The researchers were interested in the alignment between students' physics identities and physics career choices, as well as to what extent the factors surveyed were predictors of physics identity. They found that physics identity is highly correlated with physics career choices. A number of factors were important for physics identity formation, including teacher encouragement to take science courses and discussions of the benefits of being a scientist. The authors also differentiated between those factors that were important for women compared with men. The principal difference came from the explicit discussion of under representation of women in science, which had a positive impact on female students, but had no impact on male students.

In a second study using the data from the PRiSE project Hazari *et al.* (2013), the science identity of college students was assessed using the question, "Do you see yourself as a biology/chemistry/physics person?" The authors sought to understand to what extent science identity intersects with both gender and race/ethnicity, and found that Hispanic females had the lowest science identity agreement in their study. Other work unifies these ideas with the finding that academic work outside of courses was an important factor for women of color in STEM with respect to developing science identities and persistence in the science disciplines (Espinosa, 2011).

In a study of how science support programs affect science career commitment, researchers developed a model in which one of the contributing factors was science identity (Chemers *et al.*, 2010). They then surveyed undergraduates (Chemers *et al.*, 2010) or graduate students and postdoctoral fellows (Chemers *et al.*, 2011). Statements used that pertain to science identity included: "Being a scientist is an important reflection of who I am," "I have come to think of myself as a 'scientist'," and "I am a scientist." The findings from these studies support the idea that science support experienced outside formal course work—such as research experiences, community involvement, and mentoring—may positively affect students' willingness to adopt a science identity (Chemers *et al.*, 2011).

Another group showed that the adoption of science community values is important for science identity formation and used a subset of the questions developed by Chemers and colleagues (Estrada *et al.*, 2011). These results, taken together, suggest that to encourage students' persistence in and commitment to science careers, it may be critical to take an inventory of our students' science identities.

NEXT STEPS

Conceptual learning is a uniquely human behavior that engages all aspects of individuals: cognitive, metacognitive, and affective. The affective domain is key in learning. In this paper, we have explored three affective constructs that may be important for understanding biology student learning: self-efficacy—the set of beliefs that one is capable of performing a task; sense of belonging—when one feels a part of a particular group; and science identity—the extent to which a person is recognized or recognizes himself or herself as a "science person." No doubt these affective aspects of learning are interrelated, not entirely distinct, and interact in unknown ways. To be clear, these three constructs do not describe the entire affective domain. Motivation, self-regulation, and resilience, to name a few additional constructs, are also likely to be important. However, we can now attend to and monitor the affective experiences of our students alongside monitoring their conceptual understanding. While the research and assessment tools presented here represent initial explorations and are not biology specific, we suggest that many of the statements presented in the tables are starting points for instructors who wish to investigate and monitor students' affective states during the learning process in their classrooms. Investigating the role of affect in biology conceptual learning and developing tools for monitoring students' self-efficacy, sense of belonging, and science identity are areas for future biology education research that may well improve our effectiveness.

POSTSCRIPT

The ideas expressed here are intended to help all biology instructors consider the role of affect in biology teaching and learning and to provide starting points for instructors who may wish to collect informal classroom evidence that may give them insights into their students' self-efficacy, sense of belonging, and science identity. Those who wish to conduct formal biology education research in this area may find "Best Practices for Measuring Students' Attitudes toward Learning

Science" (Lovelace and Brickman, 2013) helpful, as well as the other references cited above.

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