Tips and Tools

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No Science Fair? No Problem. Engaging Students in Science Communication through Peer Review and Publication in a Remote World

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INTRODUCTION

Since the 1920s, the science fair has become a standard competition in which, in recent years, more than 9 million students participate annually (1, 2). Science fairs not only can support student understanding of experimentation processes but also can help develop key communication skills outlined by the Next Generation Science Standards (NGSS). For example, NGSS expects that students be able to communicate technical information orally, in text, and in graphical format (3). In fact, many teachers and districts view science fairs as an opportunity for students to develop and demonstrate these communication skills (4–6). However, since science fairs have been cancelled or held virtually due to the coronavirus disease 2019 (COVID-19) pandemic, educators are now reenvisioning how they encourage student-driven research projects and scientific communication. Publication in scientific journals offers one alternative possibility for engaging students in the dissemination of their research, in an entirely remote way. Although its use at the high school level is not well known, engaging undergraduates in the primary literature has beneficial outcomes for students, including gaining content knowledge, increasing literacy skills, gaining greater understanding of the nature of science, and generating more positive attitudes toward science and scientists (7). Additional evidence reveals that the act of writing a paper for publication leads to enculturation and increased identity in the STEM community for graduate students (8). These benefits could potentially be achieved at the high school level if students are given the access, opportunity, and support to engage in scientific publication. Free and completely online, the *Journal of Emerging Investigators* (*JEI*) (www.emerginginvestigators.org) is a peer-reviewed science journal dedicated to mentoring and publishing the research of middle school and high school students. Extending what students might learn from a science fair competition, *JEI* provides in-depth mentorship through peer review and editing that allows young scientists to engage in an authentic, but supportive, scientific review process, all through an online platform (9). Each student manuscript receives approximately 20 to 25 h of review and editing, with at least 13 PhD-level scientists involved (Fig. 1). In addition, published *JEI* articles continue to be read on our open-access online journal, with an audience composed primarily of middle school and high school classrooms across the world.

Since March 2020, we have seen substantial growth (a 104% increase, compared to the previous year) in the number of student papers submitted, which we hypothesize is due in part to the cancellation of science fairs. In the fall of 2020, we interviewed several teachers who had mentored students through the publication process; in addition, we analyzed survey data from past student authors. From these conversations and data, we became cognizant of the ways in which teachers, with their students, engage in the construction of the research paper. In general, teachers have taken two distinct approaches. In one approach, which we call the "finale model," teachers mentor the student through the writing of the paper after the student has already completed the research process. In the second approach, which we call the "integrated model," teachers engage students in reading and writing throughout the research process. Both models may result in students submitting a paper to *JEI*. In this article, we describe the two models and resources to help

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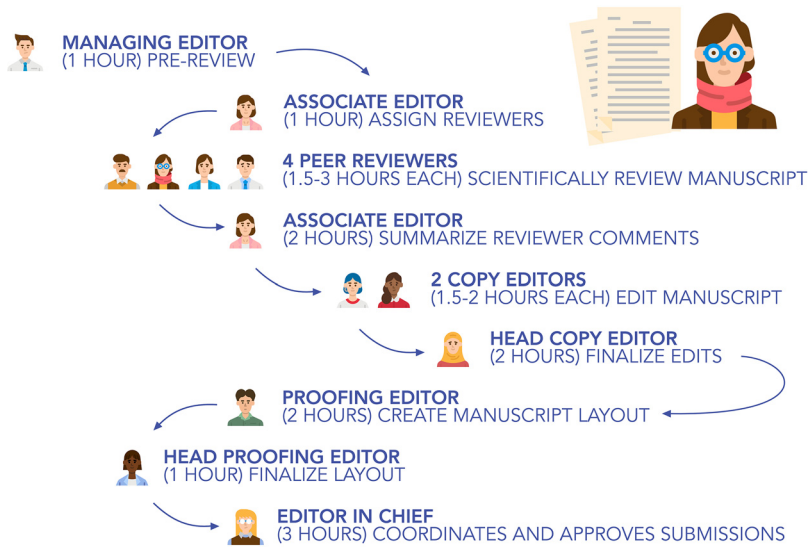

FIG 1. Publication process for *JEI*.

teachers and students successfully navigate the process of writing a primary research paper. We also present evidence that *JEI* student authors found the online resources helpful, that the publishing process helped them think more critically about their science, and that the experience increased their interest and confidence in STEM. In our remote world, *JEI* presents an opportunity for young scientists to participate in a scientific community through a peer review and publication process that reflects the authentic experiences of scientists.

PROCEDURE

Safety issues

The procedure we describe below, specific to reading and writing within the research process, presents no safety concerns. However, instructors may engage students in research projects, outside the scope of our procedure, that may impose safety concerns.

Writing research in the form of a primary paper can be accomplished by students who are currently performing or have completed a research project in any STEM field in the middle school or high school grades. Below, we describe both models of mentoring students through the writing process and provide links to the free resources for students and teachers. We also describe data from a voluntary survey that was sent through SurveyMonkey to student authors who had published a paper with *JEI* between 2018 and 2020, with 60 student respondents. Of the students who responded, 15% were in sixth to eighth grade, and the remaining 85% were in ninth to 12th grade. The survey analysis was approved by the Emory University institutional review board.

Finale model: guides to help guide students and teachers through the writing and submission of their papers

Cognizant that many students and teachers are coming into publication at the end of their research process, we wanted to develop tools to support students and their teachers in the writing of the manuscript. The finale model is appropriate for teachers with students who have a research project completed, or almost completed, and are ready to share that project with a larger audience. In the past, teachers using this model have instructed students to write the manuscript as homework. The *JEI* submission guide (https://emerginginvestigators.org/submissions/guidelines) provides detailed guidelines to help students successfully translate their research into the style of a primary research article. The main requirements for a project include a clearly stated scientific question, experiments in which the student themselves did not know the outcome, and student-derived data. Whereas professional journals evaluate the novelty of the findings and the sophistication of the techniques employed in the study, *JEI* reviews and accepts manuscripts at all levels of sophistication and originality, to encourage submissions from any student engaging in scientific research.

Integrated model: lesson plans and activities that are designed for teachers to incorporate different aspects of the primary literature into the classroom and eventually guide students in writing their own manuscripts

Although our data revealed that many students write their scientific manuscripts at the end of their experimental investigations, several teachers described trying to integrate the

publication process into a course or student research projects. Therefore, to support student publications from the beginning of the research process, the first author developed seven lesson plans for classes of 20 to 24 students, which can be adapted for the audience size or the grade level of the students. While the peer review and publication processes engage students in critical evaluation and communication of their science, these lessons scaffold the communication skills to prepare students for these processes. The activities we describe are most useful for teachers who teach research-based courses or have embedded research experiences. The lessons start by reviewing scientific methodology and then delve into introducing primary literature within that process. Lessons 6 and 7 guide students through the writing and review of their own papers. Reflective activities are provided as bookends for a majority of the lessons, allowing students to focus at the beginning of class and to ground their learning prior to exiting the class. Lessons also include intervention strategies (i.e., group work, organizers, videos, and mentor question-and-answer sessions) to engage all types of learners. The detailed lesson plans are freely available on our website (https://emerginginvestigators.org/classroom_resources), and a more in-depth summary of each lesson plan is described in supplemental material S1.

Peer review and publication

Regardless of which model students and teachers use, we encourage them all to consult the online manuscript guides; these guides cover topics such as author eligibility, animal and human subject research design, manuscript format and content, common mistakes, and review timeline. The review timeline provides information about, and an estimated timetable for, the next steps (including when to expect reviewer feedback, copyedits, and ultimately online publication). The peer review process focuses on the three NGSS practices of obtaining, evaluating, and communicating information (3). Once students submit their papers for publication, each paper is reviewed by three or four graduate students in the field. Graduate student reviewers provide constructive feedback to help students communicate their science more clearly, identify and appropriately use past literature to help support their argumentation, and critically evaluate their results and draw conclusions based on the limitations of their experiments (10). Once a manuscript has completed the review, copyediting, and proofing stages, it is immediately published online and available for the public to read and enjoy (Fig. 1). Since *JEI* papers are published on a rolling basis, new articles are continually available on the website.

Student feedback on the publication experience

We were particularly interested in the following outcomes for students who had published with *JEI*. (i) What were student perceptions of the writing and peer review process? (ii) How do students perceive publication in building their scientific skills? (iii) How do students view the outcome of publication in terms of confidence and interest in STEM? Survey questions and outcomes that address each outcome are found in Table 1.

Given that primary literature is not something that is consistently part of STEM education, we first wanted to assess students' self-reported familiarity with the primary literature. Of the students who responded, only 40% of the students agreed or strongly agreed that they were familiar with the process of writing primary literature before publishing with *JEI*. In the open-ended responses, students noted that the majority of scientific writing they had done was in the form of lab reports, not primary scientific articles; therefore, the majority of students came into the process as novice writers. Although many students expressed a lack of familiarity with writing a primary research paper, 80% of students agreed or strongly agreed that the online guides were helpful in the construction of their papers. Furthermore, 73% of students strongly agreed that the feedback they received from *JEI* reviewers was helpful. Together, student responses suggest that the peer review and publication process is attainable for students and that the online resources are helpful for students navigating the process of writing and revision.

We also asked students about their perceptions of how participating in peer review and publication changed their scientific thinking. Over 96% of students agreed or strongly agreed that going through publication helped them think more carefully about the scientific process; 93% of students agreed or strongly agreed that the feedback from *JEI* reviewers helped them think more critically about their research.

Finally, we wanted to understand how this process could impact student perceptions of their confidence and self-efficacy in STEM. Overwhelmingly, students responded that the publication process made them more confident as scientific writers. Similarly, 90% of students agreed or strongly agreed that this process increased their interest in science. Perhaps most importantly, 96% of students agreed or strongly agreed that this process helped them view themselves as scientists.

While student feedback was overwhelmingly positive, students did provide critical feedback about the publication process. In the open-ended responses in the survey, the most common critical comments were about the length of time required to make it through the entire publication process (which can vary for individual students). Time to publication is a drawback of which teachers and students need to be aware, especially in the planning of projects for which publication takes longer than the academic relationship (for example, if the student is no longer in the course in which the research project originated).

In the future, we will endeavor to continue to work on curricular materials and more rigorously assess how student understanding of peer review and publication, as well as their skills in writing and scientific evaluation, change following the publication process. Finally, a significant question remains: is there a benefit of one model over the other?

TABLE 1
Student author survey statements and outcomes

Outcome	Statement	% of students who agree or strongly agree with the statement	Representative student comments from the survey
Students' perceptions of the writing and peer review process as attainable	Before deciding to write a paper for *JEI*, I was familiar with the process of writing a primary science research paper.	40.0	"As student, I was not familiar but we learn and wrote a research paper for the course we took: Research Methods. This research paper was then formatted to meet *JEI* criteria and was then submitted."
	The *JEI* online guides were helpful during my writing process.	80.0	"Up until now, I had no idea what went into a scientific manuscript. The *JEI* online guides and advice I got from the manuscript revisers really helped me learn how to write one properly. Without them, I would just be extremely lost."
	The resources on *JEI*'s website were sufficient to write a paper according to the guidelines.	81.6	"The guidelines were very easy to understand and outlined all of the necessary parts of the paper. The example paper also helped me understand the guidelines in depth."
	The feedback I received from *JEI* reviewers was helpful.	98.3	"The feedback was really helpful because it helped me improve my writing and there were a lot of nice ideas of how I can improve my research."
	I felt capable of addressing the feedback from the *JEI* reviewers.	96.7	"The feedback was very clear and gave me directions on how to improve my paper without confusion."
Students' perceptions of publication building their scientific skills	The feedback from the *JEI* reviewers helped me think more critically about my research.	93.3	"Words fall short to express my gratitude to the reviewers for their feedback. It was indeed very helpful. Rather, it gave me immense insight about my own study and helped me comprehend my own study better."
	Submitting a paper through *JEI* helped me think more carefully about the scientific process.	96.7	"The words of advice of the reviewers helped me understand the study better and consider those questions I had not even thought of. It gave me an entirely new perspective of approach to a scientific study."
Students' perceptions of confidence and interest in STEM after publication	Submitting a paper through *JEI* helped me become more confident as a scientific writer.	96.7	"*JEI*'s editing process helped me understand what goes into writing a manuscript, therefore helping me understand and read primary papers."
	Going through the process of publishing with *JEI* increased my interest in science.	90.0	"*JEI* experience only enhanced my interest in science and encouraged me to continue my research once in college."
	Going through the process of publishing with *JEI* helped me view myself as a scientist.	96.7	"Before I wrote my paper, I thought mainly of science as doing the research work. *JEI* showed me the importance of quantifying and communicating my research and adding to the common good. I found that I not only love the science research but also found great satisfaction in seeing that my work is contributing to society through publishing and communicating what I have done. I hope that someone else reads my paper and is inspired like I was to try to do their own research project!"

Our survey analysis of students was unable to discern a difference based on the publication model used. However, evidence suggests that integrating writing in the inquiry process can support student understanding of scientific inquiry (11, 12). Thus, our future work will investigate whether the integrated model versus the finale model leads to different outcomes for student learning and communication skills.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 0.1 MB.

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