Articles

Building Confidence in Scientific Competence: Impacts of an Introduction to Primary Literature Course on Undergraduate Students' Science Identity and Interest in Research

Mariah C. Maxwell, Takunda Maisva, Jason R. Wiles

Syracuse University - Life Sciences Complex, 107 College Pl, Syracuse, NY 13210

Abstract

Introduction to Primary Literature (IPL) courses can be early-career precursors to undergraduate research experiences, whereby students can become familiar with potential mentors and their research toward better alignment with student/faculty interests and goals. IPL courses have been shown to increase student science self-efficacy and understanding of the nature of science to levels congruent with students entering Course-based Undergraduate Experiences (CUREs) and Faculty-Led Research Experiences (FLREs), which may increase the number and diversity of students engaging in these high-impact activities. Further research is needed to understand how an IPL course can impact students' science identity, defined as the extent to which one relates to science, which has been associated with student success and persistence in STEM degree programs. This study employed a quasi-experimental, mixed methods approach to explore the impacts of engaging with the products of research through reading primary research articles, communicating scientifically, and interacting with scientists of various levels on the science identities of undergraduate students enrolled in a seminar-style biology IPL course at a large, private, research-intensive institution in the Northeastern United States. Pre- and post-course surveys, as well as a focus group interview, were used to collect student information and measure the science identity of participants. Interpretation of the quantitative data and themes drawn from the qualitative responses are presented herein, notably that students became more confident in their abilities to understand science and scientific literature and in their competence as scientists in training.

Keywords: Introduction to Primary Literature (IPL) course, science identity, interest in research

Undergraduate Research Experiences (UREs), such as Faculty-Led Research Experiences (FLREs) and Course-based Undergraduate Research Experiences (CUREs) are often a student's first introduction to the true nature of science. Participation in UREs has been associated with increases in science self-efficacy and a strengthening of science identity which can help orient students towards graduate and professional programs in STEM (Chemers et al., 2011; Egan et al., 2013). URE participation has also been associated with increased student persistence and interest in pursuing research opportunities amongst students from underserved populations (Reig et al., 2018).

Despite their many benefits, UREs are often limited due to a lack of funding, staffing, or physical space (Frantz et al., 2017). To compound this issue, students from underrepresented groups and low-income households are often tasked with navigating existing barriers to research experiences, such as a lack of representation in the field, insufficient academic preparation, and historical barriers (Pierszalowski et al., 2021). STEM enrichment programs have been designed and implemented to introduce students to the research environment and provide opportunities for faculty mentoring (Merolla & Serpe, 2013).

Introduction to Primary Literature (IPL) courses have been recommended by the National Academy of Sciences (2017) as a steppingstone to help students access UREs by familiarizing students with potential mentors

and their research, allowing for better alignment with student/faculty interests and goals, and the efficacy of this practice has subsequently been shown by Schmid, Hall & Wiles (2023). IPL courses often follow a seminar-style format in which students read, discuss, and write about primary literature in order to familiarize themselves with the products of science and scientific methods of communication (Brownell et al., 2013; Sandefur et al., 2016; Schmid & Wiles, 2019). IPL courses have been shown to increase student science self-efficacy and understanding of the nature of science to levels congruent with students entering UREs (Carter et al., 2017; Schmid, Dunk, & Wiles, 2021; Schmid, Hall, & Wiles, 2023). However, further research is needed to understand how an IPL course can impact students' science identity.

Science identity can be described as the extent to which one relates to science (Carlone & Johnson, 2007). Having a strong science identity is important for undergraduate STEM students because it has been associated with student persistence in STEM degree programs and interest in scientific careers (Chang et al., 2011; Perez et al., 2014). Participation in IPL courses could strengthen undergraduate students' science identities in several ways. Practice with reading, writing, and discussing scientific research could improve students competence and performance, which are key components of science identity. Being exposed to the products of science and exploring current hot topics in science could also pique students' interest in science and students' interest in pursuing graduate programs in science (Kozeracki et al., 2006; Hathaway et al., 2002). Additionally, being exposed to diverse scientists could also help students find relatable scientific role models (Fairlie & Robert, 2014).

Understanding how early exposure to research affects students' science identity will support the development and implementation of IPL courses, which may increase the number and diversity of students engaging in high-impact activities like UREs. For this study, we used a quasi-experimental, mixed-methods approach to explore the impact of participating in an IPL course on undergraduate students' science identities, at a large, private, research-intensive (Carnegie R1 designation) university in the Northeastern United States. We aim to address the following research questions:

1. Does participating in an IPL course impact undergraduate students' science identity? If so, how?
2. Does participating in an IPL course impact undergraduate students' interest in conducting biological research? If so, how?

Carlone and Johnson (2007) described three main ways to strengthen a science identity: (1) by fostering knowledge growth, (2) by providing opportunities to display scientific knowledge and practices in the presence of others, and (3) by being acknowledged as a science person by oneself and meaningful others. Therefore, we expected that participating in an IPL course would strengthen our students' science identities by helping them to gain knowledge about scientific practices and by giving them the opportunity to practice communicating about science with their peers. We also expected that interacting with diverse members of the scientific community would combat harmful stereotypes our students may have encountered about who is and is not a scientist, providing them a space to begin envisioning themselves as scientists. We also expected that exploring the breadth of research being conducted in the biology department would increase the likelihood of connecting with an area of research of specific personal interest.

Methods

Setting and Recruitment

The seminar-style biology IPL course was similar to other iterations of an IPL course designed to introduce students to research in our institution's biology department (Carter & Wiles, 2017; Humphrey & Wiles, 2021; Schmid and Wiles, 2019; Sloane & Wiles, 2020). A novel addition to our iteration of the IPL course was that students had opportunities to engage with

potential faculty research mentors through an interview assignment and to engage with near-peer graduate researchers by attending their departmental research talks.

Students were recruited for the IPL course from among those who had taken the university's Introductory Biology course during the previous semester. The Introductory Biology course is primarily populated by first-year students, and it is required for Biology majors while also serving students from many other related and non-related majors. Ahead of the registration period for the following semester, the introductory course instructor presented the IPL course as an elective offering that could help prepare students for joining a faculty lab as an undergraduate researcher.

Data Collection

Students in the IPL course were given class time during the beginning and end of the semester to complete online surveys comprising Chemers and colleagues' (2011) science identity instrument, demographic questions, and open ended questions about students' career goals, interest in research, and reasons for taking the course. Chemers and colleagues' (2011) instrument contains seven items to which students respond using a five-point Likert scale (1 being strongly disagree, 5 being strongly agree). Pre- and post-course responses to the science identity scales were converted to percentages for graphical representation. Chronbach's alpha was .975 for the science identity scale, which indicates very good internal consistency of the instrument.

On the last day of class, students participated in a discussion led by the course instructor (Author 2). The instructor presented the discussion as a metacognition activity and the purpose and benefits of metacognition were explained. All students completed an informed consent form to be recorded and to have their contributions used for research purposes. During the class discussion, students were asked to write down their responses to a series of discussion questions which were projected on the classroom screen during the session. After a few minutes of quiet reflection, students were invited to join a discussion sharing their thoughts and feelings regarding the discussion prompts. The discussion questions were open-ended and intended to elicit students' thoughts about how the course may or may not have influenced their interest in conducting biological research and their science identity. For research purposes, this discussion group was treated like a focus group interview. This method was selected in lieu of individual interviews in order to maximize the number of students participating.

The group discussion was recorded via Zoom and transcribed using an online transcription service. The software NVivo was used to analyze qualitative data. Author 1 and Author 2 coded the data using a mix of predetermined codes and codes that arose based on the data, then compared codes until they reached 95% agreement. The responses of individual students of interest were then examined to find common themes regarding the change in science identity.

This research was conducted following a protocol approved by the Institutional Review Board of the study institution's Office of Research and Integrity and Protections (IRB#: 20-353).

Participants

Fourteen students initially enrolled in the course. One student (S12) dropped the course before the end of the add/drop period because of a change in schedule. Eleven of the students completed both surveys and agreed to have their information used for research purposes. One student (S13) only completed the post-course survey, and another student (S14) did not complete either survey. All remaining students participated in the focus group discussion. Of the 12 students whose demographic information were collected, nine identified as women, two (S5 and S13) identified as men, and one (S4) preferred not to disclose their gender identity (Table 1). Three students (S1, S3, and S13) were considered underserved marginalized (URM) students based on their self-reported race and ethnicity. All students were majoring in biology

Table 1. Demographics and majors of students enrolled in the IPL course.				
Student ID	**Category**			
	Gender	**Hispanic, Latin*, or Spanish Origin?**	**Ethnicity**	**Major**
S1	Woman	No	Black or African American	Biology
S2	Woman	No	White	Biology and Entrepreneurship
S3	Woman	Yes	I prefer not to say.	Biology
S4	Prefer not to disclose	No	White	Biology
S5	Man	No	Korean	Biology
S6	Woman	No	Korean	Biology
S7	Woman	No	White, Chinese	Biology
S8	Woman	No	White	Biotechnology and Health Humanities
S9	Woman	No	White	Biology and Neuroscience
S10	Woman	No	White	Biology
S11	Woman	No	White	Neuroscience and Biotechnology
S13	Man	Yes	Black or African American	Biotechnology
S14	Undisclosed	Undisclosed	Undisclosed	Undisclosed

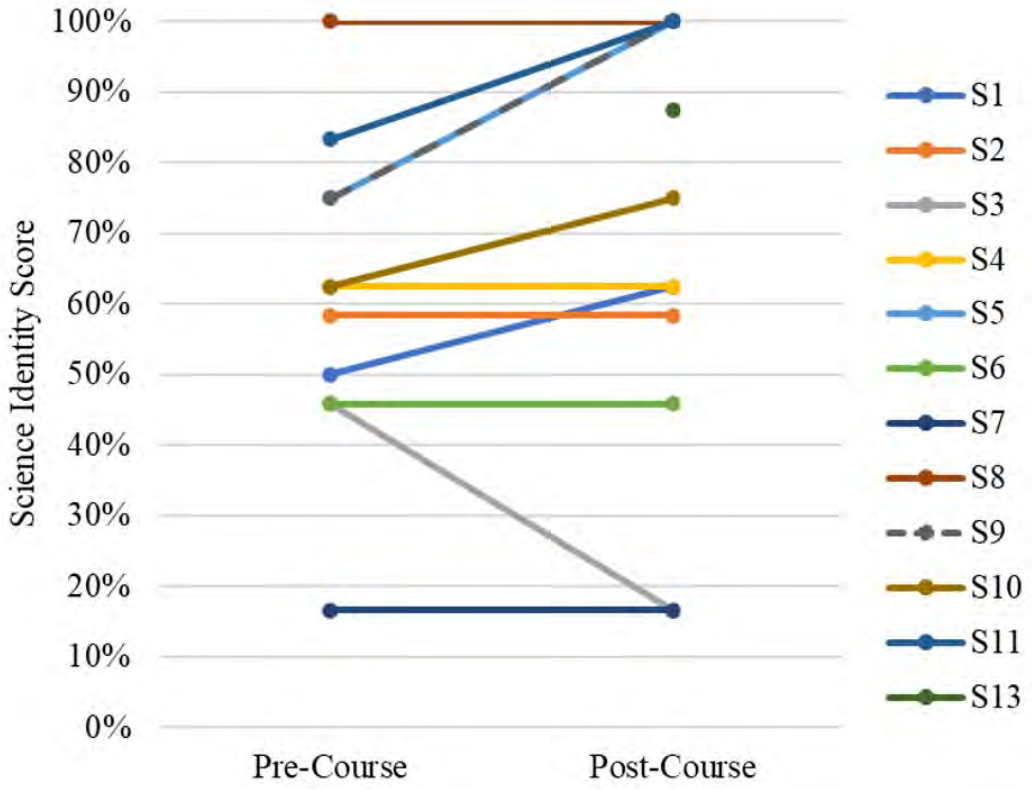
and/or a biology-related major like neuroscience or biotechnology.

Results and Discussion

Pre- to post-course, five students saw increases in their science identity score, five remained the same, and one saw a decrease (Figure 1). Inferential statistics were not performed because of the small sample size, although there was a small upward trend in science identity changes pre- to post-course for students who started with a science identity score of about 50% or higher. The median science identity score started at 63% (SD = 22%) and increased slightly to 69% (SD = 31%) by the end of the course. Three of the five students who saw increases in their science identity scored 100% on the post-course survey (S5, S9, and S11), and one student (S8) scored 100% on both the pre- and post-course surveys.

Recordings of student responses to questions asked during the metacognitive discussion were used to produce a codebook. Codes frequencies were based on the transcript. The code frequencies are meant to highlight the most relevant aspects of the discussion. It is

Figure 1. Change in science identity score pre- to post-course for each student (n=12). S5 and S9 had the same pre- and post-course scores, so their lines overlap.



important to note that though some codes like "science identity" have relatively low frequencies, some of these codes represent complex constructs that the students may not have been metacognitively aware of. Definitions of the codes and exemplar quotes have been provided for clarity and potential replication purposes (Table 2). The codebook consists of 16 codes designed to assist the researchers in organizing the experiences and responses of the participants of the course during the metacognitive discussion.

Exposure to "real science" increases competence and interest in conducting research

Student views of what a scientist looks like can influence the extent to which they see themselves in the field and whether they choose to continue pursuing STEM degrees (Cheryan et al. 2015). Though not directly engaged in the research themselves, students in our course were exposed to aspects of "real science" through discussions of primary literature and interacting with a diverse array of scientists. Examining primary literature has been associated with increases in undergraduate understanding of the nature of science particularly, the iterative nature of scientific research (Schmid et al, 2021). Our course aimed to provide students with an opportunity to engage with scientists and the products of science in a more accessible manner when compared to more traditional research experiences. Students shared that before participating in the IPL course science seemed intimidating, to the point where some students questioned their ability to succeed in their

Table 2. Group interview codebook for qualitative analysis.

Code	Frequency	Definition	Example
Interest in Research	26	Student mention of an interest in conducting research or learning more about research	"Yeah, mine was very similar. I was interested in research but like this kind of solidified it."
Research as an Undergraduate	7	Student mention of an interest in conducting research in an undergraduate program	"It made me feel better about science then if I was just not taking the course."
Research as a Graduate	2	Student mention of an interest in conducting research in a graduate program	"I was thinking about going into medicine. Maybe grad school before medical school, but I'm not sure yet."
Career Goals	9	Student mention of their career aspirations upon finishing their academic journey	"I also want to go into medicine. So it didn't really change anything, but if I didn't know what I wanted to do, it probably would have made me look into biological research more seriously."
Research Career	8	Student mention of enjoyment or fulfillment in terms of a research	"I think this course, if I go to grad school, made me want to do research in grad school, but I don't think I'd want to do research as a career."
Learned from the Course	17	Student mention of knowledge gained from participation in the course intervention	"The first couple times you read a paper it's totally hard because I thought "I don't know what you're doing," but after a while, once you know what to look for, I guess, it got a lot easier"
Aspect of the Course	5	Student mention of particular aspects of the course impacting them	"Thinking about the stuff that we talked about during the discussions when I was reading the articles on my own helped me understand them."
Writing the Literature Review	8	Student mention of completing the literature review assignment	"I think that doing [a literature review] made me realize that you can start anywhere, and it's just about actually doing the research."
Reading Literature	13	Student mention of completing the reading assignments	"When we had to read through and then pick through all the details and stuff, it really paid off because I'm much more confident in my ability to read and understand primary literature."
Guest Presenters	6	Student mention of impacts of guest presenters discussion of their research	"When you see another person, like the students who present their stuff, you see how competent they are, and it makes you think that you can do the same thing."
Presenting	1	Student mention of the impact of presenting on the information they received during lab interviews/tours	"My group's presentation was about proteins and that's a difficult topic. Having to lead the discussion and answer questions about it made me feel better about science."
Article Discussions	5	Student mention of the impact of class discussions of research articles	"Communicating with each other in the discussions and talking about science helped my confidence."
Lab Tour	7	Student mention of the impact of visiting the laboratory space during their lab tour	"Getting into a research lab and seeing the setup and how things are done really solidified in my head the process and how it would go if I were to join research."
Science Identity	2	Student mention of their perception of their science identity as well as any noticeable changes	"It's strengthened my science identity because I have a clear path of where I want to go if I do research."
Competence	11	Student mention of their perceived capability to complete scientific tasks	"It made me believe that I can actually learn the material, even though it's tricky and it may not come easy at first."
Performance	4	Student mention of how well they can display their scientific knowledge or skills to others	"Bio 200 has allowed me to become more confident incommunicating with other people, especially in science, given the questions that we were asking the presenters from the lab."

pursuing of STEM. S10 explained, "[Science] was really daunting at first because I didn't think that I was good enough to be able to get into it." S9 said, "Science can be really intimidating, especially when you're just getting into it." S14 said this course "made [science] seem less daunting. There's not as much of a learning curve as I thought there would've been to get into research." Some students even described specific science assignments as being scary, like S4 when they said,

> When I first found out about the literature review assignment, I was really scared. I was dreading it. But then I found a topic that I really liked, and I thought*, okay, I know I can actually do this*.

The fear students felt surrounding science could be in part due to having a novice understanding of the nature of science. Students mentioned that this course provided exposure to the nature of science ("real science"), something that doesn't happen in more traditional types of courses like lectures or laboratories. S9 said, "This course has provided a lot of exposure to real science. I don't get the same sort of experience in lectures or labs." S11 shared, "Before this class, I didn't really understand what happened with research." S14 stated, "Most of our experience in science so far has been as a student in the classroom. Reading the literature felt like something an actual scientist would do."

Learning about the nature of science by engaging with the products of science, conversing with research teams, and touring the spaces in which science is conducted helped students understand what it is like to conduct biological research and improved students' confidence in their ability to understand and communicate about science. S11 shared, "After reading the literature and touring the lab I understand research a lot more." S10 shared a similar sentiment when they shared that reading the articles, "made me believe that I can actually learn the material, even though it's tricky and it may not come easy at first." S10 also shared that they had a change in perspective about getting into science, stating, "I realized it just takes time and understanding. Everyone starts from somewhere." Although they did not directly use the word competence, S14 described an increase in their competence with regards to reading and understanding literature when they said, "Thinking about the stuff that we talked about during the discussions when I was reading the article on my own helped me understand them." In addition to having a better understanding of "real science", students may have a better idea of how to pursue FLREs as a result of this course. S8 shared, "I knew I was interested in doing research before this class, but I didn't know where to start. This class did a really good job of explaining how you would try to be in a research lab."

Overcoming the intimidation around science and feeling greater competence made students more interested in joining a research group. S11 shared, "I definitely want to join a research lab now." S9 summed up this theme well when she shared:

> Reading the primary literature articles … really paid off because I'm much more confident in my ability to read and understand primary literature. And that understanding has allowed me to overcome the intimidation that I have around science. And therefore, it has made me much more interested in pursuing research.

The students who experienced increases (and even some who stayed neutral) in their science identities clearly had overcome their intimidation around science, felt more competent in their ability to understand and communicate about science, and as a result, felt more inclined to pursue research opportunities.

Science identity versus other professional identities

Professional identity refers to the ways in which a student views themself as a professional member of a career pathway (Wilson et al., 2013). Professional identities, such as a science identity, or medical identity, or law identity, represent a students' beliefs about what it means to be a good professional in a specific career as well as the manner in which the student believes they should behave as a professional in a specific career (Coulehan, 2005). So, for the purpose of this article, science identity, medical identity, and law identity represent a students' thoughts about themself being and behaving as a good scientist, medical professional, and legal professional, respectively.

Of the twelve students in the course, nine (75%) were interested in a medical profession, five (50%) were interested in a research career, and three (25%) were interested in a law career (students could report being interested in multiple professions; Table 3). The large

Table 3. Career aspirations of students enrolled in the course. Letters in parentheses next to student IDs represent increases (I), no change (N), or decreases (D) in science identity scores pre- to post-course. Students are organized by magnitude of change with largest increases on the top, and largest decreases on the bottom. S13 and S14 did not complete both surveys.

Student	Career Aspiration
S5 (I)	Medical and Research
S9 (I)	Medical and Research
S11 (I)	Medical and Research
S1 (I)	Medical Only
S10 (I)	Medical Only
S2 (N)	Medical Only
S4 (N)	Law Only
S6 (N)	Research Only
S7 (N)	Law Only
S8 (N)	Medical Only
S3 (D)	Medical and Research
S13	Law and Research
S14	Medical Only

proportion of medically oriented students is not surprising, considering many of the students in the introductory biology course from which our IPL students were recruited are medically oriented, especially those from underserved backgrounds. Additionally, professional identity formation often begins before career-specific education, especially for medically oriented students (Wilson et al., 2013). Factors that influence medical identity before career specific education include having a family member who is a medical professional; the backgrounds, experiences, and values that students held when starting their medical education; or even learning about medical professions by watching medical television dramas (Baernstein et al., 2009; Cavenagh et al., 2000; Weaver & Wilson, 2011).

Science identity has not been well studied among populations of students who are interested in becoming a medical professional (Dou et al., 2021). Understanding the extent to which medically oriented students identify with science is important considering most of them start their undergraduate degree as a STEM major but fewer than half (41%) are accepted into medical school (Dou et al., 2021). One study, conducted by Dou and colleagues (2021), found that STEM majors on a pre-med/health track were more likely to have a stronger science identity than STEM majors who were not on a pre-med/health track.

The results of the current study supplement Dou and colleagues' (2012) findings, in that all of our students who saw increases in science identity were medically oriented. Additionally, one of two medically oriented students who did not see a change in science identity (S8) pre- to post-course started and ended with a score of 100%. However, we also found that medically oriented and research oriented students saw changes in their science identities in similar proportions. For students who reported interest in a medical profession, 63% (5/8) saw increases in their science identities, 25% (2/8) stayed the same pre- to post-course, and 13% (1/8) saw decreases. Similarly, for students who reported an interest in a research career, 60% (3/5) saw increases in their science identities, 20% (1/5) stayed the same, and 20% (1/5) saw decreases. For students who were interested in both medical and research careers, 75% (3/4) saw increases in their science identities and 25% (1/4) saw a decrease. In fact, the three students who saw the largest increases in their science identities were all interested in both a medical career and a research career.

Although our students' career aspirations did not change pre- to post- course, those who

were interested in medicine or law showed more interest in conducting biological research as an undergraduate student as a result of our IPL course. S4 shared that as a result of this course, "I'm definitely more interested in doing research and I do want to volunteer in a research laboratory as an undergraduate student." Additionally, some of our medically oriented students may move towards incorporating research as a part of their career goals and identities. S9 shared:

> I want to be a physician. This course hasn't changed that, but rather added to what I want to do. I was not really aware about the research sides of medicine. I'm very interested in going into surgery. And I think just attending this course, let alone the effort that I put into this course, has allowed me to realize the diversity of topics I could pursue within research, or in the surgery-side. And my mind's just sort of going in all of these places, like what kind of clinical trials I could explore one day, what kind of drugs I could research with. So, this course has led into this enormous amount of exposure [to real science], and I'm really excited to keep going.

This increased interest in research could be because students believed that research would prepare them for their future profession. S1 who wants to be an anesthesiologist wrote, "Scientific research will help prepare me for the medical field by expanding my knowledge and helping me get experience." S10 who wants to be a physician shared, "[Scientific research] could help me get into medical school and also help me grow my interest for science." The students who aspired for a law career also believed that understanding biological research would help them in their careers. S4, who is interested in patent law, shared "I want to learn how to interact with researchers, how research labs work, and how to read research papers so that I can get a better understanding of the people I will most likely be working with."

Gender differences in criteria for being a scientist

One study that explored gender differences among undergraduate students who were participating in FLREs found that while 100% of male participants identified as scientists, only 30% of women did (Schmid & Wiles, 2022). This disparity was, in part, attributed to women having different self-imposed criteria for calling themselves scientists than did men. We found similar results in the current study. Many of our women students reported an increase in their competence, or that they saw themselves as more of a "science person" as a result of participating in this course, but that they did not yet consider themself a "scientist". For example, S1, a woman URM student, felt like the IPL course improved her ability to read and write scientifically but that her improvement in those areas wasn't enough for her to qualify as a scientist. She shared "I wouldn't say I feel like a scientist, but I definitely feel more knowledgeable in certain research topics, how to write a literature review, and how to read papers."

S9, who is also a woman, felt like this course strengthened her science identity because she had a better understanding of what type of research she would like to do. She said, "I think that it's easier to consider myself more of a science person when I understand what I want to do once I'm in the field." Despite feeling like her science identity was strengthened, she would not consider herself a scientist yet. She shared, "Taking this course has reassured me that I'm not a scientist yet, and that's okay. I'm going through this journey to get there. So, while I'm confident that [my science identity] increased, I still would call it neutral." These findings are interesting considering S9 scored 100% on the science identity scale on her post-course survey.

One of the male students, S5 held a differing opinion: one can be a "science person" simply by learning about science. He shared "Not knowing stuff doesn't stop me from identifying as a science person." However, S13 a man URM student, felt more similar to the women

students, sharing "I feel like conceptually, I'd have to learn more [to identify as a scientist]." This finding was particularly interesting considering this student also shared that they were currently participating in a FLRE.

S14, whose gender identity was not disclosed, shared "I don't really feel like a scientist until I publish a paper or something like that." However, they also shared that they "feel a little closer" to being a scientist after reading biological literature.

Limitations

Limitations of this study include that the group discussion was led by the course instructor. This may have made students less likely to volunteer negative experiences with the course, feelings of having a weak science identity, or opinions having to do with a lack of interest in biological research or scientific careers. The instructor made an attempt to minimize this potential bias and encourage all students to share their thoughts before the discussion by reminding students of the experimental nature of the course. More specifically, the instructor explained that while it is important to hear positive feedback about the course, it is equally if not more important to hear negative feedback in order to make effective changes to future iterations of the course.

Another limitation of this study is that we were not able to control for factors that were external to the course that may have influenced students' science identity. Our students were likely participating in other STEM courses which may have influenced their identification with science.

Conclusions

Our findings support the implementation of IPL courses as a steppingstone to UREs. The experimental course includes interactions with scientists of all levels ranging from undergraduate researchers to principal investigators, and our data indicate that these interactions were beneficial to undergraduates. Notably, students articulated that participating in the IPL course increased their science identities in by increasing their interest in pursuing FLREs, their self-recognition as a scientist, and their competence in reading and understanding scientific content. Scaling up the methods used in this IPL course to the context of a larger enrollment introductory biology course could increase the number of students benefiting from early exposure to biological research, generating a larger impact. Underrepresented students and students from low-income communities have historically not been afforded access to early undergraduate research experiences and may experience greater benefits. We hope to use these results to inform scaling-up efforts as well as other UREs to increase the population of undergraduate students who might benefit from these interventions.

Acknowledgements

This work was financially supported by a Howard Hughes Medical Institute (HHMI) Inclusive Excellence Grant. We are grateful to the Syracuse University Office of Institutional Research for their cooperation, the undergraduate students in the IPL course who agreed to participate in this research, and Jess Dewey for her thoughtful comments. We would also like to give a special thank you to all of the professors, postdoctoral researchers, lab managers, and graduate students who engaged with our students and made several of the course activities possible. All data were collected under an IRB-approved protocol (IRB#: 20-241).

References

Baernstein, A., Oelschlager, A. M., Amies, E., Chang, T. A., and Wenrich, M. (2009). Learning Professionalism: Perspectives of Preclinical Medical Students. Academy of Medicine. 84(5), 574-581.

Brownell, S. E., Price, J. v., & Steinman, L. (2013). A writing-intensive course improves biology undergraduates' perception and confidence of their abilities to read scientific literature and communicate science. American Journal of Physiology - Advances in Physiology Education, 37(1), 70–79. https://doi.org/10.1152/advan.00138.2012

Carter, B. E., Wiles, J. R. (2017). A qualitative study examining the exclusive use of primary literature in a special topics biology course: Improving conceptions about the nature of science and boosting confidence in approaching original scientific research. International Journal of Environmental and Science Education, 12(3), 523–538.
https://doi.org/10.12973/ijese.2017.1245p

Cavenagh, P., Dewberry, C., Jones, P. (2000). Becoming professional: When and how does it start? A comparative study of first-year medical and law students in the UK. Medical Education. 34(11), 897-902.

Chang, M. J., Eagan, M. K., Lynn, M. H., & Hurlado, S. (2011). Considering the impact of racial stigmas and science identity: Persistence among biomedical and behavioral science aspirants. Journal of Higher Education, 82(5), 564–596.
https://doi.org/10.1353/jhe.2011.0030

Chemers, M. M., Zurbriggen, E. L., Syed, M., Goza, B. K., & Bearman, S. (2011). The role of efficacy and identity in science career commitment among underrepresented minority students. Journal of Social Issues, 67(3), 469–491. https://doi.org/10.1111/J.1540-4560.2011.01710.X

Cheryan, S., Master, A., & Meltzoff, A. N. (2015). Cultural stereotypes as gatekeepers: Increasing girls' interest in computer science and engineering by diversifying stereotypes. Frontiers in Psychology. https://doi.org/10.3389/FPSYG.2015.00049/BIBTEX

Coulehan, J. (2005). Today's professionalism: Engaging the mind but not the heart. Academy of Medicine. 80, 892-898.

Eagan, M. K., Hurtado, S., Chang, M. J., Garcia, G. A., Herrera, F. A., & Garibay, J. C. (2013). Making a Difference in Science Education: The Impact of Undergraduate Research Programs. American Educational Research Journal, 50(4), 683–713. https://doi.org/10.3102/0002831213482038

Fairlie, R., Hoffmann, F., & Oreopoulos, P. (2014). A community college instructor like me: Race and ethnicity interactions in the classroom. American Economic Review. 104(8)
http://dx.doi.org/10.1257/aer.104.8.2567

Frantz, K. J., Demetrikopoulos, M. K., Britner, S. L., Carruth, L. L., Williams, B. A., Pecore, J. L., Dehaan, R. L., & Goode, C. T. (2017). A comparison of internal dispositions and career trajectories after collaborative versus apprenticed research experiences for undergraduates. CBE Life Sciences Education, 16(1). https://doi.org/10.1187/CBE.16-06-0206/ASSET/IMAGES/LARGE/AR1FIG6.JPEG

Humphrey, E. A., & Wiles, J. R. (2021). Lessons learned through listening to biology students during a transition to online learning in the wake of the COVID-19 pandemic. Ecology & Evolution 11(8), 3450-3458. https://doi.org/10.1002/ece3.7303

Marx, J. D., & Cummings, K. (2007). Normalized change. American Journal of Physics, 75(1), 87–91. https://doi.org/10.1119/1.2372468

Merolla, D. M., & Serpe, R. T. (2013). STEM enrichment programs and graduate school matriculation: The role of science identity salience. Social Psychology of Education, 16(4), 575–597. https://doi.org/10.1007/S11218-013-9233-7/FIGURES/1

National Academies of Sciences, Engineering, and Medicine (NASEM). 2017. Undergraduate research experiences for STEM students: Successes, challenges, and opportunities. The National Academies Press. https://doi.org/10.17226/24622.

Perez, T., Cromley, J. G., & Kaplan, A. (2014). The role of identity development, values, and costs in college STEM retention. Journal of Educational Psychology. https://doi.org/10.1037/a0034027.supp

Pierszalowski, S., Bouwma-Gearhart, J., & Marlow, L. (2021). A systematic review of barriers to accessing undergraduate research for STEM students: Problematizing under-researched factors for students of color. Social Sciences, 10(9), 328. https://doi.org/10.3390/SOCSCI10090328

Reig, A. J., Goddard, K. A., Kohn, R. E., Jaworski, L., & Lopatto, D. (2018). The FUTURE program: Engaging underserved populations through early research experiences. ACS Symposium Series, 3–21. https://doi.org/10.1021/BK-2018-1275.CH001

Sandefur, C. I., Gordy, C., & Farm Road, M. (2016). Undergraduate journal club as an intervention to improve student development in applying the scientific process. Journal of College Science Teaching, 45(4), 52–58.

Schmid, K. M., Dunk, R. D. P., & Wiles, J. R. (2021). Early exposure to primary literature and interactions with scientists influences novice students' views on the nature of science. Journal of College Science Teaching, 50(6).

Schmid, K., Hall, S. E., & Wiles, J. R. (2023). Different approaches for engaging undergraduates in research: Variable impacts on students' self-efficacy, science research skills, and future goals. Bioscene: Journal of College Biology Teaching.

Schmid, K. M., & Wiles, J. R. (2019). Case study: An introduction to biological research course for undergraduate biology students. Journal of College Science Teaching, 49(01).
https://doi.org/10.2505/4/JCST19_049_01_48

Schmid, K. M. & Wiles, J. R. (2022). Call her a scientist: The role of mentors in faculty lab-based undergraduate biology research experiences & outcomes for student science identity. The American Biology Teacher 84(5), 273-278.
https://doi.org/10.1525/abt.2022.84.5.273

Sloane, J. D., & Wiles, J. R. (2020). Communicating the consensus on climate change to college biology majors: The importance of preaching to the choir. Ecology and Evolution, 10(2), 594–601. https://doi.org/10.1002/ece3.5960

Weaver, R., Wilson, I. (2011). Australian medical students, perceptions of professionalism and ethics in medical television programs. BMC Medical Education. 11(50).

Wilson, I., Cowin, L. S., Johnson, M. & Young, H. (2013). Professional identity in medical students: pedagogical challenges to medical education. Teaching and Learning in Medicine: An International Journal, 25(4), 369-373.