RESEARCH ON LEARNING

Nonmajors' Shifts in Attitudes & Perceptions of Biology & Biologists Following an Active-Learning Course: An Exploratory Study

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Abstract

This exploratory study examined the impacts of a student-centered, active-learning course on nonmajors' attitudes and perceptions of biology and biologists. Results revealed changes along various measured attitude variables. Most notably, participants saw significant positive shifts in their perceptions of biology as a scientific field that contrasted with their relatively stable perceptions of biologists as scientists. Implications are discussed in the context of the impacts of nonmajors biology courses on future K–12 science instructors and potential influxes of students into the science pipeline.

Key Words: *Nonmajors; biology students; attitudes; perceptions.*

○ Introduction

Improving postsecondary students' biological literacy is a common goal for instructors of general education courses designed for learners not intending to major in science (hereafter "nonmajors"; McFarlane & Richeimer, 2013; Medina et al., 2014). We define *biological literacy* as the "matrix of knowledge needed to understand about the physical universe and to deal with issues that come across the horizon of the average citizen, in the news or elsewhere" (Trefil, 2008, p. ix). This "matrix of knowledge" consists of biological content and concepts. However, within this framework, we also contend that biological literacy consists of a set of affective dimensions (attitudes, interests, perceptions, beliefs, etc.) through which individuals filter this knowledge to appropriately engage and "deal with issues" they might come across in their daily lives (Sturgis & Allum, 2004). Here, we focus on the latter component of biological literacy.

Improving postsecondary students' biological literacy is a common goal for instructors of general education courses.

Many instructors in higher education are interested in developing methods to enhance general education courses so that they improve the depth of student thinking about science while developing appropriate attitudes, skills, and knowledge (i.e., biological literacy). This is in contrast to only teaching a broad set of isolated facts (Reynolds & Ahern-Dodson, 2010; Rutledge & Sadler, 2011; Tuberty et al., 2011). For nonmajors, biological literacy is important to possess when engaged in public discourse regarding socio-scientific issues such as vaccine use or global climate change (Laugksch, 2000).

However, we contend that the aforementioned learning goals should not be the only justification for promoting biological literacy among nonmajors. Classification as a nonmajor implies that students will enroll in a science/biology course to fulfill a general education requirement, and this may be the only course they take. Historically, this group has been viewed as individuals for which developing a generalized biological literacy may be the only necessary goal (Laugksch, 2000; Trefil, 2008). However, a nonmajors biology course often has education majors who intend to teach life-science content. In addition, these courses might also enroll students who are unsure about their majors and thus could matriculate into the biology career "pipeline." Instructors in nonmajors courses should consider the impact that their instruction might have on these particular groups. For example, future K–12 biology instructors' experiences in their undergraduate biology courses could affect how they frame their future science instruction (Semsar et al., 2011).

Curriculum design that features context-based inquiry with active-learning techniques can address issues in student development of biological literacy and positive attitudes toward science (Rogers & Abell, 2008). Incorporating engaging activities into the lecture portion of a course can foster student learning while prompting student cognitive engagement (AAAS, 2011). Additionally,

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this type of course design could influence how students perceive biology and biologists or consider biology as a potential career path. To support these efforts, faculty must design courses using evidence-based pedagogical techniques, be mindful of the effectiveness of instructional changes, and utilize appropriate instruments for evaluating teaching and learning outcomes (Kober, 2015).

The purpose of this exploratory study is to examine the implementation of a curriculum designed to increase the affective component of biological literacy among nonmajors at a large southeastern public university. An instrument was designed and administered to measure students' shifts in three affective constructs: (1) attitudes toward biology, (2) perceptions of biology, and (3) perceptions of biologists. We present results showing the impact of a one-semester course on students' biological literacy along these variables of interest. We also provide a brief discussion of the utility of the developed instrument to measure potentially important constructs related to nonmajors' attitudes toward and perceptions of biology and biologists. Finally, we discuss the results in the context of the recent call for postsecondary biology education reform as outlined in *Vision and Change* (AAAS, 2011).

○ Methods

Participants

Participants (n = 49) were students enrolled in a biology course for nonmajors at a large public university in the southeastern United States. The participants included 33 females and 16 males. Participants self-identified as White (73%), multiracial (10%), Black (6%), Middle Eastern (4%), Asian (4%), and Hispanic (4%). This is typical of the enrollment demographic at this particular university. Freshmen made up 96% of the participants, with an average age of 19.47 years. Just over 50% of the participants were preservice science teachers.

Course Design & Evaluation

The course, Issues in Biology, was intended for nonmajors and met twice a week for 75 minutes; a separate laboratory section met once a week. The learning goals for the lecture portion of the course were that students should learn and apply basic biological knowledge to current issues in society and should think about these issues independently, creatively, and critically from a scientific perspective (aligned with the definition of biological literacy described above). The overall course goal was to increase students' biological literacy through a context-based, inquiry-driven curriculum. The course was based on pedagogical research supporting active learning, formative assessment, and cultural sensitivity (Kober, 2015). To this end, all of the content was taught in a contextually based manner. Relevant social issues were presented to the students, and the relevant content was taught in an embedded manner to answer these questions. It was hypothesized (based on the literature) that these pedagogical strategies would influence student affect as intended.

To support the redesign of this course from a traditional, lecture-only approach to one featuring a student-centered component, a biologist and two science-education specialists from the College of Education formed an interdisciplinary collaboration to design, implement, and evaluate the curriculum. The biologist who typically teaches this course enlisted the help of one of the science-education experts to aid in the curriculum redesign and implementation of the course. The second science-education expert was brought in to design a biological literacy instrument for evaluating the effect of the curriculum and its efficacy of implementation.

Data Sources & Analysis

A pre- and post-assessment designed by the science-education-assessment lead for the project was used to measure students' affective component of biological literacy. Items were developed and modified on the basis of an extensive review of the literature regarding conceptualizations of the critical components of scientific and biological literacy, specifically in the context of nonscientists (Lord & Rauscher, 1991; Laugksch & Spargo, 1996; Baldwin et al., 1999; Tuan et al., 2005; Britner & Pajares, 2006; Kitchen et al., 2007; Usak et al., 2009).

The pre-assessment was administered prior to the start of instruction. The post-assessment was administered along with the final exam. The instrument included metrics designed to assess the following subscales within the larger construct of biological literacy (citations of relevant work from which items were acquired, modified, or developed follow each listed construct): (a) students' perceptions of biology as a science (Kitchen et al., 2007); (b) students' perceptions of biologists (Kitchen et al., 2007); (c) students' perceptions of the usefulness of biology in their daily lives (Tuan et al., 2005); (d) students' attitude toward and interest in biology (Laugksch & Spargo, 1996; Tuan et al., 2005; Usak et al., 2009); and (e) students' self-efficacy related to understanding, utilizing, and conducting biological research (Baldwin et al., 1999; Britner & Pajares, 2006). Items in subscales a and b consisted of semantic differential items in which students were asked to indicate their perceptions along a scale between the two provided terms (Kitchen et al., 2007; see Tables 1 and 2). Items in subscales c through e were all Likert-scale items (1 = strongly agree, 5 = strongly disagree).

The pre- and post-assessments were identical, with the exception of two additional open-ended questions on the post-assessment that asked student to describe the most relevant and important aspects of the course. Responses to the open-ended questions were organized by category (i.e., most relevant and most interesting) and coded to identify emerging themes related to their perceptions of biology and biologists. Parametric dependent-sample t-tests were used to explore pre–post differences in item and subscale scores as assumptions of normality were met in the ordinal data (not necessitating other nonparametric methods such as the Wilcoxon signed-rank test). On semantic differential items (see a and b above), the analyses were run with items as the unit of analysis (see Kitchen et al., 2007). On Likert items (subscales c through e above) analysis was run on the average of the items that collapsed into factors (see factor analysis results below).

○ Results

A t-test indicated significant differences in 9 of 20 items for students' perceptions of biology as a scientific field ($\alpha < 0.001$). For ease of interpretation, a qualitative description of the direction of change is given for each item under this construct (Table 1). For example,

Table 1. Student perceptions of biology, with qualitative description of the direction of change for each item as measured by pre- and post-assessments (mean values with SD in parentheses).

Perceptions of Biology	Pre	Post	Qualitative Direction of Change	P
Personally Helpful – Personally Harmful	2.99 (0.88)	1.68 (0.67)	Less harmful	<0.001
Intriguing – Unappealing	2.93 (0.87)	1.89 (0.62)	Less unappealing	<0.001
Confusing – Enlightening	2.05 (0.86)	3.27 (0.90)	More enlightening	<0.001
Relevant – Irrelevant to Life	4.00 (0.72)	2.05 (0.89)	Less irrelevant	<0.001
Worthless – Worthwhile	3.09 (0.71)	4.11 (0.81)	More worthwhile	<0.001
Frustrating – Gratifying	4.00 (0.65)	3.45 (0.76)	Less gratifying	<0.001
Beyond my Capabilities – Attainable	2.64 (0.87)	4.14 (0.67)	More attainable	<0.001
Practical – Theoretical	2.59 (0.69)	2.55 (0.73)	Less theoretical	0.76
Empowering – Disempowering	3.91 (0.64)	2.34 (0.71)	Less disempowering	<0.001
Shallow – Meaningful	3.16 (0.94)	4.05 (0.57)	More meaningful	<0.001
Tentative – Durable	2.34 (0.75)	2.39 (0.78)	More durable	0.74
Based on Observation – Based on Ideas	4.09 (0.71)	3.93 (0.79)	Based less on ideas	0.28
Only One Method – Many Methods	3.89 (0.92)	3.66 (0.99)	Based less on many methods	0.19
Certain – Subject to Change	2.91 (1.05)	2.75 (0.94)	Less subject to change	0.31
Biased – Unbiased	2.54 (0.76)	2.66 (0.64)	More unbiased	0.44
Ethical – Unethical	3.60 (0.86)	3.74 (0.73)	More unethical	0.31

Table 2. Student perceptions of biologists, with qualitative description of the direction of change for each item as measured by pre- and post-assessments (mean values with SD in parentheses).

Perceptions about Biologists	Pre	Post	Qualitative Direction of Change	P
Antisocial – Outgoing	3.52 (0.92)	3.95 (0.66)	More outgoing	0.003
Intelligent – Unintelligent	3.76 (0.69)	3.64 (0.79)	Less unintelligent	0.38
Unimaginative – Creative	2.65 (0.61)	2.56 (0.63)	Less creative	0.42
Lazy – Hardworking	3.26 (0.85)	3.40 (0.76)	More hardworking	0.32
Boring – Interesting	2.32 (0.57)	2.44 (0.73)	More interesting	0.39
Exclusive – Inclusive	2.81 (0.71)	2.69 (0.68)	Less inclusive	0.34
Objective – Subjective	2.35 (1.10)	2.51 (0.88)	More subjective	0.38
Open-minded – Closed-minded	2.40 (0.79)	2.67 (0.81)	More closed-minded	0.08
Ethical – Unethical	2.12 (0.70)	2.30 (0.60)	More unethical	0.15
Socially Responsible – Irresponsible	2.42 (0.70)	2.58 (0.63)	More irresponsible	0.21
Moral – Immoral	1.91 (0.68)	2.09 (0.75)	More immoral	0.16
Spiritual – Atheistic	2.60 (0.88)	2.47 (0.80)	Less atheistic	0.40
Patient – Impatient	3.09 (0.53)	3.00 (0.38)	Less impatient	0.16

over the span of the course, students perceived that biology was more personally helpful to them as citizens, more intriguing to them, more enlightening, more relevant to "real-life" discussions, more worthwhile for them in seeking additional information, more gratifying to study, more understandable, more empowering, and that biology became more meaningful to them personally. One variable that changed, which might be of concern to biology educators, is that students perceived biology as more frustrating after the course. In addition, students' perceptions remained neutral on the ability of biology content to be subject to change and on the biased nature of results in biology. Finally, students demonstrated almost no change in their high perceptions of the unethical nature of some aspects of biology.

Regarding students' perceptions of biologists, tests indicated a significant difference in only 1 of 21 items measured under these semantic differential items ($P < 0.005$; Table 2). The only significant change in perceptions about biologists was that students perceived scientists as more outgoing following their experiences in the course. Items in this construct that showed a slight directional shift but were not statistically significant included students' perception of biologists as being more hardworking, less creative, less inclusive, more subjective, more immoral, and more likely to be male. The preceding qualitative changes in these items should be interpreted with caution given the nonstatistical change in these items, but they may be relevant to examine in future studies. Variables that might be of concern to biology educators on these items are that students remained neutral on (1) how creative biologists are in their work, (2) whether biologists are interesting or boring, (3) whether biologists tend to be objective or subjective in their work, and (4) whether biologists tend to be closed- or open-minded.

For the final section of the biological literacy instrument, items related to changes in general student attitudes toward biology were collapsed through exploratory factor analysis (Bartlett's: $\chi^2 = 3235.34$, df = 528, $P < 0.0001$; Kaiser-Meyer-Olkin measure of sampling adequacy, KMO = 0.893, resulting in a six-factor solution accounting for 59.37% of the variance). The collapsed item factors arising from the factor analysis included students' confidence in their learning of biology, interest in biology, perceptions of biologists' social relevance and of the personal relevance of biology, how much they personally identified with biology as a subject, and their confidence in completing laboratory activities. Coefficient alpha reliability values as calculated on the pre-assessment data are reported below as well. Results indicate that following the course, students were not more confident in their ability to learn biology ($P = 0.012$, $\alpha = 0.86$), did not seem to find biology more personally relevant to their daily lives ($P = 0.015$, $\alpha = 0.54$), and still felt difficulty identifying with biology as a field ($P = 0.088$, $\alpha = 0.76$). We again used a Bonferroni-adjusted significance value of $\alpha = 0.005$ to determine statistical significance, yet some of these constructs did show a slight shift and would have demonstrated a statistically significant shift with less stringent conditions. Results indicated that students did become more interested in biology ($P < 0.0001$, $\alpha = 0.71$), became more confident in their ability to complete tasks in the biology laboratory ($P < 0.0001$, $\alpha = 0.58$), and felt that biology had much more social relevance ($P = 0.002$, $\alpha = 0.59$). We note that although factor analysis provided validity evidence for these subscales, many had reliability values that would be considered at the high end of the "poor" range (0.50–0.60).

○ Discussion

A nonmajors science course can have both short- and long-term impacts on students, and may extend well beyond the important goal of establishing scientifically literate members of society (Sundberg & Dini, 1993). These goals often contrast with those of majors-based courses. It is necessary to consider the student demographics of a nonmajors science course and explore how the curriculum and the instructor's interactions with the students may have substantial influence on perceptions as well as matriculation into biology fields of subgroups within a class. For example, this includes education majors (who made up >50% of our current participants) as well as students who were "undecided."

Results from the biological literacy instrument indicate that the goal of improving biological literacy was effectively addressed by the curriculum and instruction along some of the aspects measured. For example, many aspects of students' attitudinal subconstructs changed as a result of this evidence-based course. Other instances of these types of attitudinal changes have been demonstrated in the literature (Cook & Mulvihill, 2008). In addition, students' perceptions of biology as a scientific practice changed along many of the items. Interestingly, students' perceptions of biologists were essentially unaffected by their engagement and interactions in the course. We believe that this is an important distinction; the data indicate that nonmajors can develop positive attitudes toward the subject matter and the practices within the field of biology, yet maintain many (if not all) of their initial perceptions regarding biologists as researchers. Based on our data, this is not due to a ceiling/floor effect at the onset of the course.

Vision and Change (AAAS, 2011) has become the policy document currently guiding much of the curriculum change in undergraduate biology education. Although it addresses the need to reform "biology education for all students," we perceive a gap in *Vision and Change*. The document doesn't address two important issues brought to light by our research, specifically in the context of nonmajors courses. First, considering the typical majors in such a general-education biology course, deficiencies in curriculum design and instruction might produce undesirable and unforeseen consequences. Study participants majoring in education showed no change in their perceptions of biologists as scientific researchers. This is an important consideration for preservice teacher preparation, because these teachers will be responsible for defining the field of biology for their own students. It is possible that an undergraduate biology course such as the one highlighted in this study may be the only and last exposure these education majors will have to interaction with practicing scientists (AAAS, 2011). It is important that this group has positive and well-informed interactions with the field of biology, as well as with biologists, because this will influence their long-term views and the efficacy of their science teaching.

In addition to influencing preservice teachers, a second issue that we find to be lacking in *Vision and Change* is the potential influence that an engaging introductory biology course can have on nonmajors and those undecided about whether to engage in science. For this demographic, a biology course can potentially "hook" a student on biology and encourage their matriculation into the field. Students who are undecided, or who are nonscience majors, may never have considered biology as a major. Providing an engaging curriculum that addresses preconceptions about biology and biologists, by enabling them to view themselves as biologists, might influence such students to enter the STEM pipeline (American Association of State Colleges and Universities, 2005). For example, work in identity development (especially with women and underrepresented minorities) indicates that students have to be able to see themselves as represented in a field before they will consider it a viable career option (Lee, 1998; Carlone & Johnson, 2007). Our results provide evidence that students' perceptions of biologists were minimally affected by this iteration of an evidence-based curriculum and offer considerations for future research in this vein. If nonmajors' perceptions of biologists are not greatly influenced by their initial biology course, does this affect their ability to perceive themselves as biologists? Undergraduate students seeking to identify themselves as a *professional something* are, according to social cognitive career theory, affected by both objective and perceived educational experiences that can alter their career choices (Lent et al., 2000). Instructors of a general-education biology course should consider this an opportunity to characterize the practice of biology as an obtainable, rewarding, and relevant career.

To influence students through curriculum and instruction, it is necessary to evaluate these aspects using appropriately designed instruments. The biological literacy instrument used in this study revealed changes in perceptions of biology and biologists held by nonmajors. The knowledge gained from this and similar instruments can inform the design and implementation of curriculum for the purpose of promoting positive characterizations about biology and biologists and potentially influence students to pursue biology or other scientific disciplines as a career. Some undergraduate student populations, including students who will become K–12 biology educators and nonmajors who have yet to decide on a field of study, are underrepresented in calls to action such as *Vision and Change*. Further research in this area should seek to increase sample size so that the impact of curriculum and instruction can be validated. Also, more in-depth information should be collected about the students in a nonmajors course to understand where preconceptions about biology and biologists are established and how they are best addressed to support improvements in students' biological literacy.

Like any study, this one has limitations. We have an admittedly small sample size, which may have affected the reliability of a few of the constructs measured. We make no claims to be able to broadly generalize from this particular data set. We treated this as an exploratory study, which has brought to light some issues for us as researchers–practitioners. We hope this narrative has (1) provided a frame through which researchers might develop larger-scale studies and more explicit research questions and (2) provided a series of considerations for postsecondary instructors regarding their roles in nonmajors courses.

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