The Development of a College Biology Self-Efficacy Instrument for Nonmajors

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ABSTRACT: In an effort to test the effectiveness of teaching and learning strategies that may increase biological literacy for nonbiology majors, an NSF-funded research project called "The Slice of Life," was conducted from 1994 to 1998. In the present study, a self-efficacy instrument was constructed and designed specifically for the project to determine students' self-reported confidence in understanding and using biology in their lives. Based on social cognitive theory, the premise for developing such an instrument was that a specific measure of biological self-efficacy was deemed to be an important predictor of the change processes necessary to improve students' biological understanding. Results of this study indicate that the Biology Self-Efficacy Scale was a valid and reliable tool for studying nonbiology majors' confidence in mastering biological literacy. Factor analysis supported the contention that the Biology Self-Efficacy Scale was a multidimensional construct consisting of at least three dimensions: methods of biology; generalization to other biology/science courses and analyzing data; and application of biological concepts and skills. These dimensions represent three components of biological literacy that have been commonly described in the literature. The instrument may lead to further understanding of student behavior, which in turn can facilitate the development of strategies that may increase students' desire to understand and study biology. More specifically, by using the self-efficacy tool as a pre- and posttest indicator, instructors can gain insight into whether students' confidence levels increase as they engage in more complex tasks during the course, and, in addition, what type of teaching strategies are most effective in building

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INTRODUCTION

A great deal of attention has been devoted to the investigation of teachers' attitudes toward science and the effects these attitudes have on teaching (Haney, Neuman, & Clark, 1969; Koballa & Crawley, 1985; Morrisey, 1981; Munby, 1983). Attitudinal scales also have been designed to measure students' impressions about science and their subsequent interest in pursuing science courses and careers (Fraser, 1979). However, there are few studies that have examined students' beliefs (as distinguished from attitudes) as possible contributors to behavior, specifically as related to learning science. Koballa and Crawley (1985) have defined beliefs as information that a person accepts to be true, whereas attitudes refer to a general positive or negative feeling toward something. For example, if a college student judges his/her ability to be lacking in science (belief), that lack in confidence may lead to a dislike for science (attitude) and to a subsequent avoidance of science education (behavior). Pajares (1996) explained that individuals' beliefs about their abilities profoundly influence the ways in which they will behave. Their behavior influences performance attainment, their environment, and their self-beliefs, which, in turn, influence their subsequent behavior. Students' self-beliefs help determine many choices throughout their academic career, such as how much time they will spend on a particular task in a course, the relative amount of effort they will expend to achieve complex tasks, and how persistent and resilient they will be when confronting obstacles (Pajares, 1996). Clearly, understanding students' beliefs as related to learning science merits further examination.

Some researchers have argued that perceived confidence in carrying out a given task (e.g., mastering biological content and processes) will strongly predict acquisition of skills and subsequent behavior, such as motivation to pursue biology education (Ebert-May, Brewer, & Allred, 1997; Ramey-Gassert, Shroyer, & Staver, 1996). This construct of perceived confidence in executing a given behavior has been referred to as self-efficacy. Because there are no known studies that have examined self-efficacy beliefs regarding the ability to learn biology, this article contributes to the field by describing and providing a self-efficacy instrument that was specifically developed to measure college students' self-reported confidence in understanding and using biological concepts and processes.

THEORETICAL BACKGROUND

Bandura (1977, 1981) has postulated that behavior change and maintenance should be viewed as a function of: (1) beliefs or expectations about behavioral outcomes; and (2) beliefs or expectations about one's ability to engage in or execute the behavior. Whereas the first part of this model refers to "outcome expectations," the second part refers to "self-efficacy expectations," which consist of beliefs about how capable one is in performing the behavior that leads to those outcomes.

According to Bandura, perceived self-efficacy influences all aspects of behavior including acquisition of new behaviors and inhibition of existing behavior. It also affects people's choices of behavioral settings, the amount of effort they will expend on a task, and the length of time they will persist in the face of obstacles (Strecher, DeVellis, Becker, & Rosenstock, 1986). Self-efficacy perceptions are derived from four major sources of information: (1) prior experiences performing a similar behavior; (2) opportunities to observe others similar to oneself performing the behavior; (3) persuasion by a respected authority; and (4) one's self-perceived level of physiological arousal.

Self-efficacy theory has thus far been extended to a wide array of psychosocial phenomena, with largely supportive results (Bandura, 1986a, 1986b). Self-efficacy has also become an important domain in research on academic and career behavior (Lent & Hackett, 1987; Multon, Brown, & Lent, 1991). Hackett and Betz (1981) proposed that self-efficacy might serve as an important career development mechanism, influencing the educational and career decisions, the achievement behavior, and the career adjustment of men and women.

RELATED RESEARCH

More recently, self-efficacy theory has been applied in science and mathematics. For example, Lent, Lopez, and Bieschke (1991) explored (1) the relation of the four hypothesized sources of efficacy information (personal performance accomplishments, vicarious learning, social persuasion, and emotional arousal) to mathematics self-efficacy beliefs; and (2) the relationship among self-efficacy, outcome expectations, interest in mathematics-related college courses, and choice of science-based careers. Similarly, Post, Stewart, and Smith (1991) showed that self-efficacy was related to consideration of mathematics and science careers among African American freshmen. Betz and Hackett (1981) also reported that mathematics self-efficacy was significantly related to students' selection of science-based college majors, thus supporting the postulated role of cognitive beliefs in educational and career choice behavior. Finally, a series of recent studies (e.g., Cannon & Scharmann, 1996; Enochs & Riggs, 1990; Ramey-Gassert et al., 1996; Riggs & Enochs, 1990) provide evidence that teacher self-efficacy is an important attribute in effective science teaching.

While the latter studies just noted have demonstrated the importance of teacher self-efficacy in delivering effective science education, there are no known studies that have reported a relationship of students' self-efficacy to becoming scientifically "literate." The dimensions of scientific literacy have been described since the late 1950s and, in general, various definitions of scientific literacy all express the aspects of science that individuals should know, do, experience, and value as citizens (Bybee, 1997). It is important to note that scientific literacy not only involves mastery of facts, but also includes use of the procedural aspects of science as well as attitudes and values that extend from the nature of science itself (Bybee, 1997).

One would predict that students with higher self-efficacy in their ability to understand and apply scientific concepts to real-world situations would be more likely to engage in learning than students with low self-efficacy who may tend to avoid efforts to learn science (McMillan & Forsyth, 1991). Self-efficacy is especially important in learning difficult subjects (such as biology and other sciences) given that students enter courses with varying levels of fear and anxiety. As concepts in the course become increasingly complex, self-efficacy becomes a more important variable that influences the potential for student learning. As students accomplish competence in the intended outcomes for the course in a way that they recognize, their own self-efficacy increases. Subsequently, as self-efficacy increases, students are more willing to undertake more complex tasks and think about more complex ideas (McMillan & Forsyth, 1991). Thus, students' self-confidence about their successes are key to achieving mastery of biological literacy skills.

PURPOSE

In an effort to test the effectiveness of teaching and learning strategies that may increase biological literacy for nonbiology majors, an NSF-funded research project (Grant No. DUE

9254280), “The Slice of Life,” was conducted from 1994 to 1998. The goals for all participating students were to (1) demonstrate biological literacy by effectively communicating an understanding of and links among biological principles and concepts to peers and others; (2) utilize the process of scientific inquiry to think creatively and formulate questions about real-world problems; (3) reason logically and critically to evaluate information; and (4) gain confidence in their ability to write about, criticize, and analyze concepts in biology (Ebert-May et al., 1997).

A self-efficacy instrument (described herein) was specifically constructed and designed for the project to determine students’ self-reported confidence in understanding and using biology in their lives. The premise for developing such an instrument was that a specific measure of biology efficacy beliefs was deemed to be an important predictor of the change processes necessary to improve students’ biology achievement. Thus, the purpose of this study is to describe the process of developing and validating this self-efficacy instrument designed to measure biological literacy among college students.

METHOD

The present study was separated into three phases investigating the following questions: (1) Phase 1 (Preliminary Scale Development)—What types of self-efficacy items would reflect a change in perceived confidence in mastering biological literacy?; (2) Phase 2 (Factor Analysis)—What are the dimensions of biology self-efficacy? What is the internal consistency of the self-efficacy measure?; and (3) Phase 3 (Validity Criteria Analysis)—Can self-efficacy be differentiated from other constructs?

Phase 1: Preliminary Scale Development

An initial item pool was developed based on conversations with the research staff regarding the methods and anticipated student outcomes of the intervention (described in Ebert-May et al., 1997) and an analysis of the literature on scientific literacy (AAAS, 1990; BSCS, 1993; NRC, 1997, 1996a, 1996b; NSF, 1996). Items reflected domains such as confidence in reading, summarizing, and critiquing biology articles and presentations; explaining biology topics or tutoring another student in related biology topics/classes; writing and thinking with a “scientific approach,” including the steps in writing and reviewing a lab report; and extrapolating information learned in class to other aspects of one’s life.

The initial scale consisting of 23 items (rated on a five-point Likert scale: 1 = strongly agree to, 5 = strongly disagree) was piloted to approximately 200 students to explore the factor structure. SPSS Procedures Principal Components was used to reduce the number of variables and to identify underlying components. Initial selection of the factors was based on the following criteria: (1) unrotated components were required to have eigenvalues $\geq$1.00; (2) the solution satisfied Cattell’s (1966) scree test; and (3) rotated dimensions had to contain items with factor loadings of $\geq$0.30 for reliable subscale development. In addition, a focus group of eight nonbiology-major students was conducted, during which specific information about the self-efficacy items was elicited regarding awkward wording, irrelevancy of questions, and other domains not yet tapped. Preliminary factor analysis and feedback from students through the focus group indicated that two questions needed to be dropped completely (due to poor variability and low factor loadings), a few items needed to be clarified and revised, and in an effort to strengthen one of the hypothesized domains (i.e., generalizability to other biology/science courses and analyzing data) two items needed to be added. The resulting scale was termed the Biology Self-Efficacy Scale and consisted of 23 items in Likert scale format.

Phase 2: Confirmatory Factor Analysis

Subjects and Instrumentation. Subjects ($N = 1096$) in Phase 2 were nonbiology-major students enrolled in BIO 100, Biology Concepts, Lecture and/or Laboratory section during Fall 1994, Spring 1995, Fall 1995, and Spring 1996 semesters at Northern Arizona University. Of the 1096 participants in the study, 64% were female and 36% were male. A majority of the participants were 17–22 years of age (88.8% were 17–22 years old, 9.5% were 23–30 years old, and 2.7% were 31–40 years old). Participants were also predominantly white (80.8% white, 7.8% Hispanic, 5.9% Native American, 2.7% Asian/South Pacific, 0.6% African American, and 2.4% other).

Procedure. Each semester students were asked to complete the self-efficacy questionnaire during the first week of classes as part of a set of instruments designed to assess pre- and posttest change in biological literacy. Each student was assured of confidentiality and that the questionnaire would not count toward or influence their grade in any way.

Data Collection and Analysis. A principal factoring solution (SPSS) was used to analyze the underlying factor structure of student responses to the 23-item Biology Self-Efficacy Scale. Three factors were extracted. As suggested by Rummel (1970), both oblique and orthogonal rotations were used to compare item loadings and degree of correlations between factors. With delta value set at zero, the oblique rotation revealed that the three factors were moderately correlated ($r = 0.48$), suggesting that the three factors were moderately related, but still relatively independent constructs (Ghiselli, Campbell, & Zedeck, 1981). A relatively rigorous level for significance of factor loadings (≥ 0.45) was selected as a criterion for inclusion of final individual items in the factor structure.

Phase 3: Validity Criteria Analysis

Subjects and Instrumentation. Another dependent measure used in the study to assess students' change in biological literacy was the National Association of Biology Teachers/National Science Teachers Association (NABT/NSTA) High School Biology Examination. Questions from this national examination were separated into two broad categories: NABT content (54 items) and NABT process (26 items). The content questions generally asked students to recall information, to apply knowledge to new situations, or to explain their understanding in the context of a new example. The questions dealing with scientific processes probed students' abilities to interpret information from a graph or to make conclusions from a table. As with the self-efficacy scale, this instrument was administered to all BIO 100 students as a pretest during the first week of their lecture section and given again during the final week of classes.

Data Analysis. Correlations of the two NABT subscales with the three self-efficacy subscales were computed to determine the discriminability of biology self-efficacy subscales from the other constructs.

RESULTS

Factor Analysis

Three substantial factors emerged from the factor analysis, with Factor 1 accounting for 20.2% of the variance, Factor 2 accounting for 19.3% of the variance, and Factor 3 accounting for 17.6% of the variance. Table 1 includes the items that loaded on each factor. The intercorrelations revealed three distinct groups of items. The items from each subscale correlated highly among themselves; however, correlations between the three subscales' items were not as high. This pattern indicates homogeneity within and distinctiveness between the three subscales, and enhances construct validity (Ghiselli et al., 1981).

Factor 1 appears to represent a student's sense of perceived confidence in writing and critiquing his/her biological ideas through laboratory reports, as well as using analytical skills to conduct experiments in biology. Factor 2 relates to perceived confidence in generalizing skills learned through this biology course to other biology/science courses and to using a scientific approach to solve problems. Factor 3 addresses a student's perceived confidence in his/her ability to apply biological concepts and skills to everyday events. These factors are consistent with broad definitions of scientific literacy (AAAS, 1990; Bybee, 1997; Champagne & Lovitts, 1989; NSF, 1996).

TABLE 1
Factor Item Loadings

Item #	Factor loading	Item
Item loadings on Factor 1 (methods of biology)		
2	0.63	How confident are you that you could critique a laboratory report written by another student?
3	0.77	How confident are you that you could write an introduction to a lab report?
5	0.48	How confident are you that you could read the procedures for an experiment and feel sure about conducting the experiment on your own?
6	0.70	How confident are you that you could write the methods section of a lab report (i.e., describe the experimental procedures)?
9	0.67	How confident are you that you could write up the results to a lab report?
12	0.71	How confident are you that you could write the conclusion to a lab report?
18	0.66	How confident are you that you could tutor another student on how to write a lab report?
19	0.60	How confident are you that you could critique an experiment described in a biology textbook (i.e., list the strengths and weaknesses)?
Total scale alpha = 0.88		
Item loadings on Factor 2 (generalization to other biology/science courses and analyzing data)		
8	0.69	How confident are you that you will be successful in this biology course?
11	0.75	How confident are you that you will be successful in another biology course?
14	0.71	How confident are you that you would be successful in an ecology course?

TABLE 1 ***(Continued from previous page.)***
Factor Item Loadings

Item #	Factor loading	Item
15	0.48	How confident are you that you could analyze a set of data (i.e., look at the relationships between variables)?
17	0.64	How confident are you that you would be successful in a human physiology course?
20	0.56	How confident are you that you could tutor another student for this biology course?
21	0.59	How confident are you that you could ask a meaningful question that could be answered experimentally?
22	0.52	How confident are you that you could explain something that you learned in this biology course to another person?
23	0.61	How confident are you that you could use a scientific approach to solve a problem at home?
Total scale alpha = 0.88		
Item loadings on Factor 3 (application of biological concepts and skills)		
1	0.62	How confident are you that *after* reading an article about a biology experiment, you could write a summary of its main points?
4	0.69	How confident are you that *after* reading an article about a biology experiment, you could explain its main ideas to another person?
7	0.76	How confident are you that *after* watching a television documentary dealing with some aspect of biology, you could write a summary of its main points?
10	0.78	How confident are you that *after* watching a television documentary dealing with some aspect of biology, you could explain its main ideas to another person?
13	0.69	How confident are you that *after* listening to a public lecture regarding some biology topic, you could write a summary of its main points?
16	0.73	How confident are you that *after* listening to a public lecture regarding some biology topic, you could explain its main ideas to another person?
Total scale alpha = 0.89		

As indicated in Table 1, analysis of internal consistency reliabilities yielded Cronbach's alpha coefficients of 0.88, 0.88, and 0.89 for Factors 1, 2, and 3, respectively.

Validity Criteria Analysis

In an effort to establish construct validity of the three domains of self-efficacy, the correlations between the NABT subscales and the self-efficacy subscales were assessed. A priori expected correlations were as follows:

	Self-Efficacy Subscale #1	Self-Efficacy Subscale #2	Self-Efficacy Subscale #3
Content Subscale (NABT)	No	Yes	Yes
Process Subscale (NABT)	Yes	Yes	No

TABLE 2
Validity Coefficients (*N* = 776)

	Self-Efficacy Subscale #1	Self-Efficacy Subscale #2	Self-Efficacy Subscale #3
Content subscale (NABT)	0.19	0.27	0.23
Process subscale (NABT)	0.18	0.23	0.21

Table 2 contains the validity coefficients (reported as Pearson *r*-values) for all criteria. While the NABT subscales were correlated with the self-efficacy subscales, the correlation coefficients were low (ranging from 0.18 to 0.27), suggesting that self-efficacy perceptions can be distinguished from content and process skills.

DISCUSSION

Results of this study indicate that the Biology Self-Efficacy Scale is a valid and reliable tool for studying nonbiology-majors' confidence in mastering biological literacy. With this tool, a more complete perspective of student's confidence levels is possible, because it allows investigation of students' belief systems to supplement the existing research base on student's attitudes toward biology/science. Factor analysis supported the contention that the biology self-efficacy scale was a multidimensional construct consisting of at least three dimensions: methods of biology; generalization to other biology/science courses and analyzing data; and application of biological concepts and skills. These dimensions represent three components of biological literacy that are commonly described in the literature (Bybee, 1997; Champagne & Lovitts, 1989).

As predicted by social learning theory, a moderate level of correlation was found between the three subscales. Nevertheless, factor analysis clearly demonstrated that the subscales measured three discrete and homogeneous domains of self-efficacy. The three dimensions of biology self-efficacy can also be differentiated from content and process skills as measured by instruments such as the NABT.

Despite the limitations of the present study (i.e., the instrument was developed with a specific population of nonmajor biology students), the instrument may be a potentially useful tool in similar introductory biology courses or introductory science courses in other disciplines. The instrument may lead to further understanding of student behavior, which in turn can facilitate the development of strategies that may increase students' desire to understand and study biology. More specifically, by using the self-efficacy tool as a pre- and posttest indicator, instructors can gain insight into their students' biology self-efficacy to see if, in fact, students' confidence levels increase as they engage in more complex tasks during the course. Because the self-efficacy subscales represent outcomes for a biologically literate student, the scales can be used as indicators to influence the choices faculty make about teaching. If, for example, students' confidence in writing and critiquing a laboratory report decrease during a semester, the instructor has evidence to critically evaluate the teaching strategies implemented in the class that influenced this outcome. Instructors then have more ways of identifying the type of professional development that would enhance their teaching. For example, Bandura (1986a) has advocated teaching strategies such as modeling skills, verbal persuasion, and provision of successful experiences for the improvement of self-efficacy beliefs.

Other teaching strategies tested and confirmed as effective through the Slice of Life project are cooperative learning, use of higher level questioning techniques, analyzing short articles, group position papers, concept maps, and daily writing and speaking in class. The evidence indicates that these instructional strategies help students develop confidence in expressing their own ideas and understanding because they are involved in active rather than passive learning (Brewer & Ebert-May, in press; Ebert-May et al., 1997). As students' confidence increases, their willingness and enthusiasm to engage in new challenges, participate in substantive activities within their cooperative groups, and to think increase.

The self-efficacy instrument and related questions can stimulate students to think about their beliefs, attitudes, and behavior patterns. Students in the introductory biology course were asked to write a self-evaluation that addressed the degree to which they had accomplished each of the outcomes of the course and to explain what happened during the course that influenced their accomplishments. Specifically, students were asked, "To what degree have you developed confidence in your ability to write about, criticize, and analyze concepts in biology?" Student comments included:

> I have always had confidence in my ability to write, but this class has helped me with my confidence in writing about science. I always was good at biology (or at least I got good grades in biology), but never really understood any connections. This class made it clear to me that everything is connected to each other. We were forced to write down how we understood concepts, not simply to memorize parts and functions. The daily quizzes and homework assignments were key in adding to my high degree of confidence in my ability to write about, criticize and analyze concepts in biology.

> I am able to do this because I obtained the skills in Bio and Bio Lab. Through critiquing articles in class about various issues and writing lab reports, I have learned to constantly question things and think of the answers from many different perspectives.

> In class and lab we were constantly pushed to think. Sometimes I hated this and just wanted to veg out, but now I realize how important questioning everything is. When we question, we obtain knowledge, and through knowledge we have power. We must use this power to improve our world.

In conclusion, a number of research issues should be addressed in future investigations. First, further elements of Bandura's theory of self-efficacy should be explored as they relate to students' biological efficacy. For example, Bandura speaks of dimensions of generality, magnitude, and strength of self-efficacy. When applied to students, it may be that generality relates to the extent to which a student feels efficacious in a variety of learning situations rather than a narrowly defined range of situations. Magnitude may be reflected in the degree of difficulty of the task for which a student feels efficacious, and strength may be manifest in the relative ease or difficulty with which it may be modified.

Second, investigations of the relationships between student characteristics (i.e., gender, age, grade level, experience with biology and other science courses, and personal attributes) and sense of efficacy are needed. Relationships with situational and organizational variables should also be investigated, because student efficacy is likely to be situation-specific and may not be generalized from one setting to another (e.g., research university compared to community college).

Third, the relationship between student and teacher efficacy should be examined. To what extent does a teacher's efficacy predict increased student efficacy and student achievement in mastering biological literacy in different settings and types of courses?

Finally, further research on the validation and refinement of this Biology Self-Efficacy Scale is needed. Specifically, construct validation should continue to be investigated across different populations and settings.

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APPENDIX: SELF-EFFICACY INSTRUMENT

This survey contains 23 statements about your confidence in doing things related to biology. For each question, think about how confident you would be in carrying out a given task. There are no right or wrong answers. These are just your own thoughts and feelings about these topics. There are *three* demographic questions as well.

All answers should be filled in on the bubble sheets provided. For each statement in the survey, fill in the bubble next to each question:

A. If you are <u>TOTALLY</u> CONFIDENT that you can do the task.
B. If you are <u>VERY</u> CONFIDENT that you can do the task.
C. If you are <u>FAIRLY</u> CONFIDENT that you can do the task
D. If you are <u>ONLY A LITTLE</u> CONFIDENT that you can do the task.
E. If you are <u>NOT AT ALL</u> CONFIDENT that you can do the task.

Practice Item

How confident are you that you could give a presentation about birds in northern Arizona?

Suppose that you were “fairly confident” that you could give a presentation about birds in northern Arizona. You would write the letter “C” in the blank next to the question.
Thank you for your participation!

1. How confident are you that after reading an article about a biology experiment, you could write a summary of its main points?
2. How confident are you that you could critique a laboratory report written by another student?
3. How confident are you that you could write an introduction to a lab report?
4. How confident are you that after reading an article about a biology experiment, you could explain its main ideas to another person?
5. How confident are you that you could read the procedures for an experiment and feel sure about conducting the experiment on your own?
6. How confident are you that you could write the methods section of a lab report (i.e., describe the experimental procedures)?
7. How confident are you that after watching a television documentary dealing with some aspect of biology, you could write a summary of its main points?
8. How confident are you that you will be successful in this biology course?
9. How confident are you that you could write up the results to a lab report?
10. How confident are you that after watching a television documentary dealing with some aspect of biology, you could explain its main ideas to another person?
11. How confident are you that you will be successful in another biology course?
12. How confident are you that you could write the conclusion to a lab report?

13. How confident are you that after listening to a public lecture regarding some biology topic, you could write a summary of its main points?
14. How confident are you that you would be successful in an ecology course?
15. How confident are you that you could analyze a set of data (i.e., look at the relationships between variables)?
16. How confident are you that after listening to a public lecture regarding some biology topic, you could explain its main ideas to another person?
17. How confident are you that you would be successful in a human physiology course?
18. How confident are you that you could tutor another student on how to write a lab report?
19. How confident are you that you could critique an experiment described in a biology textbook (i.e., list the strengths and weaknesses)?
20. How confident are you that you could tutor another student for this biology course?
21. How confident are you that you could ask a meaningful question that could be answered experimentally?
22. How confident are you that you could explain something that you learned in this biology course to another person?
23. How confident are you that you could use a scientific approach to solve a problem at home?

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