Papers to Podcasts: Curriculum for Developing Scientific Practices in Undergraduates through Annotating Primary Scientific Literature & Creating Podcasts

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Abstract
Scientific practices are still largely absent from undergraduate curricula. Incorporating primary scientific literature (PSL) and podcasting into course curricula is an engaging way to provide instruction in scientific practices to undergraduate students. We present an innovative class project for biology undergraduates where students read a piece of PSL, develop annotations to learn more about the research contained within the PSL, and develop and produce a podcast episode to share the research findings with a general audience. To understand student perceptions of the project, we conducted surveys to obtain qualitative responses along with measures of science identity and project ownership. We found that the students felt like the project belonged to them and that their work on the project would ultimately benefit the scientific community. Here, we include a project handbook, schedule, and materials that can be used by any instructor to carry out this project.

Key Words: primary scientific literature; science communication; podcast; project ownership.

Introduction
Holistic science education now includes teaching science practices such as data interpretation, problem solving, and experimental design (Coil et al., 2010; American Association for the Advancement of Science, 2011). The knowledge, skills, and competencies that make up such a holistic education (i.e., science practices), are fundamental for practicing scientists; however, most college science departments lack formalized methods for teaching or evaluating authentic scientific practices (Kozeracki et al., 2006; Momsen et al., 2010; Sato et al., 2014).

One pedagogical technique for engaging students in scientific practices, or what it means to do research, is through integrating primary scientific literature (PSL) into course content. PSL offers a unique opportunity to integrate authentic cutting-edge science into every classroom as it requires no hands-on lab component and no additional equipment. PSL can also be easily integrated into online learning platforms and used in a digital setting. In addition, PSL applies to all scientific disciplines.

A growing body of literature shows that PSL is a valuable and useful tool for teaching scientific practices. For example, closely analyzing PSL in a classroom setting engages students in discussion and debate around interpretations of experimental data while building their insight into both the nature of science and researchers themselves (Hoskins et al., 2007). PSL can also illustrate to students that, even after a study is completed and published, there are still many unanswered questions for future scientists. Therefore, reading PSL promotes the development of creativity through experimental design assignments (Gottesman & Hoskins, 2013). Published examples of PSL-based research highlight the diversity, scalability, and flexibility of PSL as a pedagogical tool. Programs include journal clubs, data and figure exploration, tutorials on how to read PSL, annotated literature, and full courses being taught only with PSL (Hoskins et al., 2007; Round & Campbell, 2013; Sato et al., 2014; Sandefur & Gordy, 2016; Kararo & McCartney, 2019).

Teaching with PSL promotes critical thinking, experimental design ability, and epistemological maturation as well as improves undergraduate students’ positive attitudes about science and scientists (Hoskins et al., 2011; Gottesman & Hoskins, 2013; Murray, 2014; Stevens & Hoskins, 2014; Kenyon et al., 2016).

A second, more modern, pedagogical technique for engaging students in scientific practices, specifically the practice of communication, is scripting and producing a podcast. Scientists’ ability to communicate effectively is vital to their contribution to society and to society’s reception of science. Communication skills are recognized as critical regardless of scientific discipline, similar to the ability to...
read PSL, and should be integrated into science curricula. Student-generated podcasts provide opportunities for students to engage in several scientific practices, including effectively working in groups, researching the scientific content discussed in the podcast, and successfully communicating the scientific content. Creative podcasting develops collaborative knowledge-building, critical thinking, and reflective thinking skills (Lee et al., 2008; Lazzari, 2009; Pegrum et al., 2015).

Here, we describe an innovative class project that engages students in the scientific practices of reading PSL and communication. Undergraduate biology majors working in small groups read a piece of PSL that instructors assigned to them. Over the course of five weeks, students annotated their PSL (i.e., they defined glossary terms, researched methods used by the authors, and broke down data figures). Annotating PSL has previously been shown to provide students with a deep understanding of the scientific content contained within the PSL and to increase communication skills (McCartney et al., 2018; Ritchie & McCartney, 2019).

Next, students developed a podcast on the PSL that they annotated. The students drafted a script for the podcast according to the instructor’s feedback. Students then practiced narrating the script and recorded the podcast episodes. Each of the episodes was edited by author Ravindra Palavalli-Nettimi (RPN), who served as the multimedia editor at The Journal of Animal Ecology, and the podcast series was posted on the British Ecological Society’s SoundCloud account where they are available to the scientific community and the general public.

To measure student engagement in this study, we adapted a project ownership survey. Project ownership can predict the degree to which students engage in conversations about their research with others (Hanauer & Hatfull, 2015). As students in this study were developing and producing their podcast (a type of project) as a way to communicate the results of scientific research, we felt that an adapted project ownership framework was suitable for our needs.

When students feel that a project belongs to them and that the project outcome reflects their authentic contributions, they are said to have project ownership (Hanauer & Hatfull, 2015). Project ownership in undergraduate STEM education has been studied mainly in relation to undergraduate research experiences and has been shown to include aspects of engagement, agency, personal connection, the recognition of community and disciplinary value, and positive emotive responses (Hatfull, 2010; Hanauer et al., 2012, 2016; Hanauer & Dolan, 2014; Hanauer & Hatfull, 2015). While students in this study did not directly engage in a research opportunity, the annotation and podcast experience has several parallels to the five categories of project ownership, including agency combined with mentorship (a student actively seeking advice), expressions of excitement toward scientific inquiry (positive emotional interaction relating to involvement in science), and expressions of a sense of personal scientific achievement (a positive emotional expression upon achieving a specific goal) (Hanauer et al., 2012; Hanauer & Dolan, 2014). We hypothesized that students completing the annotation and podcast project would impact their sense of project ownership.

Because students were creating a podcast that would be shared with practicing scientists (i.e., the students were directly participating in scientific discourse), we also measured science identity. Science identity is a construct of identity specific to science knowledge and, to date, there is no consensus on the definition of science identity (Chen & Wei, 2020). However, two characteristics of science identity are commonly emphasized: recognition of oneself as a “science person” and the recognition of being a “science person” in a social context, especially by influential persons including professors, teachers, advisors, and peers (Brickhouse et al., 2000; Carlone & Johnson, 2007; Hazari et al., 2021). We measured students’ science identity using items from Estrada and colleagues (2011). We hypothesized that participating in the annotation and podcast project would impact student science identity.

Finally, we collected qualitative data from students on their perception of the project. As a phenomenological study, we did not specifically seek to test existing theories about student learning; rather, we aimed to characterize the unique ways in which students experience the same phenomenon as a way to compile a comprehensive description of students’ “lived experiences” (Starks & Brown Trinidad, 2007; Van Manen, 2016).

○ Activity Overview & Materials

Intended Audience
This activity is designed for undergraduate biology students who have completed the introductory biology sequence.

Learning Time
This paper describes a semester-long activity that could easily be implemented into any preexisting biology (or STEM) course (Appendix I).

Prerequisite Student Knowledge
Students should have completed introductory biology courses and should be familiar with PSL. Being able to read and deconstruct PSL is a central tenant of this activity and we do not suggest implementing this activity with novice PSL readers. Activities for helping undergraduate students become familiar with reading PSL can be completed before implementing this activity and include the C.R.E.A.T.E. method (Consider, Read, Elucidate hypotheses, Analyze and interpret data, Think of the next Experiment) (Hoskins et al., 2007; www.teachcreate.org) and exploration of annotated PSL (Kararo & McCartney, 2019).

Learning Objectives
Engage students in the scientific practices of reading PSL and communicating scientific results. Specifically, students will interpret a piece of PSL to articulate its main points (PSL annotations), and they will communicate scientific findings contained within PSL (scripting and producing a podcast).

Selection of Primary Scientific Literature
There is no easy method for selecting appropriate PSL for a given population of students. Finding appropriate PSL takes time and effort and, based on course content and student knowledge levels, may need to be adapted each time this activity is implemented. When choosing PSL for this activity, we asked our undergraduate research assistants, who are closer to our student population with regard to content knowledge and vocabulary level, to read the PSL and give us their feedback, which was a successful “first screen” for us. For a separate study, we have listed 14 pieces of PSL that we used with introductory biology students and have provided a brief reason why we used each piece, which may be helpful for instructors looking for PSL (Chatzikyriakidou et al., 2021). Finally,
the Science in the Classroom website (www.scienceintheclassroom.org), a collection of annotated PSL that has been carefully selected to be accessible to an introductory-level undergraduate and to be cutting-edge science, is an easily searchable database and may be helpful to instructors as they decide which PSL to select for their class.

PSL was selected by the course instructors and was intended to match the content of the course (evolution or genetics) with the content of the research found in the PSL. All papers were selected from the Journal of Animal Ecology (published by the British Ecological Society) for the podcasts to be posted on the journal’s website and shared with the journal’s audience. For future adaptations, PSL can be selected from any peer-reviewed journal; the important factor is that the PSL connects to course content.

Annotation Process

Annotated primary scientific literature is designed to help readers interpret complex science by overlaying additional information on a scientific research article (Kararo & McCartney, 2019). Science in the Classroom (www.scienceintheclassroom.org) is the model for the annotation process used in this study (Appendix 5). Students were asked to work together in groups (of three to four students) and annotate their paper using the online platform Xodo (www.xodo.com). Specifically, students were asked to identify and annotate the overall hypothesis, a total of 24 vocabulary words, a total of four real-world connections, and to annotate at least four of the figures presented. The annotation process served two purposes: to engage the students in a comprehensive understanding of the research and to provide an annotated version of the research paper that will be available to future students. At our institution, we archive the annotated PDFs developed using Xodo and make them available to future students in biology courses as a way of inserting more PSL across our curriculum. Students were made aware of this resource, and the newly annotated papers from this study were added to our collection.

Podcast Scripting

Podcast scripting instructions were provided in the course manual, along with an example script and links to a few popular science podcasts (Appendix 2 and Appendix 5). The example script was color-coded to highlight how each line contributes to telling a story about the annotated paper. Students were told to put “why” before “how” and to start the script with a “hook.” The hook is typically the paper’s real-world connection (which the students discovered through the annotation process) or information that can generate interest in the listener; the goal was to make the audience interested in learning more. The students were instructed to exclude technical details of methods and to write a concise script without jargon (e.g., “narration,” where the script is narrated, or “conversational,” which involves a conversation between the podcast hosts). Students were encouraged to incorporate sounds, such as the roaring of a panther or a buzzing bee, if they felt that it would increase the value of their story. It is important to note that we are asking students to create a “short” podcast that is 3–5 minutes long in the narrative style.

To craft the first draft of the podcast script, students had to follow written instructions and use examples in their handbook (Appendix 2 and 5). For the second draft, in a short oral presentation to the whole class (Appendix 3), RPN (one of this article’s authors) identified common mistakes of the student scripts and explained how students could improve their stories. Students (in their groups) and RPN then went through at least two iterations of script editing outside of class. RPN edited and provided comments on the scripts and shared them with each student group, who were then encouraged to follow RPN’s suggestions and consult him over email for further feedback. Then, each student team and RPN practiced reading the final script aloud (“table read,” as they call it in the movie industry) and recorded it in a quiet classroom using the free built-in audio recording app of an iPhone. RPN edited the recordings on GarageBand, free software on a Macintosh computer.

Podcast Posting

The podcast series was named Audio Abstracts. As RPN was a multimedia editor for www.animalecologyinfocus.com—a blog run by the British Ecological Society’s Journal of Animal Ecology—the series was posted on the SoundCloud account (https://soundcloud.com/besjournals/sets/audio-abstracts) of the British Ecological Society journal, which is freely available to the general public. The podcasts can also be accessed on our website (https://melissamccartneyphd.com/about-the-lab/student-podcasts).

Faculty Instructions

Faculty should first select a list of PSL that connects to course content and is at the appropriate level for students to read. Previously, we had let students select their own PSL, and issues always arose such as students not choosing PSL (e.g., a review paper or a news article), choosing a piece of PSL that did not match course content, or choosing a piece of PSL that was far too complicated for their knowledge level. Therefore, we suggest selecting more PSL than you will need and allowing students to choose from a curated list.

Next, faculty should create a schedule of assignments and due dates; a sample schedule is shown in Appendix 1. We suggest providing ample time for editing podcast scripts, as this was the segment that consumed the most time, since none of the students had any experience in scripting podcasts and therefore required major editing by the teachers, and engaged the students the most, in our experience. An outline for developing a script and an example script are shown in Appendix 2.

Teachers in our study had small class sizes (18–25 students), and we are hesitant to recommend this activity to larger classes. Teachers invested time in checking tasks for completion, reviewing annotations, and reviewing podcast drafts. This worked for our instructors; these activities satisfied part of the writing requirements of our college, and the students were happy to receive feedback throughout the project. To implement this activity in a larger class, we strongly recommend collaborating with one (or more) learning assistant / undergraduate assistant during the review process.

Faculty with no prior podcasting experience can learn tips from YouTube tutorials on sound editing in open-source free software such as Audacity and GarageBand, which can be shared with students. The students need to learn only the most basic steps in editing (such as cutting, adding sound effects, transitioning between sound clips, and exporting a final mp3 file). For this purpose, any short tutorial on YouTube is sufficient (Buzzsprout, 2019). Once there is a template for an episode, it can be used to edit new episodes. For faculty without access to a journal editor and/or posting privileges on a journal website, edited podcasts can be posted on any podcast hosting website, such as Soundcloud or Buzzsprout, both of which offer free versions. Alternatively, the faculty can interact with their university press office to upload the podcasts on their websites and social media.
Suggestions for Determining Student Learning

Teachers in our study graded individual tasks within the project (Appendix 1), assigning points to each weekly task. In our experience, students appreciated having the project and corresponding grades subdivided into tasks (and associated deadlines).

Data Collection

Project Ownership Survey

To measure whether students perceived the project as belonging to them and whether the project outcome reflected their authentic contributions, we adapted eight items from the “project ownership” factor of the project ownership survey (POS) and used these items for a postcourse questionnaire only (Hanauer & Dolan, 2014; see Appendix 4). As the original POS was developed for research experiences, we selected items that we were able to translate into a nonresearch setting. We do not measure project ownership over the course of the project and have no control group to compare to, allowing us to use these items directly without the need for further validation with our sample population. Because we knew we would be unable to validate these items with our small population, we only selected positive coded items as a way to keep the assessment simple for students. Similarly, we asked students only about their impressions of scripting the podcast, and not recording the podcast, as we felt this best aligned with our learning objective of engaging students in the scientific practices of communicating scientific results.

Science Identity

To measure whether annotating a research paper and developing and producing a podcast based on that research paper to share with the scientific community resulted in students feeling more like a scientist, we measured students’ science identity using items from Estrada and colleagues (2011), administered both as pre- and postcourse questionnaires (Appendix 4). Using student ID numbers, we matched all student data using the VLOOKUP function in Excel, ensuring that only data from students participating in both the pre- and postcourse questionnaires were analyzed, which is why our n values are lower than the total number of students participating. Our data set did not have a normal distribution, and therefore we utilized the nonparametric Mann-Whitney U-test to determine if there were significant changes in students pre- and postcourse science identity scores.

Qualitative Data

We asked short-answer, qualitative questions as part of the postcourse questionnaire. We designed questions specifically to gain a deeper insight into student perspectives on the project itself, as well as their feelings of project ownership and science identity.

- Was the annotation portion of this project helpful?
- Was the podcast portion of this project helpful?
- How do you feel about your annotations being available for future students to learn from?
- How do you feel about your podcast being available for other scientists to listen to?
- What was your favorite part about this project?
- What part of this project surprised you the most?

Questionnaire Distribution

All questionnaire data were collected using Qualtrics (online survey software). Online links to the questionnaire were provided to students using Canvas classroom management software. At the beginning of the semester, the questionnaire was administered to all participating students as a voluntary precourse assignment. Students who completed the questionnaire were given extra credit points, regardless of whether they agreed for their data to be included in the study. The students then participated in the annotation and podcast activity. At the end of the semester, all students were given a postcourse questionnaire and were again provided with extra credit upon completion.

Participating Students

Students from two courses participated in this study. First was Evolution (n = 25), an upper level (junior/senior) requirement for a degree in biology. The main conceptual areas are an overview of evolutionary processes and their contribution to biological change over time and space; the study of these processes, with an emphasis on adaptation; and the origin and evolution of life, through the use of the fossil record, phylogenies, and evolutionary models. Second was the QBIC Genetics Journal Club (n = 18), a sophomore-level requirement for students in the Quantifying Biology in the Classroom program (Weeks & Koptur, 2013). The Genetics Journal Club involves student-led discussion of primary scientific literature in the field of genetics. Each week, students read and discuss as a group one genetics-related journal article, with a different student serving as the “discussion leader” each week.

Student projects spanned 14 weeks and included several group assignments and deadlines (Appendix 1). Students annotated their papers as a way to prepare for the scripting of the corresponding podcast, described in the project handbook (Appendix 5).

Evidence of Student Engagement

Project Ownership

Results from the POS indicate that, overall, students perceived the project as belonging to them and that the project outcome reflected their authentic contributions (Figure 1). There are some slight differences between scores for the annotation portion and podcast portion, most noticeable in challenges that students were able to overcome (the annotation portion seemed to lead to more challenges). Despite reporting more challenges with the annotation portion, students reported seeking more advice and assistance with the podcast portion.

Science Identity

We saw no change in students’ overall self-reported science identity (Figure 2A), despite the prompt of “[activity] is important to the scientific community” receiving the highest scores on the POS (Figure 1). While disappointing, these results are perhaps not surprising, because it was unlikely that a single activity was enough to shift a student’s identity, as science identity unfolds over time (Kim & Sinatra, 2018).

We also asked three stand-alone questions to gain more understanding of students’ perceptions of how the project made them feel as scientists (Figure 2B), all of which suggests that the students did feel like scientists and felt they were contributing to the scientific community through this project.
Looking closer at science identity (Figure 3), when we look at student responses to each individual item on the science identity questionnaire (Appendix 4), we do see a slight, nonsignificant increase in the items “I have a strong sense of belonging to the community of scientists” and “I have come to think of myself as a scientist.” These two items relate to the two main characteristics of science identity: the recognition of being a “science person” in a social context and recognition of oneself as a “science person” (Brickhouse et al., 2000; Carlone & Johnson, 2007; Hazari et al., 2021).

Qualitative Data

Because our sample size is small (the qualitative data questions were optional), we were unable to do a thematic analysis of our qualitative data. In general we had approximately 22 student replies for each qualitative question, however these included students who answered with “sure,” “yes,” and “no comment.” After separating these types of answers out of the data set, we believe the nine responses shown for each question are representative of our overall sample. The feedback we received on these questions was overall positive and suggested that students enjoyed the project. We see no differences in student perceptions of the annotation portion versus the podcast portion (i.e., students preferring one portion over the other). Instead, we see students describing synergy between the two portions, as students often cite the annotation portion in helping them develop the podcast script and the podcast serving as a way for them to communicate the science that they learned through annotating PSL (Table 1).

Figure 1. Project ownership. Student project ownership data for both annotating primary scientific literature (PSL) and developing and producing a podcast. Project Ownership Survey (POS) items were measured using a six-point Likert-type scale. The data labels show the number of students (n = 33) that selected each category in the Likert scale.
Figure 2. Science identity. (A) Science identity data for both pre- and postcourse activities. Science identity items were measured using a six-point Likert-type scale (n = 24). All data were paired so only students who completed both the pre- and postactivity surveys are included in these data. (B) Stand-alone questions used to further investigate students’ perception of the project on their feeling like a scientist. The data labels show the number of students (n = 33, postanswer only; data were not paired) that selected each category in the Likert scale.

Figure 3. A closer look at science identity. Science identity scores for both pre- and postcourse activities are shown item by item. Science identity items were measured using a six-point Likert-type scale (n = 24). All data were paired so only students who completed both the pre- and postactivity surveys are included in these data.
We see qualitative data for student perceptions of their work being shared with the larger scientific community (Table 2), providing a more comprehensive understanding of the data in Figure 2B. Students are truly excited to share their work with others in a beneficial way.

Finally, we asked students what they liked about the project (Table 3). Recording the podcast received the most mentions, both as the most challenging and as the most fun. We see some mentions of creativity, which is always rewarding to see in connection to a science project.

Dissemination of the Podcast
The podcast series has been listened to over 3897 times (with each podcast episode played at least 227 times) on the SoundCloud platform (accessed on June 27, 2022). The number is likely higher as the podcasts could be listened to on various other platforms. Most of the listeners on SoundCloud were from the US and the UK. We are thrilled that so many members of the scientific community were able to benefit from our students’ podcasts!

Table 1. A sample of student responses to the questions “Was the annotation portion of this project helpful? Why or why not?” (selected from 22 responses) and “Was the podcast portion of this project helpful? Why or why not?” (selected from 23 responses).

| Was the annotation portion of this project helpful? Why or why not? | Was the podcast portion of this project helpful? Why or why not? |
|---------------------------------------------------------------|---------------------------------------------------------------|
| It was because you had to make sure you understood the concepts to be able to write notes and it helped in writing the script. | Yes, I thought that the podcast was the most interesting and helpful part because it helped to better understand and communicate my understanding of the paper. |
| Extremely helpful. By dissecting the scientific paper it became easier to understand. | It’s helped to figure out how to speak to scientists and articulate yourself well. |
| Very helpful in allowing me to fully comprehend what the paper was about and why the study was conducted in the first place. It facilitated my learning process. | Yes, it was interesting giving our own voices on the topic and allowing scientists to listen to what we have to say. |
| Yes, it had us investigate and familiarize ourselves with the topic of our paper. | Yes because this is the part that makes it simple for other people to understand and enjoy. |
| It was helpful in the sense that it made me annotate words and figures that otherwise I would have looked over and not paid attention to if I had not been asked to annotate them. | It added everything together in a way that made us think of writing it short and concisely so I think it was helpful. |
| Yes because it allowed for easy creation of the podcast transcript. | It was helpful in understanding the article in a smaller amount of words. |
| It helped break the paper down into manageable parts so yes it was helpful. | The podcast was fun to record and really brought the annotation to life, so I did like it a lot despite how many times I've verbally mispronounced and butchered sentences on live recording. |
| Yes. It helped to break down the article in a way that made it more simple to understand by doing it little by little | The podcast was a very creative way to display what our group understood from the research paper. I think it helped to strengthen the understanding of the paper because we had to explain it in simple terms for the purpose of the podcast. |
| Yes because it helped us break down the paper into words we could understand. | Yes, because it shows how a scientist would interpret a paper and describe it to the people that are not in the scientific community. |

Table 2. A sample of student responses to the questions “How do you feel about your annotations being available for future students to learn from?” (selected from 22 responses) and “How do you feel about your podcast being available for other scientists to listen to?” (selected from 23 responses).

| How do you feel about your annotations being available for future students to learn from? | How do you feel about your podcast being available for other scientists to listen to? |
|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| I hope that annotations being available can help other students learn about the paper and get excited about the topic. | I think it is a good opportunity to communicate and hope it is considered well written and informative. |
| It feels good to know that a project that I worked on will be used for more than a grade in the class. | A bit nervous since these people are already established in their field. |
Excited. I'm hoping other students can use the annotations to help them. | It's good to be put out there in the science field, however it would be more beneficial if I could receive feedback from these other scientists.
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I think it's a useful tool for students to have a general idea of these scientific papers so that they can have a better understanding of the paper once they read it in full. | I'm very happy that other scientists will be able to listen in on what me and my group have to say about the paper and the topic it's researching.
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Students will be able to quickly go through the paper and easily understand what they are reading, without having to stop and search up every unknown word or topic. | That's exciting as well because it makes me feel closer to the scientific community.
---|---
I'm very excited for the students that can use this in the future. When I started I didn't have anything annotated and had to figure out how to read it on my own. | Very excited because scientists can hear how advanced undergrads can be.
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I feel like it is good so other students can feel confident in doing their own annotations by learning from other students. | I think that’s great as well because sometimes people can be inspired by younger people heading into their field.
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I think that the students could better understand the article from my annotations. | I think it’s great to be able to record feedback in podcasts and interpretation of scientific articles for other scientists to listen to since some of these articles go unheard of. So reviewing and doing a podcast just sheds new light and appreciation to them.
---|---
I think it is a great idea, especially for those struggling with primary scientific literature. | I feel very proud about this creative assignment. I believe it adds to my experience and helped me gain a unique perspective into how information can be shared to the scientific community.

**Table 3.** A sample of student responses to the questions “What was your favorite part about this project?” (selected from 24 responses) and “What part of this project surprised you the most?” (selected from 24 responses).

| What was your favorite part about this project? | What part of this project surprised you the most? |
|-----------------------------------------------|--------------------------------------------------|
| My favorite part of this project was the actual recording of the podcast. It was a fun, interactive experience and I think the final recording brought the experience full circle. | The part of the project that surprised me the most was the podcast scripting, it was not what I expected and offered more room for creativity. |
| I believe that my favorite part was recording the podcast, very different from other classes and very helpful to the community. | The recording for the speaking part of the project was more difficult than I anticipated. |
| My favorite part was annotating the figures. | Making the script. |
| Recording because the process was tedious but following the recording I had a strong sense of achievement. | Recording. I didn’t think I’d be so proud of it. |
| My favorite part was taking the literature and breaking it up into pieces. This shows a different way to approach a research paper. | How annotating the paper made it easier to understand. |
| Working as a group. I think working in groups is much better than alone. | Having to write and record a podcast. |
| Favorite part of the projection was the podcast because I found that one to be the most fun. | Having to do a podcast, because I’ve never had to do one before. |
| I enjoyed collaborating in a team to create the script for the podcast. | The podcast being published was the most shocking. |
| Recording the podcast. | The time it took to simplify the details of the paper to make them simple for everyone to understand. |
Conclusion & Future Directions

This paper outlines the undergraduate curriculum for incorporating the scientific practices of reading PSL and communicating research findings to a lay audience. Students successfully learned to read and annotate PSL in addition to learning how to script and produce short podcasts based on the PSL. We show that the students perceived a sense of project ownership and reflected on how their authentic contributions would benefit the scientific community. Notably, the students reported that they felt proud of the final products (annotated papers and podcasts) and learning outcomes.

We are confident that our learning objectives were met and that our hypotheses were accepted. While the quantitative science identity data were not significant, students quantitative answers support students recognizing themselves as scientists and contributing to the scientific community. If we were to implement this project again, we would consider expanding the communication skills involved in scripting the podcast. For example, encouraging students to have more of a conversational dialogue between themselves or even reaching out to interview the author of a paper. This could potentially develop the students’ communication skills in scientific discussions and scientific argumentation. In parallel, developing a podcast in this way may also lead to students further engaging with PSL, as they would have to understand the research in a deeper way than just describing the general narrative.

We feel that the material provided here can be used by any instructor to add this project to their undergraduate curriculum. While we have implemented this project with upper-level students, we believe that with the right level of support (i.e., learning assistants and/or teaching assistants available for help), and the right level of PSL being selected, that this project could be successfully implemented with introductory students. Investing in this model could potentially reap huge future benefits, as starting freshman students out positively engaging with PSL in this way could position them for productively reading PSL throughout their future careers.

In summary, providing students the experience and engagement with scientific skills, including reading PSL and communicating scientific results, is an important factor of any science education. We believe that these skills should be included and promoted in curricula whenever possible, and we encourage our colleagues to implement and adapt our project for use with their own student populations.

Supplemental Material

- Appendix 1: Timeline for annotation and podcast project
- Appendix 2: Instructions for scripting the podcast along with an example podcast script
- Appendix 3: Ravindra’s class presentation on scripting and feedback on their scripts
- Appendix 4: A complete list of items for project ownership survey for annotating and podcasting and science identity items
- Appendix 5: Project handbook

Use of Human Subjects

This work was certified as exempt by the FIU Review Board (IRB # 19-0283).

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References

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

Brickhouse, N.W., Lowery, P. & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. Journal of Research in Science Teaching, 37, 441–58.

Buzzsprout. (2019). How to Edit a Podcast in Audacity. https://www.youtube.com/watch?v=Zw9nkEHQ588.

Carlone, H.B. & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. Journal of Research in Science Teaching, 44, 1187–1218.

Chatzikyriakidou, K., Tacloban, M.J., Concepcion, K., Geiger, J. & McCartney, M. (2021). Student association of lecture content with the five core concepts of biology: novel results from an introductory biology course. Journal of Microbiology & Biology Education, 22, e00105-21.

Chen, S. & Wei, B. (2020). Development and validation of an instrument to measure high school students’ science identity in science learning. Research in Science Education. https://doi.org/10.1007/s11165-020-09932-y.

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, 524–35.

Estrada, M., Woodcock, A., Hernandez, P.R. & Schultz, P.W. (2011). Toward a model of social influence that explains minority student integration into the scientific community. Journal of Educational Psychology, 103, 206–22.

Gottesman, A.J. & Hoskins, S.G. (2013). CREATE cornerstone: Introduction to scientific thinking, a new course for STEM-interested freshmen, demystifies scientific thinking through analysis of scientific literature. CBE—Life Sciences Education, 12, 59–72.

Hanauer, D.I. & Dolan, E.L. (2024). The project ownership survey: Measuring differences in scientific inquiry experiences. CBE—Life Sciences Education, 13, 149–58.

Hanauer, D.I., Frederick, J., Fotinakes, B. & Strobel, S.A. (2012). Linguistic analysis of project ownership for undergraduate research experiences. CBE—Life Sciences Education, 11, 378–85.

Hanauer, D.I., Graham, M.J. & Hatfull, G.F. (2016). A measure of college student persistence in the sciences (PITS). CBE—Life Sciences Education, 15, ar54.

Hanauer, D.I. & Hatfull, G. (2015). Measuring networking as an outcome variable in undergraduate research experiences. CBE—Life Sciences Education, 14, ar38.

Hatfull, G.F. (2010). Bacteriophage research: Gateway to learning science. Students in the phage hunters integrating research and education program learn about science by doing research on phages. Microbe Magazine, 5, 243–50.

Hazari, Z., Sadler, P.M. & Sonnert, G. (2021). The science identity of college students: Exploring the intersection of gender, race, and ethnicity. Journal of College Science Teaching, 42, 82–91.

Hoskins, S.G., Lopatto, D. & Stevens, L.M. (2011). The C.R.E.A.T.E. approach to primary literature shifts undergraduates’ self-assessed ability to read and analyze journal articles, attitudes about science, and epistemological beliefs. CBE—Life Sciences Education, 10, 368–78.

Hoskins, S.G., Stevens, L.M. & Nehm, R.H. (2007). Selective use of the primary literature transforms the classroom into a virtual laboratory. Genetics, 176, 1381–89.
Kararo, M. & McCartney, M. (2019). Annotated primary scientific literature: A pedagogical tool for undergraduate courses. *PLOS Biology, 17*, e3000103.

Kenyon, K.L., Onorato, M.E., Gottesman, A.J., Hoque, J. & Hoskins, S.G. (2016). Testing CREATE at community colleges: An examination of faculty perspectives and diverse student gains. *CBE—Life Sciences Education, 15*, ar8.

Kim, A.Y. & Sinatra, G.M. (2018). Science identity development: An interactionist approach. *International Journal of STEM Education, 5*, 51.

Kozerski, C.A., Carey, M.F., Colicelli, J. & Levis-Fitzgerald, M. (2006). An intensive primary-literature–based teaching program directly benefits undergraduate science majors and facilitates their transition to doctoral programs. *CBE—Life Sciences Education, 5*, 346–47.

Lazzari, M. (2009). Creative use of podcasting in higher education and its effect on competitive agency. *Computers & Education, 52*, 27–34.

Lee, M.J.W., McLoughlin, C. & Chan, A. (2008). Talk the talk: Learner-generated podcasts as catalysts for knowledge creation. *British Journal of Educational Technology, 39*, 501–21.

McCartney, M., Childers, C., Baiduc, R.R., & Barnicle, K. (2018). Annotated primary literature: A professional development opportunity in science communication for graduate students and postdocs. *Journal of Microbiology & Biology Education, 19*, Article 1.

Momsen, J.L., Long, T.M., Wyse, S.A. & Ebert-May, D. (2010). Just the facts? Introductory undergraduate biology courses focus on low-level cognitive skills. *CBE—Life Sciences Education, 9*, 435–40.

Murray, T.A. (2014). Teaching students to read the primary literature using POGIL activities. *Biochemistry and Molecular Biology Education, 42*, 165–73.

Pegrum, M., Bartle, E. & Longnecker, N. (2015). Can creative podcasting promote deep learning? The use of podcasting for learning content in an undergraduate science unit. *British Journal of Educational Technology, 46*, 192–52.

Ritchie, T.S. & McCartney, M. (2019). Providing transferable, professional skills for the next generation of scientific professionals through an outreach opportunity. *Journal of STEM Outreach, 2*, 1–13.

Round, J.E. & Campbell, A.M. (2013). Figure facts: Encouraging undergraduates to take a data-centered approach to reading primary literature. *CBE—Life Sciences Education, 12*, 39–46.

Sandefur, C. & Gordy, C. (2016). Undergraduate journal club as an intervention to improve student development in applying the scientific process. *Journal of College Science Teaching, 45*, https://doi.org/10.2505/4/jcst16_045_04_52.

Sato, B.K., Kadandale, P., He, W., Murata, P.M.N., Latif, Y. & Warschauer, M. (2019). Practice makes pretty good: Assessment of primary literature reading abilities across multiple large-enrollment biology laboratory courses. *CBE—Life Sciences Education, 13*, 677–86.

Starks, H., & Brown Trinidad, S. (2007). Choose your method: A comparison of phenomenology, discourse analysis, and grounded theory. *Qualitative Health Research, 17*, 1372–80.

Stevens, L.M. & Hoskins, S.G. (2014). The CREATE strategy for intensive analysis of primary literature can be used effectively by newly trained faculty to produce multiple gains in diverse students. *CBE—Life Sciences Education, 13*, 224–42.

Van Manen, M. (2016). Researching lived experience: Human science for an action sensitive pedagogy. Routledge.

Weeks, O. & Koptur, S. (2013). Quantifying Biology in the Classroom. Final report to the National Institutes of Health. Florida International University.

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