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Low-Level Learning

Leaving Behind Nonscience Majors

By Austin Heil, Cara Gormally, and Peggy Brickman

More than 8 out of every 10 college students are not STEM majors, yet we have little understanding about learning expectations for them. We used the results of the Howard Hughes Medical Institute BioInteractive learning objectives survey of 38 instructors teaching nonscience major courses to characterize learning objectives (LOs) in these courses. The survey included demographics questions, and instructors were asked to contribute at least 10 LOs from their nonscience major introductory biology course. We coded the LOs (n = 872) for Bloom's level, content area, and competencies related to Vision and Change in Undergraduate Biology Education. As a comparison, we coded LOs (n = 1390) from three best-selling textbooks for nonscience majors. We found that most instructors report creating LOs themselves, and most share LOs with students. Overall, 80% of LOs focus on low-level thinking skills. Few LOs (11.5%) from instructors or textbooks focused on science process skills that students might use in everyday life to make science-informed decisions. Our findings indicate a need to revisit the goals of instruction for nonscience majors—the vast majority of people in our society.

The United States is one of the only countries that requires nonmajors to take a full year of science courses in college (Miller & Barrington, 1981). Thus, general education science courses have the unique responsibility of educating the 8 out of every 10 college student who are nonscience majors and who will become contributing citizens (McFarland et al., 2018; Snyder & Dillow, 2013). There is no national consensus, however, about what the focus should be in courses for nonscience majors. We know that nonscience major students differ from science major students in a number of ways. Specifically, nonscience majors are less likely to describe themselves as a science person (Hebert & Cotner, 2019), report lower science motivation (Glynn et al., 2011), find science less relevant to their careers (Knight & Smith, 2010), and are more likely to hold misconceptions about the nature of science (Cotner et al., 2017). This begs the following question: What do instructors want their nonscience majors to know about science?

Learning objectives (LOs) are a critical part of backward design in higher education. LOs reflect the content and cognitive level (e.g., as measured by Bloom's taxonomy) instructors will use to build their assessment and design their instruction (American Association for the Advancement of Science, 2010; Wiggins

et al., 2005). Thus, if LOs are not well written or aligned with instruction and assessment, the entire process breaks down. Studies on introductory undergraduate science major courses found instructors tended to focus more on rote memorization and facts instead of on higher-level cognitive skills (Momsen et al., 2010; Zheng et al., 2008). As a result, there have been efforts to help science instructors write assessments and LOs at various cognitive levels for science-major courses, such as the Blooming Biology Tool (Crowe et al., 2008). Unfortunately, a recent analysis of LOs included on a wide range of syllabi from leading U.S. universities revealed that almost 90% were poorly written and 40% contained verbs or phrases such as “appreciate,” “consider,” “reflect,” or “observe” that were not measurable (Schoepp, 2019).

The core goal of science education is to develop a scientifically literate citizenry (Anderson et al., 1997; Lee & Roth, 2003; NGSS Lead States, 2013). Roberts (2007) suggests that students need to be exposed to relevant scientific situations that they are likely to encounter as a citizen. However, students often do not see relevance in traditional school science (Roth & Barton, 2004; Roth & Lee, 2002; Zacharia & Barton, 2004). Students also may not acquire the skills they need to engage with science as a citizen. There is little research on what nonscience major college students and instructors find relevant. In one study, nonscience majors' sci-

ence instructors ($n = 63$) rated more relevant topics, such as genetics and socioscientific issues concepts, as less important than content acquisition (Bowling et al., 2008). Additionally, instructors in nonscience major courses may not use the guidance of *Vision and Change* (American Association for the Advancement of Science, 2010), a document that prioritizes concepts and competencies for biology majors.

If the goal of general education science courses is to promote science literacy (Feinstein, 2011; Wright, 2005), we should see more LOs that involve higher-level thinking skills, are based on relevant content, and focus on science competencies. In recent years, numerous efforts to support faculty pedagogical development have focused on using LOs in the context of curricular design. However, we know little about instructors' actual use of LOs. In this study, we asked the following questions:

1. Where do nonscience major instructors get their LOs, and how do they share them with their students?
2. What kind of LOs (in terms of Bloom's taxonomy level, content area, and competencies) do instructors write and share with nonscience majors?
3. How do instructors' LOs differ from LOs presented in textbooks?

Methods

Survey

We used Howard Hughes Medical Institute (HHMI) BioInteractive learning objectives survey results of 38 instructors teaching nonscience major courses to characterize LOs in these courses. We recruited participants for the learning objectives survey from BioInteractive's higher

education newsletter subscribers, the Partnership for Undergraduate Life Sciences Education community, the Society for the Advancement of Biology Education Research, and the American Society for Cell Biology education group; we encouraged interested individuals to share the survey. The learning objectives survey included demographics questions about instructors' affiliations, including institution type, position (tenure track or non-tenure track), and appointment type (full time or part time). Additionally, we asked survey respondents to contribute at least 10 LOs that they had used in their most recently taught introductory biology course. HHMI specifically requested fine-grained LOs (i.e., the knowledge and skills faculty want students to gain by completing a class day, learning module, or activity used to guide specific formative and summative assessment questions). Instructors were asked about the sources of their LOs. Possible responses included the following: "I created them," other instructor, course coordinator, textbook, or other (e.g., departmental decision or Association of American Colleges and Universities rubrics).

Articulation agreement survey

The majority of instructors at 2-year institutions (82%, or 14 of 17 respondents) reported that they created their own LOs. We conducted a brief follow-up articulation agreement survey with all 2-year institution instructors to determine (i) whether they adhered to articulation agreements when writing their LOs, which usually determine the content that 2-year institution instructors must teach (Lennon, 2018); and (ii) to what extent they relied on articulation agreements when writing their LOs. Findings from respondents (n

$= 5$) indicated that 2-year instructors either (i) did not have articulation agreements ($n = 1$); (ii) did not adhere to articulation agreements ($n = 1$); or (iii) created their own LOs that aligned with the articulation agreement ($n = 3$).

Analysis of demographic data

We analyzed the demographic data to determine who submitted LOs for nonscience major courses in terms of institution type (e.g., PhD granting, MS granting, 4-year, 2-year, unspecified) and an instructor position's (e.g., tenure track or non-tenure track) and appointment (full time or part time).

Analysis of source and how instructors share learning objectives

We analyzed data about the LOs, including the source of the LOs, as reported by the instructor. Additionally, we analyzed responses about how instructors report using LOs in their course (e.g., shares LOs on a PowerPoint in class; shares LOs on a syllabus or in a course manual; shares LOs in a study guide; shares LOs on the course website; other; does not share the LOs with students). We also analyzed responses about the extent to which the LOs inform the instructors' design of tests.

Analysis of learning objectives

We coded the LOs ($n = 872$) from the survey for the following: (i) Bloom's level, (ii) *Vision and Change* core competencies as articulated in *BioSkills* (Clemmons et al., 2020), and (iii) content as described by core units in biology via a review of commonly used textbooks and *Vision and Change BioCore* (American Association for the Advancement of Science, 2010). For comparison, we obtained and

coded LOs ($n = 1390$) from three best-selling textbooks for non-science majors. Textbook LOs were coded following the same process described in the following sections.

Bloom's taxonomy of instructor and textbook LOs

LOs were coded for Bloom's level using Bloom's taxonomy action verbs (Stanny, 2016). Some LOs had multiple Bloom's action verbs present within a single LO. For example, in the LO "Critique news reports about scientific discoveries and recognize source bias," we coded the action verbs "critique" as Evaluate and "recognize" as Remember. When action verbs were not demonstrable or measurable (e.g., "appreciate scientific discoveries"), we coded the LO as a 0 to indicate that no Bloom's action verb was present.

BioSkill competencies of instructor and textbook LOs

Each LO was coded for *Vision and Change* competencies using the *BioCore* and *BioSkills* guides (Clemmons et al., 2020). Clemmons and colleagues (2020) developed the *BioSkills Guide* as a tool to help instructors articulate the six *Vision and Change* core competencies as measurable LOs. Specifically, we coded for the *BioSkills* program-level LOs, which identified the broad skills students should develop by the time they graduate. For example, in the LO "Critique news reports about scientific discoveries and recognize source bias," we coded the *Vision and Change* competency as "Process of Science" and *BioSkills* program-level competency as "Scientific Thinking."

Content area of instructor and textbook LOs

All LOs were also coded for their content categories (e.g., Molecular Basis of Life, Cells, Genetics, Evolution, Diversity of Life, Plants, Animals, Ecology, Process Skills), which were identified as core units in biology via a review of commonly used textbooks.

Findings

Demographic data

Of the 38 instructors who participated in the LOs survey, 50% were from 2-year colleges, 31% were from 4-year institutions, 8% were from master's-granting institutions, and 10% were from PhD-granting institutions. Additionally, 71% of the instructors held full-time appointments, and 58% were non-tenure track.

Source of instructors' LOs

We found that 74% of instructors reported that they created their own LOs. Additionally, instructors reported getting their LOs from textbooks (24%), course coordinators (16%), other instructors (13%), and other (e.g., verbal communication, Google Classroom, and student packets; 8%).

How instructors share LOs with students

We found that instructors shared their LOs with their students on the syllabus or in a course manual (50%), in a study guide (42%), on the course website (42%), on PowerPoint slides in class (31%), and through other methods (e.g., verbal communication, activities, class handouts; 7%). Only 5% of instructors reported that they did not share their LOs with their students.

Bloom's taxonomy of instructor and textbook LOs

Of the 872 LOs submitted to the LOs survey by 38 instructors teaching introductory nonscience majors biology, 66% were rated Bloom's Level 1 or 2 (Remember and Understand; Figure 1). Of the remaining items, 13% were rated Level 3 (Apply), 9.1% were rated Level 4 (Analyze), and less than 2% were rated Level 5 (Evaluate) and Level 6 (Create). Additionally, 7.3% of LOs did not have a Bloom's verb and were rated as "No Bloom's Present." Of instructors' LOs, 15% had either one or no Bloom's verbs present. The most common Bloom's verbs for the LOs survey were Explain (Level 2), Describe (Level 2), and Define (Level 1).

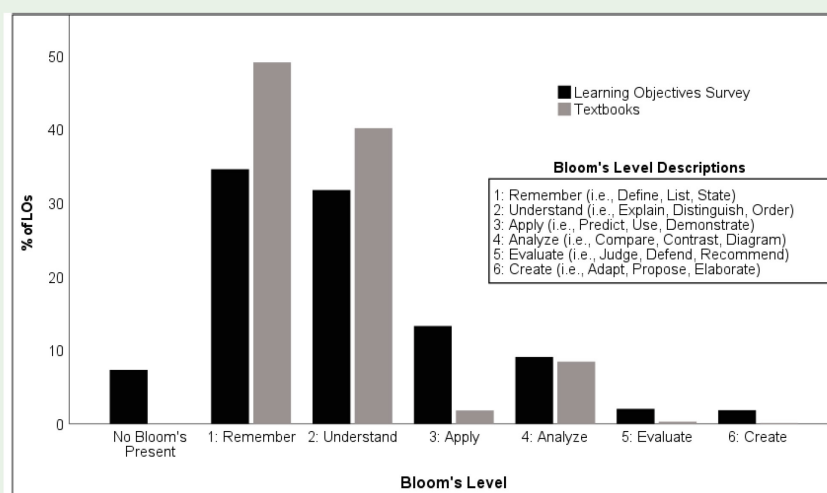
Of the 1,390 LOs analyzed from the three textbooks, 89% were rated Bloom's Level 1 or 2 (Figure 1). Of the remaining items, 8% were rated Level 4, with less than 2% rated Levels 3, 5, or 6. Of textbook LOs, 21.3% of the LOs analyzed from the textbooks had either one or no Bloom's verbs present.

BioSkills competencies of instructor and textbook LOs

Competency skills were present in only 17.7% of instructors' LOs and 7% of the textbook LOs. Of the competency skills present in instructors' LOs ($n = 162$), 53% represented Process of Science, 18% represented Modeling, 14.2% represented Science and Society, and the remaining topic-level competencies in the survey accounted for less than 10% (Figure 2). When competency skills were present in textbook LOs ($n = 98$), 57% represented Science and Society, 19% represented Process of Science, and the remaining topic-level competencies in textbook LOs accounted for 5% or less.

FIGURE 1

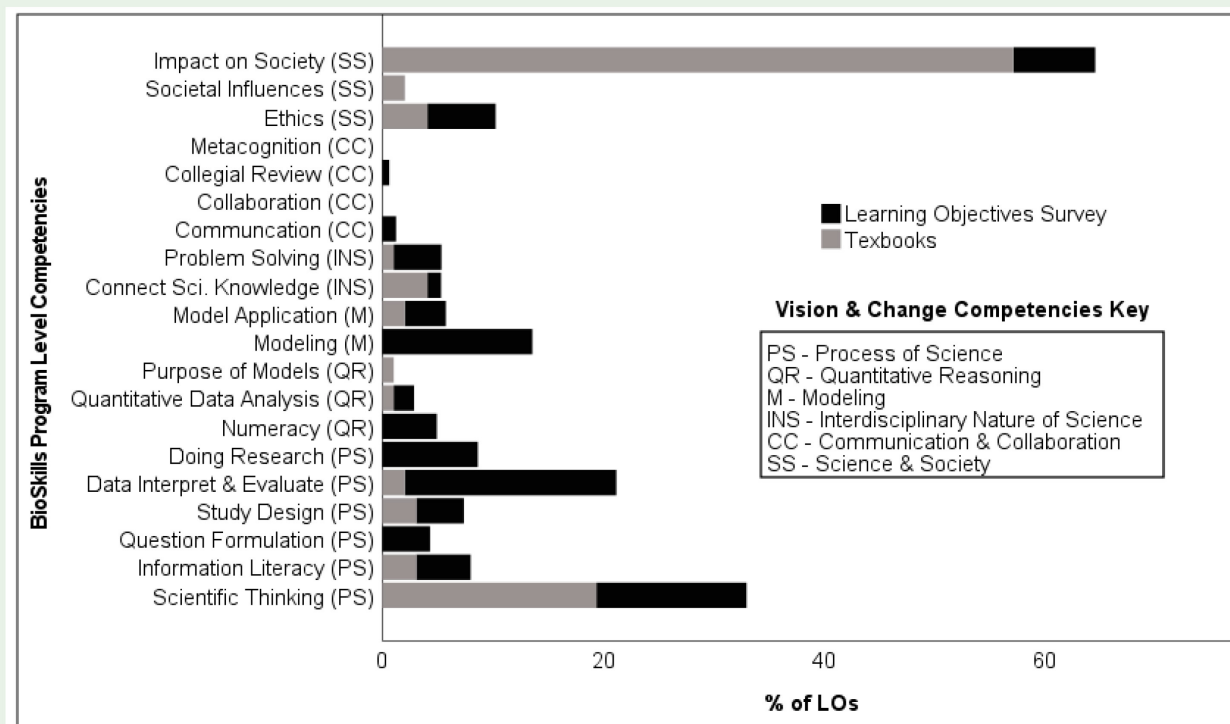
Cognitive level of nonscience major learning objectives (LOs) from the analysis of learning objectives instructor survey (black) and textbook analysis (gray).



Note. The nonscience majors' LOs from the Learning Objectives survey ($n = 872$) and textbooks ($n = 1390$) were coded for Bloom's taxonomy as described by Stanny (2016). Lower-level Bloom's (Level 1: Remember and Level 2: Understand) accounted for 80.5% of all nonscience majors' LOs that were coded for this study. Of instructors' LOs, 13% had at least one Bloom's verb present. "No Bloom's Present" represents LOs that were unable to be coded using Bloom's taxonomy because they did not contain a recognizable Bloom's action verb.

FIGURE 2

Frequency of *BioSkills* program level competencies in nonscience major learning objectives (LOs) from the learning objectives instructor survey (black) and textbooks analysis (gray).



Note. In total, only 17.7% of the instructors' LOs and 7% of the textbook LOs possessed a *BioSkills* competency. Of the competency skills present in instructors' LOs ($n = 162$), Process of Science (PS; 53%) and Modeling (M; 18%) were the most frequent. When competency skills were present in textbook LOs ($n = 98$), 63% represented Science & Society (SS) and 27.5% represented Process of Science.

The most frequent *BioSkills* competencies in the survey LOs were Data Interpretation and Evaluation (20.2%), Modeling (12.1%), Scientific Thinking (10.9%), and Doing Research (10.1%).

Content area of instructor and textbook LOs

Molecular Basis of Life, Cells, and Genetics content areas represented 62.3% of the instructors' LOs and 33.5% of the textbook LOs (Figure 3). Individually, the Diversity of Life, Ecology, Plants, Animals, and Structure and Function content areas represented 5% or less of the LOs from the survey. Textbook LOs were more uniform across content areas, with Structure and Function representing the largest percentage (21.8%) and Plants (6.4%) and Evolution (4.9%) representing the smallest percentages. Less than 1% of textbook LOs and 9.8% of the survey LOs were science skills.

Additionally, 3.4% of the survey LOs did not fit into one of these 10 content areas and were coded as none.

Study limitations

Our current study does not include complete sets of LOs from survey participants, so it is possible there is a larger diversity of LOs for non-science major courses. However, this survey targeted instructors who were already concerned with improving their courses (e.g., the survey was sent to instructors who use HHMI BioInteractive and to members of the Society for the Advancement of Biology Education Research). Thus, our survey participants should represent the "cream of the crop" of non-science majors' biology courses.

Discussion

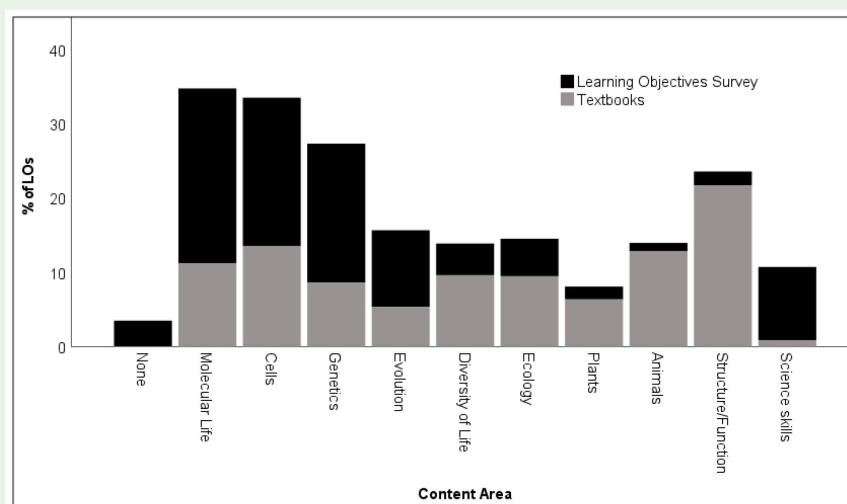
LOs are an important aspect of backward design (Wiggins et al., 2005)

because they help instructors articulate what students will learn and align learning activities with matching assessments. Our analysis revealed that non-science majors' instructors typically created their own LOs rather than using them from another source (e.g., textbooks, other instructors, or course coordinator). This result was somewhat surprising because half of the survey participants were from 2-year institutions, where articulation agreements usually determine the content that instructors must teach (Lennon, 2018).

The vast majority of LOs created by instructors, as well as those included in textbooks, included action verbs rated as low-level Bloom's (e.g., Understand and Remember). Few LOs focused on higher-level thinking skills (e.g., Evaluate and Create), similar to the paucity of high-level thinking skills found in introductory major courses,

FIGURE 3

Comparative responses from the learning objectives instructor survey (black) and textbook analysis (gray) shown by content area.



Note. Content areas were coded using *Vision and Change BioCore* guide, which included Evolution, Information Flow, Transformation, Systems, and Structure/Function. Additional areas such as Diversity of Life, Plants, Animals, Molecular Basis of Life, and Cellular Biology were also included to better reflect common content units in textbooks. We also coded for Science Process Skills. Molecular Basis of Life, Cells, and Genetics accounted for 62.3% of the content found in the survey non-science majors' LOs. The LOs that did not fit within a content area were coded as None.

college entrance exams, and first-year medical school courses (Momsen et al., 2010; Zheng et al., 2008). This finding suggests that nonscience major course instructors tend to overemphasize factual understanding and comprehension rather than the science literacy skills their students could use to make scientifically informed decisions.

Few competency skills were present in LOs from instructors and textbooks. Based on our analysis, it seems that nonscience major instructors tend to focus on content rather than science competency skills. Although there has been a push to incorporate *Vision and Change* competency skills in major courses (American Association for the Advancement of Science, 2010), there is no such policy that informs nonscience major courses. As a result, nonscience major students may miss out on critical science learning useful for their lives.

Overall, these findings indicate that we are leaving our nonscience majors—the vast majority of our citizens who will also be consumers of science—behind. Nonscience majors need to understand how scientists make and evaluate claims. Additionally, our nonscience major students need to be exposed to relevant scientific situations that they are likely to encounter as citizens. Evidence suggests that conceptual understanding of scientific topics has little impact on the actual decisions citizens make on real-world issues (Allum et al., 2008; Nisbet & Scheufele, 2009). Our findings indicate there is a need to revisit the goals of instruction for nonscience majors. Previous research shows that nonscience majors are just as capable of doing science as students who are science majors (Hebert & Cotner, 2019), yet instructors continue to focus on low-level cognitive skills and science content in courses for nonscience

majors. We argue that instructors of nonscience major courses should incorporate science competency skills and create opportunities for students to engage with science they will encounter as citizens.

We recommend that future studies continue to explore whether LOs differ between institution types. Questions remain about how instructors share LOs with their classes and then, in turn, how students use these LOs. Future studies might also compare LOs from major and nonscience majors' courses.

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