JMBE Journal of Microbiology & Biology Education

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Seeing Yourself as a Scientist: Increasing Science Identity Using Professional Development Modules Designed for Undergraduate Students

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As educators, we should not assume that students are progressing toward intended STEM careers simply because they have persisted and received a STEM degree. In addition to learning biology content and scientific skills, students need guidance in making optimal career choices. In this study, we present seven career development modules designed specifically to motivate students to consider their successes as scientists and to consider applying their biological knowledge and scientific skills to a range of biology careers. These modules highlight the value and the utility of a biology degree and are, therefore, designed to increase students' self-confidence as well as their science and biology identities. The career development modules presented here are easy to implement and, in our experience, encourage engagement and class discussions. Our analyses confirm that these modules collectively increase student science and biology identities, two predictors for entry into STEM careers.

KEYWORDS biology identity, career development, professional development, science identity, undergraduate

INTRODUCTION

Improving the rate at which individuals enter STEM careers remains a national concern. Many STEM fields are unable to fill jobs with qualified workers (1, 2), suggesting that STEM jobs are available yet remain open and waiting for qualified graduates. As educators, we should not assume that students are progressing toward intended STEM careers simply because they have persisted and received a STEM degree. In fact, only 44.6% of all degree holders in the life sciences and only 35.5% of all degree holders in the physical sciences are employed in science and engineering (S&E) occupations (2).

Although researchers have previously investigated how demographics and attrition rates affect the lack of STEM graduates available to fill job vacancies, there remains a critical need for additional research examining the how career development training provided to STEM undergraduates may influence these career choices and outcomes (3–5). For undergraduate STEM students, who are still discovering their interests, exploring opportunities, and developing personal strengths, determining a future career path can be challenging. For every student who has a clear vision of their career path, there is a student struggling to identify a career path and another student in the process of changing a career goal (6). Almost half of undergraduates in a STEM major choose to pursue different careers than they had originally intended, and many students continue to debate possible careers after their undergraduate education (7, 8).

University administrators have long realized that students need guidance to make optimal career choices. Career development courses (CDC), or other interventions based on career assessments, have been implemented and studied to better understand college students' career decision-making skills. CDCs are most often offered as one-time, semester-long experiences and are open to students in all majors. Studies have shown that positive effects (e.g., increased career decision-making ability) of career development courses were greater than those of individual counseling and other interventions (9–11). Furthermore, student participation in career development courses increases vocational identity, career maturity, and career decision-making (12).

The few studies that have been published specifically on STEM-centered career development courses have yielded positive results, including increased student awareness and confidence toward STEM career preparation (6, 13). In general, studies have focused on career interest as a predictor of STEM persistence and retention in the major (14, 15). However, retention in the major does not correlate with the number of STEM graduates entering the STEM workforce (7, 8). Other studies have shown that participation in a STEM-focused CDC decreased negative career thoughts (15, 16).

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The authors declare no conflict of interest.
Received: 3 January 2022, Accepted: 1 February 2022, Published: 14 March 2022

At our institution, most undergraduate biology majors are preparing for careers in health sciences, with over half of students in an introductory biology course pursuing a career in medicine, dentistry, or other health-focused professions that require advanced degrees (17). These students often see their undergraduate experiences more as a checklist of courses and exams to complete before applying to professional/graduate school and less as a comprehensive training to become a scientist, and, more specifically, a biologist. Anecdotal evidence from our experience working with senior-level students suggests that upon graduation many of our students consider themselves to be credentialed baccalaureates who are now eligible to apply to graduate school in the health professions, rather than seeing themselves as biologists *per se*.

Many of our students graduate, take a gap year to study for medical/graduate school admissions exams, and then spend a second year waiting for the application process to play out. In some cases, 2–3 years may pass before graduates realize their career goals may need to change, and by this point they are far removed from their undergraduate institution and its career resources. To prepare our graduates to navigate these future career transitions when they arise, we worked to implement career development training specific for all biology majors, not just those interested in health-centered careers. Our training centers on providing resources and experiences that graduates will be able to use if, and when, their career trajectories change, and they find themselves away from their undergraduate institutions. We believe the first step in this process is to foster our students' self-perception not only as simply a future applicant to graduate school but even more as a biologist. In other words, we aim to improve students' science and biology identities.

Identity is a set of meanings that define who a person perceives themselves to be (18). Science identity is a construct of identity specific to science knowledge and, to date, there is no consensus on the definition of science identity (19). However, two characteristics of science identity are commonly emphasized: recognition of oneself as a "science person" and recognition of being a "science person" in a social context, especially by influential persons, including professors, teachers, advisors, and peers (20, 21). Science identity is dynamic, and student trajectories may shift directions over time depending on students' lived experiences and social interactions with others (21, 22).

Because we are biology instructors and work with biology students, we are also interested in students' biology identities. While science identity is more general and applies to all STEM disciplines, biology identity is more specific and connected to discipline, allowing for a more granular exploration of student identity. For this study, we adapted research showing that discipline-specific identity is composed of three constructs: interest in the discipline, recognition from others as a legitimate member of the discipline, and performance and competence in the discipline (23). Interest in a specific discipline has been shown to positively influence whether a student enters a career related to the discipline (23, 24). Recognition, or perception that others (e.g., parents, teachers, and other students) view one as a member of one's discipline, is important during discipline-specific identity development in college (23). Performance and competence, or students' beliefs about their abilities to perform the practices of their discipline and understand the content of their discipline, has been shown to influence students' abilities to see themselves as people who can legitimately participate in the discipline (25).

In this study, we present seven career development modules designed specifically for students to consider their successes as scientists and reflect on applying their biological knowledge and scientific skills to a range of biology careers as a way to increase their science identities. These modules include activities and assignments highlighting the value and the utility of a biology degree, with the goal of increasing students' confidence as scientists and increasing their science and biology identities. If students see themselves as scientists and biologists, rather than only graduates prepared to take the MCAT, will they approach their post-undergraduate lives differently? Although the long-term understanding of this question is beyond the scope of this study, we have started taking the first steps by creating, implementing, and refining the career development modules presented here.

Intended audience

For this study, we engaged with biology majors during their last two semesters of undergraduate coursework. However, our results suggest that students could benefit from experiencing these modules earlier in their academic careers. In addition, student feedback indicates that rather than learning this information on the cusp of graduation, they wished they had received this information earlier in their undergraduate careers when they could have better accessed the career development resources and opportunities at our institution.

Learning time

Our course, Senior Seminar, meets weekly for one 75-min lecture. Most often, we introduced a module in one class, assigned related homework to the students, and then discussed results of the homework during the following class section (Fig. S1).

Prerequisite student knowledge

At our institution, Senior Seminar is a course designed to be taken by graduating seniors, so upper-level biology courses are required as a way to ensure course availability only to graduating seniors. However, we recommend that students have completed only the introductory biology sequence to ensure an interest in biology as a way to offer these modules earlier, as no specific biology content is discussed in these modules. We also recommend that students have an interest in a future career that might leverage their biological content knowledge and the scientific training they will have developed during their undergraduate careers.

Learning objectives

Upon completion of the career development modules, students will have developed effective communication skills, a

TABLE 1
An overview of our career development modules

Module	Task	Students begin to. . .	Described in
Scientific portfolios	Students assemble a tangible, visual representation of their past accomplishments	see their whole self as contributing to making them a scientist.	Appendix S2
Scientific societies	Students identify three societies that match their interests and join them	identify scientific groups they can join and participate in.	Appendix S3
Skills charts	Students work on matching their current skills to employer needs listed in job ads	see their scientific skills as applicable across a wide range of STEM professions	Appendix S4
Resume workshop	Students develop a professional resume	present themselves as scientists	Appendix S5
Elevator pitch	Students learn to present themselves professionally in a short amt of time	present themselves as scientists	Appendix S6
Personal statement	Students reflect and write a statement that represents their goals and visions	visualize their scientific futures	Appendix S7
Reference letter	Students practice writing a recommendation letter for themselves	present themselves as scientists	Appendix S8

greater understanding of careers in biology, a greater understanding of the skills they have as biologists, and the ability to develop a resume and personal statement. Our research question is independent of these learning objectives, as we collect data to determine whether these modules enable students to increase their science and biology identity.

PROCEDURE

Materials

We present here seven career development modules (Table 1) plus one introductory exercise. We have experimented with the order of these modules and have had the greatest engagement when we started with "bigger picture" modules, such as portfolios and scientific societies, and work our way down to more specific modules, such as personal statements and reference letters. We illustrate this conceptual framework for our students using an inverted pyramid (Fig. 1).

myIDP assessment: To start the semester, we have students complete the freely available myIDP assessment, a web-based career-planning tool which, while intended to be used by PhD students and postdocs in the biomedical sciences, works very well with our population of undergraduates (https://myidp.sciencecareers.org/). Specific details for implementation are provided in Appendix S1. In addition to providing students with valuable career information, we use the myIDP assessment as a way to introduce career skills, interests, and values, topics we will continuously revisit throughout the semester.

Scientific portfolios: Developing a scientific portfolio not only provides students with an opportunity to reflect on their successes within science, but also allows them to integrate their talents, creativity, and individuality represented by their nonacademic activities that are often not the focus of an academic CV. Previous studies on the use of portfolio development to increase professional identity have been successful in the fields of engineering (26), business (27), and teaching (28). This portfolio activity builds on these examples by providing students a chance to reflect on their past experiences and on how they all combine to make the student a more well-rounded scientist. Specific details for implementation (and example portfolios) are provided in Appendix S2.

Scientific societies: In our experience, students are often not familiar with scientific or professional societies. We start this module with a general discussion using the prompts "what are professional societies," "why are they important," "what is

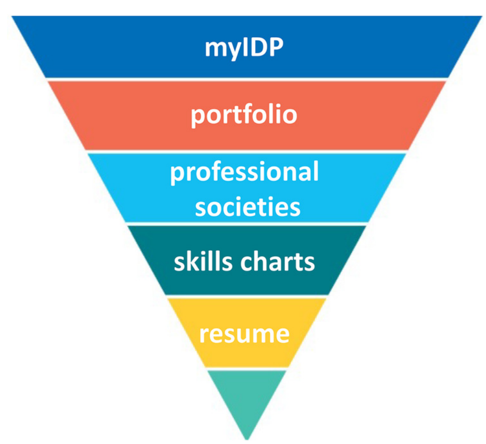

FIG 1. An inverse triangle representing the order of the modules from the more general "bigger picture" modules that become more and more specific.

the value of joining a professional society," and "are any of you already in any professional societies?" (Some students are in professional societies and do not even realize it until after this discussion.) We discuss the benefits of being an active member of a professional society, including leadership, networking, writing, and social media opportunities.

We then have students pull out their phones, tablets, or laptops and ask them to find three professional societies that match their career interests. For each of these professional societies, we ask students to follow them on social media or subscribe to a listserv in order to receive society information, rather than leaving the student to remember to check in on the society. We also ask students to see if there is a local (campus) or state chapter they could join. Finally, we ask students to see if a student membership is offered; if the cost is free, we encourage them to join immediately. To complete this module, we have each student present one of their societies to the rest of the class. This exercise has the benefit of (i) forcing students to practice talking about their scientific interests and (ii) having students learn about other societies discovered by their classmates. Additional details for implementation are provided in Appendix S3.

Skills charts: Originally, this module was titled "job charts," however we soon realized that students who are preparing for graduate or professional school were not interested in thinking about jobs. They are, however, interested in thinking about skills needed for future careers. Therefore, we are very careful to use "careers" and "skills" and to avoid the word "jobs" during this module.

In our experience, students see their academic courses as necessary requirements en route to a degree that is itself necessary for entry into graduate or professional school. They often fail to realize the diverse and valuable skill sets they are amassing along the way. The overall goal of this module is to encourage students to think about a wide range of careers in biology, and how they, as biology graduates, have a skill set that is desired by employers. Essentially, we aim to teach students how to connect their scientific skill set to a real career by examining job postings. Additional details for implementation are provided in Appendix S4. Example skills charts, both good and bad, are also provided. We have found that it is necessary to show these examples to students, so they know the expectations for completing a skills chart.

Resume workshop: In our experience, students have had little to no guidance drafting a resume and are often anxious that they "don't have enough experience" to fill out a resume. Additional details for implementation are provided in Appendix S5.

We start with trying to ameliorate their anxiety by showing an example resume from when we were about to graduate college as a way to emphasize that most people start with a "weak" resume (Appendix S5). Next, we spend time encouraging students to consider the skills they have learned from "routine" experiences they have had as biology majors. For example, instead of listing that they have completed "Gen Bio 1" on a resume, they might instead list that they have a comprehensive understanding of biological concepts, are on track to complete a degree in biology and have developed collaborative skills by working with peers (Appendix S5).

Considering the demographics of our mostly commuter student body, we also devote time discussing part-time jobs, firmly stressing that retail/hospitality jobs provide students with communication skills and customer service skills. Students often omit these jobs from their resume for fear of not seeming "academic." However, most of our students are interested in patient-centered health professions, where communication and customer service are extremely valuable.

Additional topics covered in the resume workshop are listed in Appendix S5. We complete the workshop by discussing some examples of student resumes and by returning to the example "weak" resume for a debriefing of how many ways this resume could be improved.

Elevator pitch: Being able to succinctly explain one's skills and goals, and why they would be assets on a team or project, is the goal of the elevator pitch. To mitigate the anxiety most students have for public speaking, we frame our class as being a safe place to practice, a place where students can make mistakes and be flustered now, with a friendly audience, so that they are more prepared for real elevator pitch opportunities.

The key to a strong elevator pitch is to focus on presenting one's own valuable skills. We teach students not to spend time repeating the opportunity/position to their audience, but rather to focus on the unique skill set they will bring to the position. To do this, we suggest students structure the elevator pitch (30 s to 1 min) in three phases: (i) communicate who they are, (ii) communicate what they are looking for, and (iii) communicate how their skills and experiences could benefit a company or organization. When tasked with three specific items, students tend to be less flustered. In class, students are asked to (i) identify a potential audience, such as a hiring manager, (ii) draft an elevator pitch for this audience, and (iii) stand in front of the class and give their elevator pitch. Our students routinely ask for an example, so Instructors should be prepared to deliver their own elevator speech. Additional details for implementation are provided in Appendix S6.

Personal statement: This module tends to be the module with which students struggle the most, usually because they are overwhelmed at starting a personal statement from scratch. To alleviate this, we developed an outline system that encourages students to think through the framework of their personal statement before they begin writing sentences and paragraphs. Several semesters of student self-reporting data suggest that this structured exercise lowers stress and leads to more well-written personal statements. Example outlines are provided in Appendix S7.

Reference letter: While students know that they need reference letters and that they need to ask professors for these letters, they often have no idea what a letter of reference looks like. We start this module with example letters that we have written for students, with one example being a letter for a student we hardly know and another example being for a student we know very well–the contrast is intended to highlight the value of in-depth engagement with potential reference letter writers. We also review the Association of American Medical Colleges (AAMC) guidelines for reference letters, so students are aware of the personal attributes, specifically for medical school applicants but also broadly desirable for any other career path, to highlight.

Next, we give students time to brainstorm what their professors or other mentors might write about in a reference letter and which characteristics and supporting evidence these professors/mentors can write about. The brainstorming chart we use for this is shown in Appendix S8. This activity takes time, between 20 and 30 min, as this is often the first time students have thought strategically about who their references might be. Ultimately, we encourage students to draft their own letters, from the viewpoint of their reference letter writer, and to provide the draft when they formally ask for the letter. This approach makes a lot of students nervous, so at the very least we encourage students to describe the results of their brainstorming session when they approach their references for a letter. The module concludes with a review of etiquette surrounding reference letter requests.

Student instructions: Students are asked to attend class and participate in class discussions. Because so much of this content is new to students and is also often accompanied by high levels of anxiety, class discussions are especially critical for helping students engage with the content.

Faculty instructions: To coordinate content across sections, we have a weekly meeting of instructors in which we discuss (i) content presented the previous week, what did and did not work, and any potential changes to the modules, and (ii) review and prepare for content to be presented the next week. We also keep an open mind that each section of students will have different questions and needs and that we need to be ready to lead compelling discussions and be willing to reply honestly to student questions. While we teach the same core content in each class section, each instructor has their own personal teaching style and developed and implemented their own grading rubrics. Our data analysis revealed no significant differences between instructors, suggesting that these slight differences among instructors had no effect (discussed further in field testing).

Suggestions for determining student learning: In our implementation, each instructor had different rubrics for different modules. For the portfolio module, we asked students to submit at least three potential portfolio pages through our learning management system, and we provided feedback. The scientific societies module was completed in class, and grades/feedback were provided during student presentations of the societies that interested them. For the skills chart module, we were very clear about the instructions to find two different jobs and to list each skill as a separate entry in the chart (Appendix S4). Instructor grading rubrics penalized students for not following directions, but as long as students made an effort to think about each skill (whether they have the skill, and/or how they can gain/improve upon the skill), students received full credit with constructive feedback as necessary. Because each student resume was unique, and there was no single template for what a good resume should include, we again gave full credit to students who made an effort, with constructive feedback as necessary. Similar to the scientific societies module, the elevator pitch was implemented entirely in class and students were graded on the effort they made to follow the outline we provided (Appendix S6). We did not penalize students for any stumbles they had with the presentation itself as this would have worked against the safe space we were trying to create. For the personal statement module, we checked for alignment between the outline the students submitted and the written personal statement and provided constructive feedback as necessary. For the reference letter module, we checked that the student had put forth effort in completing the brainstorming chart and provided constructive feedback as necessary.

Sample data: We have included examples of student portfolios (Appendix S2) and skills charts (Appendix S4) in the supplemental material.

Safety issues: There are no safety issues associated with this curriculum.

DISCUSSION

Field testing

This study was approved by FIU IRB (IRB-20-0015-AM01). We collected student data during the Spring 2020 (4 sections, 72 students), Fall 2020 (8 sections, 141 students), and Spring 2021 (8 sections, 139 students) semesters. FIU closed their campus on March 12, 2020, resulting in the last 5 weeks of this course being taught synchronously and remotely using Zoom software. Fall 2020 and Spring 2021 were also taught synchronously and remotely. Although the switch to online instruction was not ideal, the success we had online confirms that even greater student gains may be possible during in-person instruction. At our institution, class size for Senior Seminar is capped at 18 students.

We collected science and biology identity data during the first and last weeks of the semester (n = 250). The post-questionnaire also included questions related to whether students liked the modules, whether the modules made them feel more like scientists, and short answer responses addressing how and why each module made them feel more like scientists.

Evidence of changes in science and biology identity

Identity data: To quantitatively measure science identity, we used the 5-item "Scientific identity: Indicator of role orientation" questionnaire (29). To confirm these items behaved the same way with FIU students as they did in the original study, Confirmatory Factor Analysis (CFA) was run. Pre-data collected (n = 159) was large enough to perform CFA (30, 31), and results support the use of these items as a singular construct among FIU

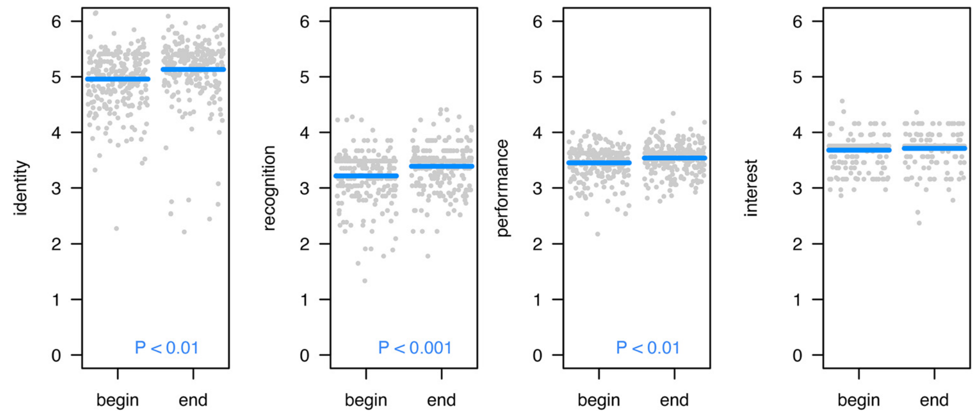

FIG 2. Student science and biology identity (Fig. S2) were measured using a 6-point Likert-type scale (1 = strongly disagree, 2 = moderately disagree, 3 = slightly disagree, 4 = slightly agree, 5 = moderately agree, 6 = strongly agree). We see significant increases in students post-scores in science identity, biology recognition, and biology performance. Student pre/post estimated mean scores are as follows: science identity (4.96/5.13), biology recognition (3.22/3.39), biology performance (3.45/3.54), and biology interest (3.68/3.71); (n = 250).

students (32). Items are listed in Fig. S9, and CFA results are provided in Appendix S9.

Biology identity: To measure biology identity, we adapted research showing that discipline-specific identity is composed of three constructs: interest in the discipline, recognition from others as a legitimate member of the discipline, and performance and competence in the discipline (23). Items from Goodwin et al. (2016) were adapted for use with biology students. CFA was performed using data previously collected across courses in all levels in biology in the Fall of 2018 (n = 755). Results support the use of the rewritten items with FIU biology students. Items are listed in Fig. S9, and CFA results are provided in Appendix S10.

Student data relating to science and biology identities are shown in Fig. 2. To control for different baseline identity values for each student and for the effects of different instructors, we used linear mixed-effects models that allowed for fixed and random effects (R package 'lme4' (33) and R package 'visreg' (34)). All analyses were conducted in R v. 4.1.0 (35). A preliminary analysis that included the fixed effects of semester and time (i.e., surveys collected at the beginning versus at the end of the semester) and the random effects of instructor identity and student identity showed that there were no significant differences among semesters. In addition, we found no significant differences between instructors, suggesting that the effects of these modules were robust to differences in module delivery by different instructors. As a result, we used a simpler model that included only a fixed effect of time in the semester and a random effect of student identity on each identity variable in order to test how students' identities changed as a result of these modules. To generate a P value, we used analysis of variance to compare each of these simpler models to a null model that included only the random effect of student identity. We saw significant increases from the beginning of the semester to the end of the semester in students' self-reported science identities, biology recognition, and biology performance (Fig. 2), suggesting that these modules are helping students to see themselves as more than someone who has simply completed undergraduate degree requirements. However, we saw no change in biology interest, which is not surprising given that students were on the cusp of graduation with a degree in biology and had likely reached their peak interest levels.

To understand student perceptions of the modules further, we asked students if they found the module to be helpful and whether the module made them feel more like a scientist (Fig. 3). In general, quantitative data showed that students found all the modules to be helpful, with even the lowest scoring module

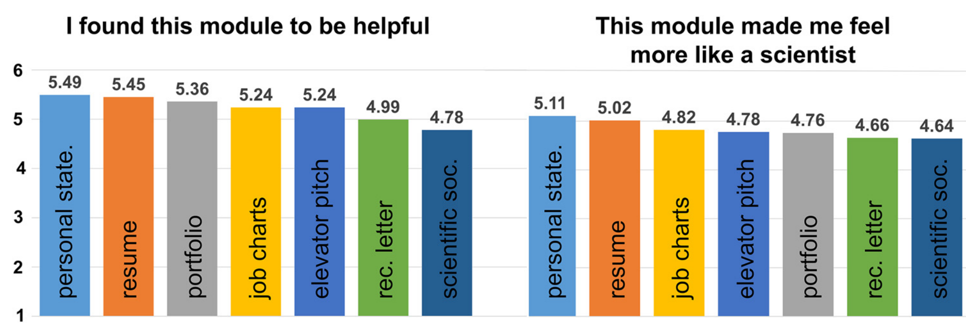

FIG 3. Student perceptions of career development modules. For each module, students (n = 118) were asked if they 1) found it helpful and 2) if it made them feel more like a scientist. Questionnaire items were measured using a 6-point Likert-type scale (1 = strongly disagree, 2 = moderately disagree, 3 = slightly disagree, 4 = slightly agree, 5 = moderately agree, 6 = strongly agree).

receiving a 4.78 out of 6. Asking whether the modules made the students feel more like a scientist was intended to be a secondary measurement of science identity and to determine whether engaging in career development activities increases self-identification as a scientist. These data are very encouraging: expressing science identity while engaging in career development activities suggests that students are starting to see themselves as trained biologists with valuable skills that are in demand.

Possible modifications: As previously mentioned, we recommend integration of these modules into the curriculum before students' final semester. We also envision that these modules could be implemented into other courses individually as "pocket modules." For example, the scientific society module can be completed in ∼30 min and could be implemented into large, intro courses on the first day of class after the syllabus review or in a class period falling before the Thanksgiving holiday as an efficient use of class time that might otherwise go unused.

Conclusions: These modules seem to be pushing students to see their undergraduate careers and degrees as more than mere requirements for future schooling. Encouraging students to envision their undergraduate careers as crafting identities and a sense of community may help cultivate their interests and influence later career trajectories, potentially outside the health sciences. We developed and implemented the modules presented here as the first step in a larger process of changing our students' perceptions of themselves from being future applicants for graduate or professional school to seeing themselves as biologists. The career development modules presented here are easy to implement and result in excellent student engagement and class discussions. Our data suggest that collectively these modules increase student science and biology identity. We are encouraged by these early data and are investigating the larger questions of how and/or why these modules are able to shift students' science and biology identities.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 2.7 MB.

ACKNOWLEDGMENTS

We thank all our students for their hard work, enthusiasm, and willingness to share their feedback with us. We thank Dione L. Rossiter and Sherry Marts for inspiration in developing modules. M.M. was supported by a FIU start-up package. A.B.R. was supported by NSF grants DEB-1838327 and CMMI-2029756.

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