A Comparison of Nonmajors' & Majors' Incoming Science Process Skills

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Abstract

Recommendations for undergraduate biology education include integration of research experiences into the curriculum, regardless of major. While non-biology majors and biology majors differ in affective characteristics, it is not clear if they differ in their incoming science process skills. We created a scenario-based assessment instrument – designed to gauge science process skills – that was accessible to nonmajors and majors. We evaluated nonmajors' and majors' open-ended responses using a rubric. We also assessed students' science identity, confidence, and attitudes with a pre-course survey. While affective differences between the populations are evident, we did not detect meaningful differences in science competency. These findings indicate that nonmajors and majors are skilled in the process of science and have the ability to engage in meaningful scientific inquiry, confirming our hypothesis that, in supporting a scientifically literate citizenry, educators must emphasize teaching strategies that target affective differences between nonmajors and majors.

Key Words: *Science process skill; undergraduate; nonmajors; biology majors; assessment.*

○ Introduction

Building on the foundational work of the "Science: A Process Approach" program (Livermore, 1964), recent recommendations for undergraduate biology education include the promotion of an inquiry-based curriculum, regardless of a student's major (AAAS, 2011). In response, science educators are incorporating research experiences into their courses that emphasize developing students' science process skills (SPS): hypothesis construction, experimental design, data interpretation, and communication (Coil et al., 2010; Luckie et al., 2013).

While recommendations for integrating research experiences into the curriculum are independent of major, notable differences between non-biology majors and biology majors (hereafter "nonmajors" and "majors") may need consideration when designing course research experiences (Ballen et al., 2017). Nonmajors are less motivated by science (Knight & Smith, 2010; Glynn et al., 2011), less interested in it (Knight & Smith, 2010), less confident with respect to it (Cotner et al., 2017), and have less positive attitudes toward it (Sundberg et al., 1994; Cotner et al., 2017) than majors. While nonmajors and majors differ in affective characteristics, it is unclear whether nonmajors are less skilled in their ability to *do* science (e.g., developing testable questions and hypotheses, designing experiments, interpreting results, and communicating scientific information) than majors. Gauging differences in these core competencies will be beneficial to instructors designing curricula for these students.

Our SPS learning objectives for introductory biology students are as follows:

(1) Ask a testable question.
(2) Propose a testable hypothesis and prediction that aligns with the question.
(3) Evaluate the strengths and weaknesses of an experiment or design a well-controlled experiment that aligns with the hypothesis.
(4) Interpret data from tables and graphs.
(5) Draw conclusions that are supported by the data.
(6) Develop future research plans based on previous results.
(7) Communicate research plans and findings in writing.
(8) Use science in daily life.

In addition to being able to assess these learning objectives, we wanted an instrument that was accessible to nonmajors and majors with an open-ended question format. While each existing SPS assessment instrument (Shortlidge & Brownell, 2016) met some of our goals, no single instrument met them all. Thus, we developed a scenario-based SPS assessment instrument (hereafter "SPS scenario") and rubric.

Our goal was to assess nonmajors' and majors' incoming science process skills. We evaluated students' responses from the SPS scenario using a rubric to meet this goal. We ensured that our sample

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populations of nonmajors and majors were representative of the larger populations at our institution in their affective characteristics (Cotner et al., 2017) by evaluating their responses on a pre-course science identity, confidence, and attitudes survey.

○ Methods

Participants

We define "majors" as undergraduate students enrolled in the College of Biological Sciences and "nonmajors" as undergraduate students enrolled in any other college at the University of Minnesota. The majors discussed here are incoming (first-year) students, and the nonmajors are students enrolled in an introductory biology course for nonmajors (described in Cotner & Gallup, 2011; Cotner et al., 2013; Cotner & Hebert, 2016). The data are students' SPS scenario or survey responses or institutional data. Our Institutional Review Board reviewed the research plans and granted an exempt status (Study 1405E50826). All participants gave informed consent to participate and were free to opt out of the study.

Assessment Instrument

Instrument development

We developed the SPS scenario (available at https://cbs.umn.edu/cotner-lab/sps-scenario-whipworm) through an iterative process – during which the wording changed considerably – based on feedback from four biology experts. We began by generating our SPS learning objectives (see above), drawing from recommendations from national reports (AAAS, 2011), the biology education literature (Coil et al., 2010; Luckie et al., 2013), and discussions with biology faculty. While developing the instrument, we followed these guidelines: (1) the basis for the scenario should have valid research support (i.e., be peer-reviewed), (2) the topic should be relevant to nonscientists, (3) the language and content should be accessible to nonscientists (i.e., no jargon or specialized knowledge required), and (4) the instrument should follow a progressive format that displays a portion of the scenario and related questions at a time. The progressive format prevented students from modifying previous answers after receiving additional information. The SPS scenario consisted of open-ended questions that covered a range of skills. The corresponding learning objective(s) are listed at the end of each SPS scenario question (see https://cbs.umn.edu/cotner-lab/sps-scenario-whipworm).

SPS scenario

The SPS scenario describes the use of parasites to mitigate the impact of inflammatory bowel disease (IBD). The scenario is based on the work of Weinstock and colleagues (Summers et al., 2003, 2005a, 2005b) and begins by explaining IBD, an autoimmune reaction, and the possible role of parasites in preventing immune system diseases. The SPS scenario continues with scientists hypothesizing that parasite infection could mitigate the impact of IBD. At this point, students design an experiment to test the scientists' hypothesis. Once the students' experiments are entered in the online instrument, the scientists' methods are provided and students list strengths and weaknesses of the scientists' experiment. Then the students interpret results from the scientists' data and generate follow-up questions, hypotheses, and predictions. Finally, they apply the scenario data to make a hypothetical decision about their own health.

Instrument validation

The SPS scenario was validated with biology faculty and students. The scenario was developed and revised, in a year-long series of discussions, with four biology experts. The resulting version of the scenario was shared with faculty members and postdoctoral associates throughout the College of Biological Sciences for feedback. After incorporating this feedback, the instrument was validated through student interviews with nonmajors (n = 12) and majors (n = 12). Although some students' responses highlighted some scientific misconceptions, there was a clear understanding of the scenario's language and content. Therefore, no changes to the scenario assessment were made following student interviews. Students were compensated with an hourly wage or a gift card to the university bookstore.

Identity, Confidence & Attitudes Survey

The identity, confidence, and attitudes survey (Figure 1) consisted of published Likert-scale items that asked participants to report their science identity (Cole, 2012), science confidence (based on similar items in Seymour et al., 2004; Robnett et al., 2015), and attitudes toward science (Lopatto, 2004; Cole, 2012). The survey also asked if participants had taken advanced science classes (Cole, 2012).

Assessment Administration

We administered the SPS scenario and the identity, confidence, and attitudes survey before students took any biology classes at the university. Surveys were administered to incoming majors online one week before they attended a 2015 summer orientation program and were completed before they participated in that program. Surveys were distributed to nonmajors online one week before the start of the fall 2015 semester and were completed prior to the first day of class. The scenario and the survey took students ~30 minutes and ~10 minutes to complete, respectively. Nonmajors were awarded one point of assignment credit for completing the scenario and one point of extra credit for completing the survey. Completion of both instruments contributed two-thirds of one percentage point to an individual's final grade. Students could omit survey item(s) and still receive credit, provided they entered their ID. The structure of the majors' program prohibited awarding course points for completing the surveys. However, survey response rates were >90% for both nonmajors and majors.

Rubric Development & Scoring

We developed a rubric to collect data from students' responses to the open-ended SPS scenario questions (Figure 2). The rubric had a scaled design (Humphry & Heldsinger, 2014) and was aligned with our eight learning objectives (see above).

Because collecting data from open-ended responses is time intensive, we evaluated a random, small sample of nonmajors' (n = 30) and majors' (n = 25) SPS scenario responses. Two or three individuals (S.H. and upper-level undergraduate students) scored each de-identified student response using the rubric. The average percent agreement after individual coding was 93%, with the percent agreement for each item ranging from 81% to 100%. Student scorers were compensated with an hourly wage. Representative student responses and scoring examples are available at https://cbs.umn.edu/cotner-lab/rubric-scoring.

Science identity (modified from Cole, 2012):
People are complex! How well do the following describe the way you think of yourself?
(Not at all like me, Not much like me, Somewhat like me, Mostly like me, Very much like me)

- A science person

Science process skills confidence (generated in house, loosely based on similar items in Seymour *et al.*, 2004):
Please rate your level of confidence in your abilities to do each of the following.
(Not confident, Slightly confident, Mostly confident, Very confident)

- Analyze a set of observations, tables, or graphs to identify possible patterns.
- Pose questions about observations that can be answered with an experiment.
- Develop a hypothesis related to a question that has been posed.
- Design a well-controlled experiment to test a hypothesis.
- Make predictions about the results I could expect to get from an experiment.
- Use statistics or other appropriate methods to analyze the results of an experiment.
- Draw conclusions about a hypothesis based on the results of the experiment (taking into account possible sources of error in the experiment).
- Explain an experiment, the results, and analysis in writing.

Attitudes towards science (modified from Lopatto, 2004 and Cole, 2012):
For each item below, please rate your level of agreement with the item.
(Strongly disagree, Disagree, Neutral, Agree, Strongly agree)

- I think that science is extremely valuable for society.
- Solving scientific problems is interesting.
- Scientific topics do not interest me.

Science activities (modified from Cole, 2012)
Do/did you participate in or enjoy any of the following?

- Advanced science classes at school (AP classes, science electives, etc.)

Figure 1. Survey items on science identity, attitudes, confidence, and activities.

Data Analysis

One-way ANOVAs were used to compare our sample population (n = 55) to the larger student population (n = 1450) that completed the survey, with respect to gender, ethnicity, and ACT score. Participant ethnicity was collapsed into two categories (white and nonwhite) due to low numbers of American Indian, Asian American, and African American participants.

Continuous data are reported as means ± standard deviation and were analyzed using a t-test. Categorical data are reported as counts and percentages (excluding missing responses) and were analyzed using a chi-square test. Statistical significance was defined as $P < 0.05$.

○ RESULTS

Samples Were Representative of the Larger Populations

The nonmajors (n = 30) and majors (n = 25) samples were similar in demographic and affective characteristics ($P > 0.05$) to the larger nonmajors and majors groups from the same semester described in Cotner et al. (2017).

Most participants were female (57% of nonmajors and 64% of majors) and white (90% of nonmajors and 72% of majors). The mean ACT score was significantly different ($P < 0.001$) between nonmajors and majors (26 ± 2.86 vs. 30 ± 2.20), a consistent distinction

Score	0	1	2	3
Question:				
is testable	Question is not provided	Question is not testable	Question is testable	-
Hypothesis or Prediction:				
is testable	Hypothesis and prediction are not provided	Hypothesis and prediction are not testable	Hypothesis or prediction is testable	-
aligns with question	Hypothesis and prediction are not provided (or question was not provided)	Hypothesis and prediction do not align with the question	Hypothesis or prediction does align with the question	-
Experimental Design:				
includes detailed procedure	Procedure is not provided	A general procedure is described but most details are missing *(Includes 0-3 items below)*	Procedure is described but a few details are missing *(Includes 4-6 items below)*	Procedure is described in detail *(Includes 7-8 items below)*
includes control group	Procedure is not provided	Does not include a control group	Includes a control group	-
sample size	Procedure is not provided	Describes a single subject per group	Describes multiple subjects per group	-
aligns with hypothesis or prediction	Procedure is not provided (or hypothesis and prediction were not provided)	Procedure does not align with the hypothesis and prediction	Procedure does align with the hypothesis or prediction	-
Results:				
are interpreted correctly	Response not provided	Interprets results incorrectly or unclear	Interprets results correctly	-
Data-Supported Decision:				
is provided	Response not provided	Did not use data to support decision	Wanted more information	Used data to support decision

Detailed procedure items:

- Includes a control group
- Sample size is explicit
- Procedure aligns with the hypothesis or prediction
- Describes how at least one variable will be controlled
- Includes duration of the experiment
- Describes what data will be collected
- Describes how data will be analyzed (e.g., comparisons, statistics)
- Uses specific terminology for variables (e.g., whipworm instead of parasite, IBD instead of disease)

Figure 2. Science process skills rubric.

between these two groups. Significantly fewer nonmajors than majors reported taking advanced high school science classes (37% vs. 100%, $P < 0.001$).

Nonmajors Differ from Majors in Science Identity, Confidence & Attitudes Toward Science

Affective differences between the nonmajors and majors samples mirrored those observed by Cotner et al. (2017). Nonmajors were less likely to describe themselves as "a science person," were less confident in their ability to "do" science, and had less interest in science than majors.

Nonmajors & Majors Demonstrated Science Competencies

When asking questions and proposing hypotheses, nonmajors and majors performed similarly. All nonmajors (100%) and majors (100%) asked testable questions and proposed testable hypotheses or predictions, and most nonmajors (97%) and majors (96%) proposed a hypothesis or prediction that was aligned with their question. Questions, hypotheses, or predictions were considered testable if they were about the natural world (i.e., data to test the hypothesis are available).

Nonmajors and majors performed similarly for most aspects of designing an experiment. All nonmajors' (100%) and most majors' (96%) experiments were aligned with the scientists' hypothesis. Most nonmajors (90%) and majors (96%) included a control group. Most nonmajors (97%) and majors (88%) included more than one subject per control or experimental group. Likewise, nonmajors performed as well as majors when identifying strengths and weaknesses of the scientists' experiment. For example, 17% of nonmajors and 16% of majors identified participant randomization as a strength, and 27% of nonmajors and 28% of majors recognized that using only patients' self-reported outcomes was a weakness. One difference between nonmajors and majors was the level of detail in their experiment, with nonmajors providing fewer details than majors (Figure 3). An experiment was categorized as "a detailed experiment" if it included at least seven of the eight detailed procedure items listed in Figure 2, "a few details missing" if it included four to six items, and "most details missing" if it included fewer than four items. None of the nonmajors (0%) provided a detailed experiment, while 16% of the majors did; 53% of nonmajors' experiments were missing a few details, compared to 80% of majors'; and 47% of nonmajors provided an experiment that was missing most details, compared to 4% of majors.

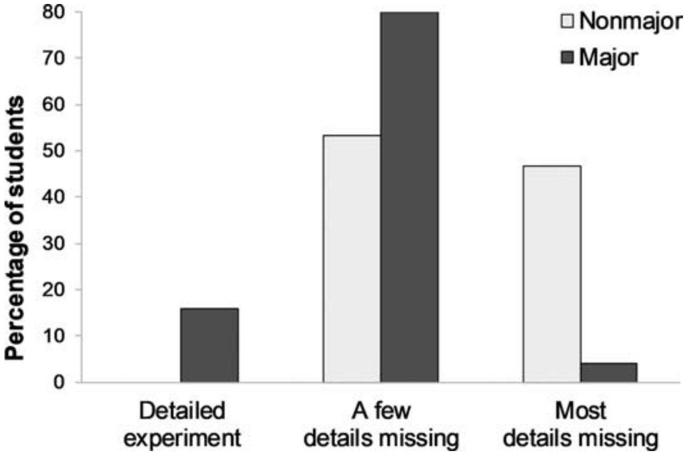

Figure 3. Comparison of nonmajors' and majors' level of experimental detail: percentage of nonmajors' (light gray) and majors' (dark gray) experiments that were categorized as a "detailed experiment," "a few details missing," or "most details missing."

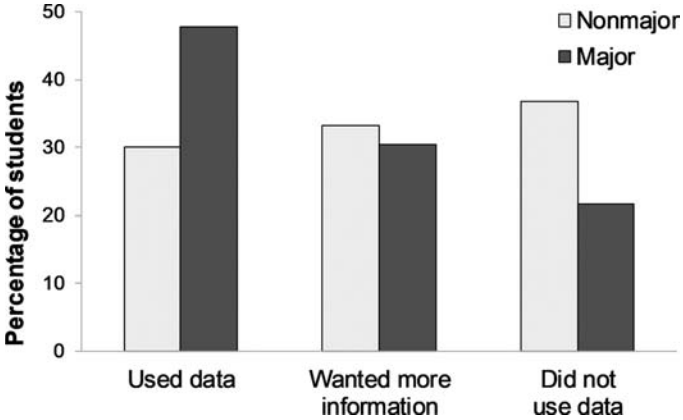

Figure 4. Comparison of nonmajors' and majors' use of data in personal health decisions: percentage of nonmajors' (light gray) and majors' (dark gray) responses that were categorized as "used data," "wanted more information," or "did not use data."

Nonmajors and majors interpreted results similarly. The scientists' interpretation of the results provided in the scenario was reasonable; 73% of nonmajors and 70% of majors agreed with the scientists' interpretation. The remaining nonmajors (27%) and majors (30%) either disagreed with the scientists' interpretation or did not definitively agree or disagree. Typically, the nonmajors and majors who disagreed with the scientists' claim did so because they didn't think the scientists' claim was valid given the small sample size of the study, not because they misinterpreted the data.

The other difference between nonmajors and majors was their use of data to make a hypothetical decision about their own health (Figure 4). Fewer nonmajors (30%) used data to support their decision than majors (48%). Among the nonmajors (37%) and majors (22%) who did not use data, responses ranged from a willingness to "try anything," to taking an expert's advice (e.g., a doctor's or scientist's), to being disgusted by the idea of ingesting parasites. The remaining nonmajors (33%) and majors (30%) wanted additional studies performed or more information (e.g., about side effects or other risks); because we weren't sure whether they were using data or not, they were grouped into the "wanted more information" category.

Finally, a total SPS score was calculated for each student by adding the scores (top of rubric; Figure 2) for all nine SPS items. The maximum possible score was 20 and the minimum zero. Nonmajors' and majors' total SPS scores were not significantly different (17.03 ± 1.38 vs. 17.04 ± 3.03, $P = 0.99$). Excluding majors that did not complete all questions ($n = 2$), the average total SPS score of the majors was 17.87 (± 1.01). All nonmajors completed all questions. Comparing complete cases, nonmajors' total SPS scores (17.03 ± 1.38) were significantly different ($P = 0.02$) than majors' (17.87 ± 1.01); however, both groups scored high (>17/20), and the difference in their mean scores is less than one point.

○ Discussion

Nonmajors and majors do not differ markedly in their abilities to "do" science, as evaluated by our scenario-based assessment. Nonmajors, like majors, can pose questions, analyze results, and draw conclusions based on data. The main difference between groups was the level of detail provided for the experimental design – a distinction that may be a proxy for differential motivation (Knight & Smith, 2010; Glynn et al., 2011) rather than competency. Nonmajors may have less patience for doing science during this exercise and may stop writing details before the majors do. Majors may be more motivated to appease or impress the survey distributors – staff and faculty, with whom the students will be engaged over the next several years. However, nonmajors receive a survey e-mail from their instructor, which may be motivating. Given that all majors reported taking advanced science courses compared to one-third of the nonmajors, differences in the level of experimental detail could also be due to majors being more comfortable with the language of science.

Interestingly, where the two populations differ is in their *perceptions* of their abilities to pose questions, analyze results, and draw conclusions based on data; nonmajors report less confidence in their abilities than majors. Nonmajors also report different perceptions of science and the utility of science than majors, but in general most students, in both groups, see science as relevant and important, a finding that complements those of studies by Miller (2004) and Allum et al. (2008) that investigated pro-science sentiments in the general public.

Our findings echo affective differences previously reported (Knight & Smith, 2010; Glynn et al., 2011; Cotner et al., 2017) and highlight a key message to science educators designing courses for nonmajors: *Nonmajors have the skills to engage in the practice of science*. Thus, nonmajors can probably be tasked with the same level of material and projects as majors. However, nonmajors may be less motivated, confident, and likely to see science as personally relevant. These affective differences likely suggest different approaches to teaching.

Several investigators have espoused using personal examples, in an applied context, when the goal is scientific literacy. For example, Forte and Guzdial (2005) found increased student interest and motivation after tailoring a nonmajors introductory computer science course to focus on programming to manipulate digital media – a skill students could immediately incorporate into their extracurricular interests. Similarly, transforming a nonmajors neuroscience course by using course materials at the intersection of the humanities and the sciences (e.g., books by Oliver Sacks and V. S. Ramachandran) led to increased student motivation to take additional science courses and, for some students, a decision to major in science (McFarlane & Richeimer, 2015). Another course, entitled "Issues in Biology" and taught in a context-based, inquiry-driven manner, shows promise for increasing positive perceptions of biology as a discipline; students saw biology as more relevant, worthwhile, and meaningful at the course's end than they had before it began (Gardner et al., 2016). Finally, the most popular lab activity in the nonmajors course described here studies human evolution by focusing on sperm competition in humans – an appealing topic by nature of being somewhat subversive and controversial (Cotner & Gallup, 2011).

We see a positive message in our findings – that nonmajors have the ability to *do* science, as recommended by AAAS (2011) and others (Nelson, 1999; Handelsman et al., 2007), a finding that reduces instructional barriers to implementing flipped classrooms (Herreid & Schiller, 2013), inquiry (Gormally et al., 2009), and course-based undergraduate research experiences (CUREs; Auchincloss et al., 2014) in courses that include nonmajors. The greater challenge is appealing to these students' motivation, interest, and confidence. Doing so, by learning from some of the examples cited above, may represent a shift in instructor perceptions, from strictly focusing on skills and content to considering students' affective characteristics. In conclusion, we encourage our peers in STEM to share successes in the domain of teaching to motivate, interest, and inspire confidence, with the goal of promoting a scientifically literate society.

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References

AAAS (2011). *Vision and Change in Undergraduate Biology Education: A Call to Action*. Washington, DC: American Association for the Advancement of Science.

Allum, N., Sturgis, P., Tabourazi, D. & Brunton-Smith, I. (2008). Science knowledge and attitudes across cultures: a meta-analysis. *Public Understanding of Science*, *17*, 35–54.

Auchincloss, L.C., Laursen, S.L., Branchaw, J.L., Eagan, K., Graham, M., Hanauer, D.I., et al. (2014). Assessment of course-based undergraduate research experiences: a meeting report. *CBE–Life Sciences Education*, *13*, 29–40.

Ballen, C.J., Blum, J.E., Brownell, S., Hebert, S., Hewlett, J., Klein, J.R., et al. (2017). A call to develop course-based undergraduate research experiences (CUREs) for nonmajors courses. *CBE–Life Sciences Education, 16*, mr2.

Coil, D., Wenderoth, M.P., Cunningham, M. & Dirks, C. (2010). Teaching the process of science: faculty perceptions and an effective methodology. *CBE–Life Sciences Education*, *9*, 524–535.

Cole, S. (2012). The development of science identity: an evaluation of youth development programs at the Museum of Science and Industry, Chicago. PhD dissertation, Loyola University Chicago.

Cotner, S. & Gallup, G.G. (2011). Introductory biology labs . . . They just aren't sexy enough! *Bioscience Education, 18*(1).

Cotner, S. & Hebert, S. (2016). Bean beetles make biology research sexy. *American Biology Teacher*, *78*, 233–240.

Cotner, S., Loper, J., Walker, J.D. & Brooks, D.C. (2013). "It's not you, it's the room" – Are the high-tech, active learning classrooms worth it? *Journal of College Science Teaching*, *42*, 82–88.

Cotner, S., Thompson, S. & Wright, R. (2017). Do biology majors really differ from non-STEM majors? *CBE–Life Sciences Education, 16*(3), ar48.

Forte, A. & Guzdial, M. (2005). Motivation and nonmajors in computer science: identifying discrete audiences for introductory courses. *IEEE Transactions on Education*, *48*, 248–253.

Gardner, G.E., Bonner, J., Landin, J., Ferzli, M. & Shea, D. (2016). Nonmajors' shifts in attitudes & perceptions of biology & biologists following an active-learning course: an exploratory study. *American Biology Teacher*, *78*, 43–48.

Glynn, S.M., Brickman, P., Armstrong, N. & Taasoobshirazi, G. (2011). Science motivation questionnaire II: validation with science majors and nonscience majors. *Journal of Research in Science Teaching*, *48*, 1159–1176.

Gormally, C., Brickman, P., Hallar, B. & Armstrong, N. (2009). Effects of inquiry-based learning on students' science literacy skills and confidence. *International Journal for the Scholarship of Teaching and Learning*, *3*(2), article 16.

Handelsman, J., Miller, S. & Pfund, C. (2007). *Scientific Teaching*. New York, NY: W.H. Freeman.

Herreid, C.F. & Schiller, N.A. (2013). Case study: case studies and the flipped classroom. *Journal of College Science Teaching*, *42*, 62–67.

Humphry, S.M. & Heldsinger, S.A. (2014). Common structural design features of rubrics may represent a threat to validity. *Educational Researcher*, *43*, 253–263.

Knight, J.K. & Smith, M.K. (2010). Different but equal? How nonmajors and majors approach and learn genetics. *CBE–Life Sciences Education*, *9*, 34–44.

Livermore, A.H. (1964). The process approach of the AAAS Commission on Science Education. *Journal of Research in Science Teaching*, *2*, 271–282.

Lopatto, D. (2004). Survey of Undergraduate Research Experiences (SURE): first findings. *Cell Biology Education*, *3*, 270–277.

Luckie, D.B., Smith, J.J., Cheruvelil, K.S., Fata-Hartley, C., Murphy, C.A. & Urquhart, G.R. (2013). The "anti-cookbook laboratory": converting "canned" introductory biology laboratories to multi-week independent investigations. *Studies for Laboratory Teaching: Proceedings of the Association for Biology Laboratory Education*, *3*, 196–213.

McFarlane, H.G. & Richeimer, J. (2015). Using the humanities to teach neuroscience to non-majors. *Journal of Undergraduate Neuroscience Education*, *13*, A225–A233.

Miller, J.D. (2004). Public understanding of, and attitudes toward, scientific research: what we know and what we need to know. *Public Understanding of Science*, *13*, 273–294.

Nelson, G. (1999). Science literacy for all in the 21st century. *Educational Leadership*, *57*, 14–17.

Robnett, R.D., Chemers, M.M. & Zurbriggen, E.L. (2015). Longitudinal associations among undergraduates' research experience, self-efficacy, and identity. *Journal of Research in Science Teaching*, *52*, 847–867.

Seymour, E., Hunter, A.-B., Laursen, S.L. & DeAntoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: first findings from a three-year study. *Science Education*, *88*, 493–534.

Shortlidge, E.E. & Brownell, S.E. (2016). How to assess your CURE: a practical guide for instructors of course-based undergraduate research experiences. *Journal of Microbiology & Biology Education*, *17*, 399–408.

Summers, R.W., Elliott, D.E., Qadir, K., Urban, J.F., Thompson, R. & Weinstock, J.V. (2003). *Trichuris suis* seems to be safe and possibly effective in the treatment of inflammatory bowel disease. *American Journal of Gastroenterology*, *98*, 2034–2041.

Summers, R.W., Elliott, D.E., Urban, J.F., Thompson, R. & Weinstock, J.V. (2005a). Trichuris suis therapy in Crohn's disease. *Gut*, *54*, 87–90.

Summers, R.W., Elliott, D.E., Urban, J.F., Thompson, R. & Weinstock, J.V. (2005b). *Trichuris suis* therapy for active ulcerative colitis: a randomized controlled trial. *Gastroenterology*, *128*, 825–832.

Sundberg, M.D., Dini, M.L. & Li, E. (1994). Decreasing course content improves student comprehension of science and attitudes towards science in freshman biology. *Journal of Research in Science Teaching*, *31*, 679–693.

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