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Engaging young scholars in science through publication: A survey analysis of published middle and high school authors

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Abstract: Young researchers are often excluded from the scholarly processes of peer-review and publication, which are cornerstones of scholarly work. The *Journal of Emerging Investigators* is an open access journal dedicated to publishing the research of middle and high school students. We surveyed student authors before and after they participated in the peer-review and publication process of their scientific articles. Following peer-review and publication, students report gains in their confidence and self-efficacy in science, and increased feelings of identity and belonging in science. Our findings demonstrate that even the youngest scholars are capable of participating in the publication process, and our data suggest that participation in the process has positive outcomes.

Keywords: STEM disciplinary literacy, peer-review, early career researchers, middle school, high school

INTRODUCTION

The peer-review and publication processes are cornerstones of scholarly knowledge construction and communication (Bornmann, 2015) and the 'lynchpin of academic life' (Eisenhart, 2002). Researchers, academics, and publishing professionals have an advanced understanding of the critical roles that these processes have in the

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refinement and dissemination of scholarly knowledge. Moreover, they understand how peer-review helps ensure research legitimacy and accuracy, and reduce the spread of misinformation (Brown, 2006; Macrina, 2005).

Although peer-review and publication processes are essential to research and other scholarly work, they are rarely explicitly or consistently taught to developing scholars (Early-Career Researchers, 2018; Shanaban & Shanaban, 2012; Yarden et al., 2015; Florence & Yore, 2004). For many early career researchers (ECRs) in the sciences, the first exposure to peer-review often occurs when they receive reviews of the first submitted manuscript, and many ECRs report that they do not receive any explicit training in the peer-review process (Early-Career Researchers, 2018).

This delay, and lack of explicit training, can have detrimental effects on the development of young scholars and the propagation of STEM's 'hidden curriculum' which often disadvantages students of underrepresented backgrounds (Margolis, 2001). The 'hidden curriculum' encompasses the logistics and technicalities of science and science communication, but also includes the unwritten standards and practices that were created by, and benefit, white men. The more exposure a trainee has to the scientific community, the more opportunity they have to learn the standard expectations for behaviour, communication, and success. Just as importantly, the general lack of education on the purpose and process of peer-review and publication may contribute to the public misunderstanding of what constitutes valid scientific knowledge (Braund, 2021; Fasce & Picó, 2019).

The public response to the COVID-19 pandemic has highlighted the divisiveness that can occur when the public has a less-developed understanding of science and its related processes (Braund, 2021). The need to improve the public understanding of science (i.e., science literacy) is evident. Appreciating how scientific knowledge is constructed, validated, and communicated via the peer-review literature is essential to the development of science literacy. Providing explicit instruction about these processes during the formative school years may give students the skills to differentiate accurate from inaccurate information about science-based topics leading to a more science literate population as they carry these skills forward into adulthood.

Beyond educating the general public, it is imperative that young (pre-college) and early career (college and beyond) researchers understand and participate in the practices required by their target professions. Neglecting scientific process-related peer-review and publication, an integral part of conducting science, can result in misconceptions about how scientists engage in their work. Scientists spend approximately 60% of their time communicating (mostly reading and contributing to primary literature), but these activities are not included in the suggested high school-level science curricula in the United States (NGSS Lead States, 2013; Tenopir & King, 2003). It is illogical to expect adults to understand the scientific process and the work of scientists when a key piece of the process is generally absent from their course of study as students (Lederman et al., 2013).

Key points

- Middle and high school students are capable of participating in the peer-review and publication of their science research articles.
- Students who publish their papers in the *Journal of Emerging Investigators* report increased self-efficacy, confidence and scholarly identity.
- More effort should be made to increase young and early career researchers in peer-review and publication.

There is a growing body of evidence that shows that engaging ECRs in the peer-review process and manuscript revision has positive impacts. For example, participation in writing, revision, and peer-review provides a scaffold for learning how to communicate in a way aligned with disciplinary norms (Walker & Sampson, 2013). Furthermore, by engaging in the publication process, ECRs experience the nuances of research practices that reflect the experience of professional scientists. Experiencing these nuances of research through participation in the scientific manuscript writing and publishing process has been shown to enculturate ECRs into the research community (Florence & Yore, 2004). We believe these benefits can be achieved at the pre-college level if students are provided appropriate support and opportunities, thus better preparing students for academic trajectories.

Given that there are journals dedicated to young scholars (e.g., undergraduate journals) (Spronken-Smith et al., 2013; Weiner & Watkinson, 2014), we can now begin to examine the effects of participation in peer-review and publication on young and early career researchers. In this study, we examined the experience of middle and high school students who published results of scientific research in the nonprofit, open access *Journal of Emerging Investigators* (JEI). The JEI process guides students through the peer-review and publication process of their own scientific research. Its academic journal structure promotes scientific learning by providing a platform for middle and high school students (11–18 year old students) to engage with the scientific community through the peer-review process. The mission statement reflects these core principles by 'providing the tools, mentorship, and community necessary for any middle or high school student to publish research', and 'recognizing students' potential as scientists early in their academic careers' (Home Page: Journal of Emerging Investigators, 2022). Until this study, the efficacy of the JEI team's efforts to achieve this mission was unknown.

Since JEI's inception in 2011, the numbers of submitted manuscripts have increased exponentially each year. As of December 2021, JEI has published over 500 student articles, with 153 articles published in 2021. Originally, JEI's scope was limited to the biological sciences, but it now includes any hypothesis-driven research (e.g., mathematics to computer science to social sciences). The increase in scope has allowed over 1,000 students to

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test a hypothesis, present the results in written form, and critically examine the manuscript with assistance from volunteer editors and reviewers. Student authors come from around the world, but the majority are from United States-based students. Student authors typically do their scientific research under the guidance of a teacher, parent, or professional scientist, and the majority indicate that their project is affiliated with a school programme, but the research is primarily performed at home (such as through science fair or science competition). Some students have remarked that their research was inspired by their own interests or observations, and they pursued a project independent of their school (Fankhauser et al., 2021).

Volunteer graduate students, postdoctoral fellows, and professionals in various fields of study, primarily from the United States, serve as reviewers for the submitted JEI manuscripts. Volunteers are recruited through a combination of word of mouth and emails campaigns sent to offices of professional development, programme directors and/or assistants, and student organizations at universities across the United States. Volunteers are provided with a training video and must pass a quiz on their role and responsibility as a reviewer in order to review any manuscripts. All reviewers have access to the JEI Handbook (Appendix S1), which outlines their expectations and provides guidelines for reviewing and making decisions on manuscripts and is specific to each role. These guidelines include emphasis on writing supportive and positive reviews in order to encourage young authors to continue in their pursuit of science. A comprehensive explanation of the editorial and reviewer training is described in Otero et al. (2022).

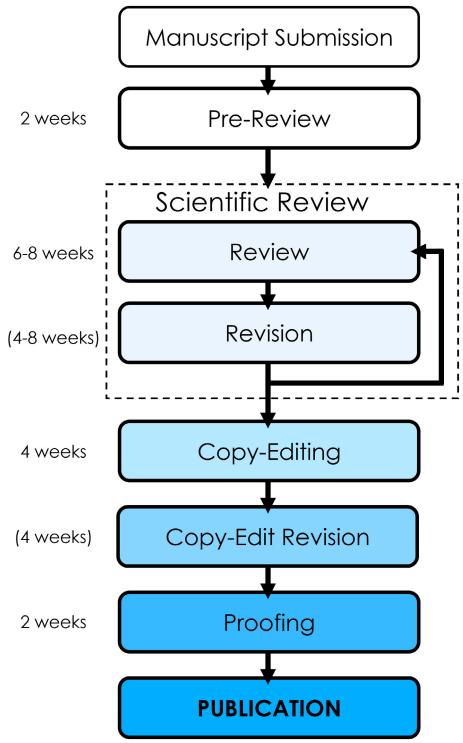


FIGURE 1 Workflow of the review process for manuscripts submitted to *Journal of Emerging Investigators* (JEI). JEI editors and reviewers are volunteer experts in a variety of STEM fields.

The submission to publication process of JEI reflects the standard practices of most academic publishing companies (e.g., use of the online portal: Editorial Manager to direct peer-review, copy-editing, proof editing, and publication of the articlel Fig. 1). Given the young age of our authors, JEI differs from standard publication and editorial practices in that it includes an in-depth supportive review process that often involves links to useful online learning tools, proposed re-writes, and discussion topics with mentors. Suggestions for improvement may include lessons on statistics, restructuring the narrative form, precise conclusion development, and examination of the best presentation style and structure for the manuscript (an example editorial letter is provided in Appendix S2). Due to the age range of JEI authors, JEI does not reject papers based on the level of sophistication of the writing, but only rejects papers where plagiarism or ethical issues are evident and too pervasive to fix without submission of a brand new manuscript.

The positive effects of engaging ECRs in publication are evident, and we predict that these same benefits will be experienced by younger authors as well (Seymour et al., 2004; Stone et al., 2016; Tatalovic, 2008; Walker & Sampson, 2013; Walkington, 2012). The expansion of JEI created the opportunity to track authors more thoroughly through the publication process and to better understand who our authors are, what they are learning, and how they perceive the publication process. In this study, we focused on three categories of outcomes: students' self-efficacy (i.e., the ability to accomplish tasks independently) and confidence, identity and belonging in science, technology, engineering, and mathematics (STEM) fields, and perceptions of the peer-review and publication processes. These factors are primary determinants of retention in STEM fields, especially for groups who have not been traditionally represented in academia (Chemmers et al., 2011; Lederman et al., 2013). We found that the students thought the peer-review process improved their writing and understood why changes were useful. We also found that following the peer-review process students were more likely to identify as scientists and scientific thinkers. Although the results are specific to pre-college students, they reveal the value of early participation in the peer-review and publication process.

METHODS

Survey development

During the summer months of 2020, we developed a set of pre- and post-surveys to assess JEI student-author outcomes. These surveys addressed student author self-efficacy and confidence, and identity and belonging in STEM fields. Table 1 presents survey questions and scales, and sources used for the survey and analysis. Additional questions were included that asked about the academic setting, demographic characteristics, and opinions

TABLE 1 Survey questions that assessed specific research questions.

Research question	Survey questions	Scale	Source
Confidence and self-efficacy	I am confident that I can generate a research question to answer.	1–5 from 'strongly disagree' to 'strongly agree'	Persistence in the Sciences (Hanauer et al., 2016)
	I am confident that I can figure out what data/observations to collect for a research project.		
	I am confident that I can use scientific literature and reports to guide my research.		
	I am confident that I can create explanations for the results of my science.		
	The writing process was challenging for me.		Created by the authors
	I am confident as a scientific writer.		
Identity and belonging in STEM	A person who thinks discussing new theories and ideas between scientists is important.[a]	1–6 from 'not like me at all' to 'very much like me'	Persistence in the Sciences (Hanauer et al., 2016)
	A person who thinks it is valuable to conduct research that builds the world's scientific knowledge.		
	A person who thinks that scientific research can solve many of today's world challenges.		
	A person who feels discovering something new in the sciences is thrilling.		
	I have a strong sense of belonging to the community of scientists.	1–5 from 'strongly disagree' to 'strongly agree'	
	I have come to think of myself as a scientist.		
	I feel like I belong in the field of science.		

about the peer-review process. The study was approved by the Emory University Institutional Review Board.

Survey administration

Both surveys were administered using the Qualtrics survey tool. Every student submitted a manuscript to the JEI from November 2020 to November 2021,received an email invitation to complete the pre-survey. Survey completion was voluntary and had no effect on the manuscript review process or outcome. At the time of submission, 125 students had submitted the pre-survey, from a population of approximately 700 student authors. This represents an 18% response rate to the pre-survey. However, not all student authors on a paper provide their email address. Once student papers completed the peer-review and copy-editing processes, the students were sent the final manuscript proofs. The final proofs included a request to voluntarily complete the post-survey; 103 students submitted the post-survey from approximately 300 student authors contacted, representing a 34% response rate. All students who submitted a survey were eligible to receive a $5 Amazon gift card by completing a Google-based form. The survey responses were anonymous and unmatched and therefore we are unable to determine which students completed both surveys.

Statistical analysis

Analysis of the surveys was performed using the Statistical Package for the Social Sciences (SPSS). Vectors were created using the survey items related to each research construct (Table 1). We converted the Likert scale responses to a numeric scale, from which we calculated the mean values for each group of pre- and post-survey questions, and only responses were included from individuals who answered all questions. We report the means calculated out of the total possible value for the group of questions. We performed *t*-tests of the means to test for significant

differences between the pre- and post-survey answers for each vector. We used Cronbach's alpha values to assess the reliability of each vector.

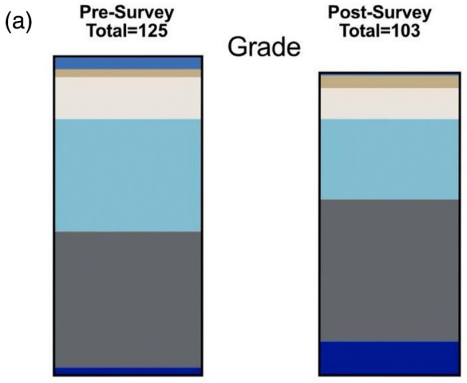
Spearman's rank correlation was performed for select questions to identify potential correlations in responses.

RESULTS

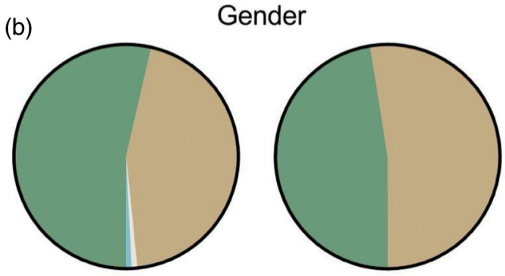
The survey analysis examined student perceptions of the writing process before publication (pre-survey questions), changes in student self-efficacy and confidence after peer-review (pre- and post-survey comparative analysis), changes in student identity and belonging after peer-review (pre- and post-survey comparative analysis), and student perceptions of the peer-review process (post-survey questions).

Participants

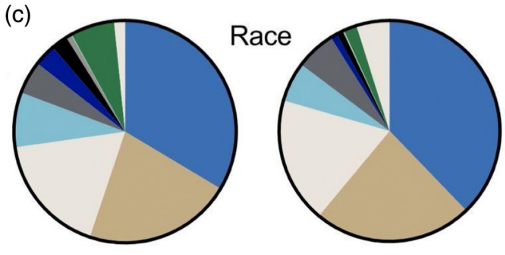
Within the study period (November 2020–November 2021), the majority of papers were submitted by authors from the United States (73.4% of submitted papers and 79.5% of published papers); of the US-based papers submitted, 25% came from students residing in the state of California. Approximately 20% of the papers came from authors who reside in an Asian country. Of the students who responded the survey, the participants ranged from the eighth grade (about 14 years old) through college students (Fig. 2a). A prerequisite for submission to JEI is that the students not yet be enrolled in college, indicating that those who selected 'college' had most likely submitted their manuscripts the summer after 12th grade (the final grade before college in the US system) and survey collection was completed after matriculation in college. 80% of the respondents indicated that they were in the 11th grade or



	Pre-Survey	Post-Survey
8th grade	4.10%	1.02%
9th grade	2.46%	4.08%
10th grade	13.11%	10.20%
11th grade	35.25%	26.53%
12th grade	42.62%	46.94%
College	2.46%	11.22%



	Pre-Survey	Post-Survey
Female	53.60%	47.52%
Male	44.80%	52.48%
Prefer not to answer	0.80%	0.00%
Prefer to self-describe	0.80%	0.00%



	Pre-Survey	Post-Survey
South Asian or Indian	33.60%	37.86%
East Asian	21.60%	23.30%
White	17.60%	18.45%
Southeast Asian	8.00%	5.83%
Latinx	4.80%	5.83%
Black or African American	3.20%	0.97%
Middle Eastern	2.40%	0.97%
American Indian or Alaska Native	0.80%	0.00%
Native Hawaiian or Pacific Islander	0.00%	0.00%
Other	6.40%	1.94%
Prefer not to answer	1.60%	4.85%

FIGURE 2 Demographic information of student respondents to pre- and post- surveys. (a) The grade level of students; (b) The self-reported gender of the students; (c) The self-reported race of the students.

higher suggesting JEI is mostly serving students in late high school. In fact, though JEI is aimed at both middle school and high school students, less than 5% of surveyed respondents indicated that they were currently enrolled in middle school (6th–8th grade, 11–14 years old).

Gender disparities do not seem to be evidenced in our outcomes as authors identifying as female consisted of 53% and 47% of respondents pre- and post-survey, respectively (Fig. 2b). However, there do appear to be racial disparities as 63% of respondents are of Asian descent while only 3% of respondents are of Black or African American heritage and 5% are of Latinx heritage (Fig. 2c). These are noteworthy as 77% of our authors live in the United States, which has a demographic makeup of 6% Asian, 12% Black, 19% Hispanic or Latinx (Explore Census Data, 2022). While there is a sizable group of international student authors from Asian countries (16% of all submissions), it is important to note that students identifying as Black and Latinx are underrepresented. These groups are traditionally underrepresented in STEM and efforts must be redoubled to ensure that these groups receive early exposure to promote a sense of belongingness in these fields.

Initial perceptions of the writing process

The pre-survey asked students about their level of familiarity with science writing and its challenges to better understand student preparation and understanding about the writing process. In response to the question 'Before deciding to write a paper for the JEI I was familiar with the process of writing a primary science research paper', 29.09% of students responded 'strongly disagree' or 'disagree', 54.54% of students responded 'agree' or 'strongly agree', and 16.36% responded 'neither agree nor disagree' (Fig. 3). In response to the statement, 'The writing process was challenging for me', 49.09% of students responded 'agree' or 'strongly agree' and 25.46% responded 'strongly disagree' or 'disagree'. Although 54.54% of students reported being familiar with writing a primary research paper, responses to an open-ended question 'describe (if applicable) your experience with the primary literature' indicated that many students did not have prior experience with the primary literature. Most students noted that their previous scientific writing experience was in the form of laboratory class reports, or papers associated with a science competition (see Appendix S3 which provides answers to the open-ended questions of our survey). Spearman's rank correlation was computed to assess the relationship between familiarity with the scientific writing process and perceived challenge of the writing process. There was no significant correlation between students who indicated familiarity with the process of writing a primary science research paper and students who found the writing process challenging ($r(110) = 0.017$, $p = 0.863$). However, the Spearman's correlation test did indicate a positive correlation between confidence as a writer and familiarity with the process of writing a primary science research paper ($r(110) = 0.338$, $p = <0.001$), indicating previous experience slightly predicts confidence as a writer, but not whether or not the writing process was challenging. Taken together, the students' responses to these questions indicated they pursued publication with a mix of perceived abilities and understanding about the writing process associated with a professional-level manuscript.

Confidence and self-efficacy

We asked a series of pre- and post-survey questions to assess potential changes in student confidence and self-efficacy after peer-review. The mean values for the responses to each question were summed and Cronbach's alpha was calculated to determine the relatedness of the questions (Table 2). Compared with the pre-survey, there was a significant increase in the mean value in the post-survey for the six questions that asked about student confidence and self-efficacy ($p < 0.05$), indicating that after the peer-review process the students expressed greater confidence and self-efficacy. This result suggested that the peer-review process can help students develop these qualities. Although a greater

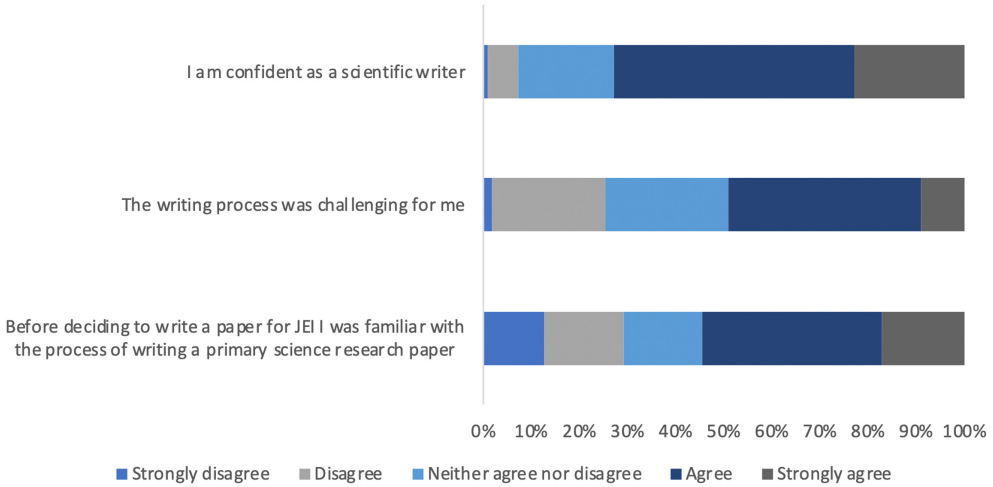


FIGURE 3 Student perceptions of the writing process from the *Journal of Emerging Investigators* student author pre-survey ($n = 110$).

TABLE 2 Analysis of primary factors from student-author pre- and post-surveys.

Factors and associated questions	Mean pre-survey	Mean post-survey	Cronbach's alpha	Bonferroni adjusted *p* value
Confidence and self-efficacy[a]	24.47 (out of 30)	25.42 (out of 30)	0.786	0.033
I am confident that I can generate a research question to answer	4.31	4.34		
I am confident that I can figure out what data/observations to collect for a research project	4.28	4.47		
I am confident that I can create explanations for the results of my science	4.28	4.39		
I am confident that I can use scientific literature and reports to guide my research	4.33	4.42		
I am confident as a scientific writer	3.87	4.07		
The writing process was challenging for me	3.31	3.57		
Identity and Belonging	33.27 (out of 39)	34.64 (out of 39)	0.851	0.017
A person who thinks discussing new theories and ideas between scientists is important[b]	5.15	5.33		
A person who thinks it is valuable to conduct research that builds the world's scientific knowledge[b]	5.33	5.60		
A person who thinks that scientific research can solve many of today's world challenges[b]	5.37	5.62		
A person who feels discovering something new in the sciences is thrilling[b]	5.41	5.63		
I have a strong sense of belonging to the community of scientists[a]	3.91	4.13		
I have come to think of myself as a scientist[a]	3.88	3.93		
I feel like I belong in the field of science[a]				

[a] Scale for questions was 1–5 from 'strongly disagree' to 'strongly agree'. $N = 110$ for pre-survey, $N = 93$ for post-survey. Individual question means are shown next to each question.
[b] Scale for questions was 1–6, from 'not like me at all' to 'very much like me'.

proportion of students expressed that the writing process was more challenging for them in the post-survey than in the pre-survey, in the post-survey, more students expressed greater confidence in their writing and research skills (Table 2). Student comments in the open-response portion of the survey supported this result. For example, one student responded that the process '… made me feel more confident in my abilities as a researcher' (Table 3).

Identity and belonging

Writing a manuscript for publication can enculturate more advanced scholars in the field (Florence & Yore, 2004; Walkington, 2012). Therefore, we investigated JEI student authors' perceptions of belongingness to the scientific community by asking seven questions: five about how students identified with the characteristics of a scientist and two questions about their sense of belonging to the scientific community. Among these seven questions, there was a significant increase in the mean responses in the post-survey (33.27 in the pre-survey, compared with 34.64 in the post-survey; $p < 0.05$). Open-ended responses also reflect a sense of identity and belonging as students expressed validation and pride from their experience (Table 3).

Perceptions of the peer-review process (post-survey)

Students reported that their first experience with peer-review was through JEI. Therefore, we wanted to understand their general perceptions of the process. Most students reported making substantial changes to their manuscripts following the peer-review feedback, and after the copy-editing stage (Fig. 4). In response to the open-ended question, 'Please provide any additional thoughts or comments on the peer-review and publication process that you experienced', a few students mentioned the length of the process and/or the many stages of revision (Table 3, Appendix S3). One student noted, 'I learned that the

TABLE 3 Examples of responses to the post-survey open-ended question: 'Please provide additional thoughts or comments on the peer-review and publication process that you experienced'.

Applicable research question	Example student comments
Confidence and self-efficacy	I loved the process of peer-review! It allowed me to understand what other members of the scientific community had to say about my research, and it made me feel more confident in my abilities as a researcher. I deeply enjoyed correspondence during the publication process and will use the feedback to improve my future research papers. I think that the peer-review and publication process helped me improve my manuscript and appreciate the scientific process. I gained a deeper respect for scientists and became more confident in my abilities to follow a project through to completion.
Identity and belonging	I am more proud of my work now that it means something in the scientific world. I feel accomplished and recognized. The comments that I received were so positive that they always motivated me to keep on with the research. It was helpful in understanding that other scientists see my work as valuable.
Perceptions of the peer-review process	JEI Peer-review made me think in dimensions which were perhaps missed or biased from my side. I found it exciting to find answers to questions raised by peer-reviewers. It was very insightful to receive feedback from qualified scientists and not only improved my manuscript, but also taught me skills that are necessary for future research. Peer-review motivated me more than you can imagine.

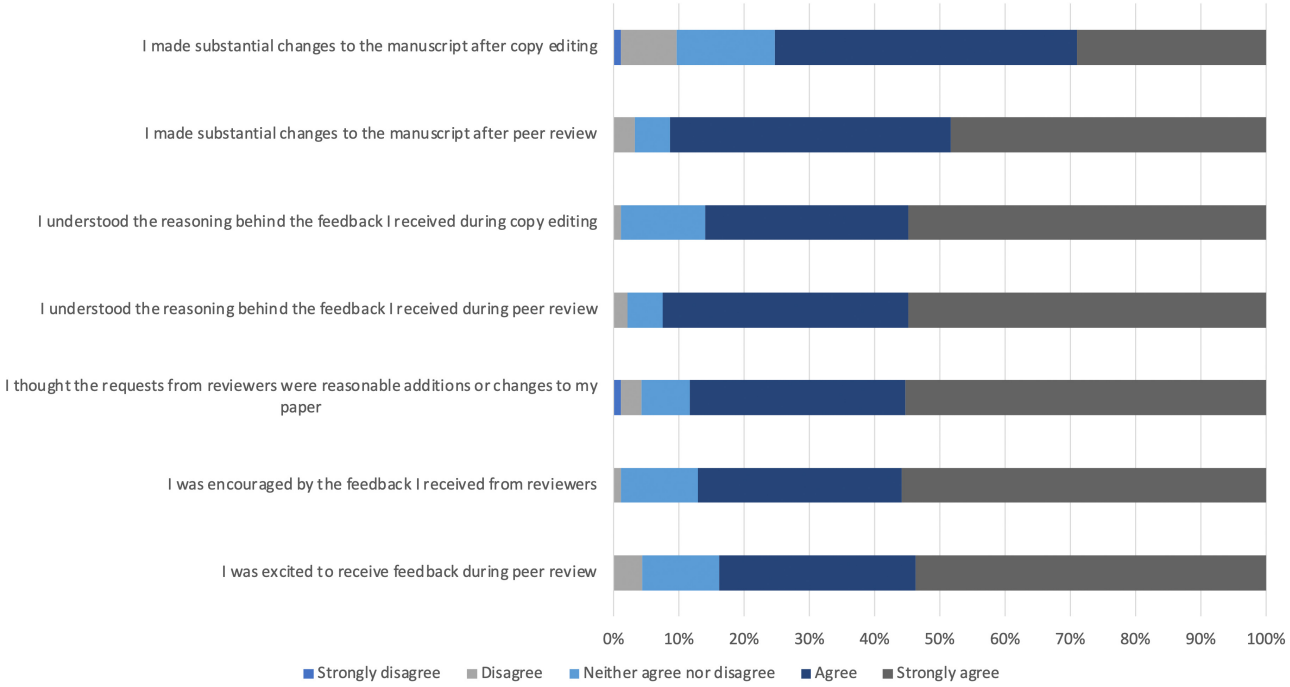


FIGURE 4 Student perceptions of the peer-review process, post-survey results ($n = 93$).

process of publishing a paper is very long (the whole process took nearly a year since the first submission)'. Although most students reported making substantial manuscript revisions, the responses about the peer-review process were generally positive. Most students reported that they were excited to receive, and were encouraged by, the peer-review feedback (Fig. 4). The comments from the open-ended response question were consistent with these results. Many students commented that the peer-review feedback helped improve their manuscripts. Students also connected the peer-review feedback to feelings of accomplishment, confidence, and value (Table 3). These comments further supported the survey results indicating that the students expressed greater self-efficacy, confidence, and identity in STEM fields after experience with the peer-review process.

DISCUSSION

This study assessed the effect of early exposure to scientific publication processes on young researcher's perceptions of peer review and their own development as scientists. By collecting and examining survey responses from student authors at the beginning of the peer-review process with JEI and again after publication, we revealed three main findings:

1. The students began manuscript preparation and the submission process as novice writers. By experiencing a rigorous peer-review and publication process involving iterative manuscript revisions over time, the students created a final product in which they expressed pride.
2. The students expressed increased confidence, self-efficacy, and identity and belonging in STEM fields after the publication process.
3. The results of this study suggest that young scholars can participate in a scholarly field by engaging in the peer-review and publication process, even if they did not initially identify as exceptional writers or scholars.

Participating in authentic communication

Many middle and high school students are not exposed to explicit instruction and participation in the primary literature (Bell et al., 2012; Chiappetta & Fillman, 2007; Phillips & Norris, 2009; Yarden et al., 2015). This is due to many reasons, including the lack of classroom time, appropriate resources, and support to appropriately prepare teachers to use the primary literature (Moje, 2008; O'Brien et al., 1995; Pearson et al., 2010). Although many students (54.54%) who submitted papers to JEI indicated familiarity with primary scientific literature, their open-ended responses revealed that their perceived familiarity may be overstated. Indeed, the open-ended responses demonstrated that students equated primary papers to classroom lab reports or science competition papers, which is consistent with past research (Bell et al., 2012; Fankhauser et al., 2021). These findings suggest that students have an initial misconception about the nature of primary literature, which may be due to the lack of explicit instruction and participation in the primary literature noted above. Although students entered the publication process as novice writers, they are able to produce a sophisticated and authentic product following the JEI publication process. While students noted frustration with the tediousness of revisions, they ultimately described the process as helpful and expressed pride in their final product. Our findings demonstrate that even novice scholars can engage in a process that is usually reserved for more advanced scholars. Thus, more opportunities to engage in authentic communication practices should be provided to students, and these opportunities may help unveil misconceptions about the primary literature and the role of the primary literature within scholarship.

Engaging in a community of scientists

Past work has shown a mix of attitudes towards the peer-review process with critics labelling the process as biased, exclusive, non-transparent, and fostering a gatekeeping environment (Atkinson, 1994; Benos et al., 2007; Bornmann, 2015; Eisenhart, 2002; Lăzăroiu, 2019; Schnell, 2018). The JEI peer-review process serves as an opportunity for student authors to meaningfully engage with scientists in their field of study on the topic of their hypothesis-driven research. For all students surveyed, this is the first time that they have participated in this type of process and likely the first time they have received individual and detailed scientific feedback from a community of science professionals. Our results show that although students entered into the process as novices, and noted that the peer-review process was time-consuming, it is clear that students emerge from the publication process with a greater sense of ability. Similarly, students also report increases in identity and belonging in the field of STEM following the publication process. Although we cannot fully attribute these changes to the peer-review process, the students' comments suggest that engaging with the peer-reviewers contributed to these results. Indeed, others have shown similar results with more advanced scholars (Florence & Yore, 2004; Spronken-Smith et al., 2013; Weiner & Watkinson, 2014).

Increasing participation in the publication process

While our results are specific to STEM, we contend that they demonstrate the ability to develop academic identity and belonging in young scholars in many different fields through participation in the processes of peer review and publication. Moreover, JEI is operated by ECRs from across the United States, and our past research has shown that involving ECRs in the review and editorial processes can improve communication, experimental design, and career skills (Johnson & Fankhauser, 2018). Thus, along with our past study, we demonstrate that even the youngest scholars are capable of understanding and participating in a process that has been generally reserved for more advanced scholars. Feelings of identity and belonging are directly connected to retention in STEM (Carpi et al., 2016; Robnett et al., 2015), and thus our results suggest that including young and early career researchers in the cornerstone process of their academic field could have significant and long-term impacts in terms of recruitment and retention of students in academic studies. We provide the following recommendations to publishers to increase inclusion in publication:

1. Provide educational material aimed at teachers and young scholars to help unveil the peer-review and publication processes.
2. Increase young investigator journal issues that are dedicated to publishing the work of young scholars.
3. Evaluate peer-review processes to ensure that peer-reviewers and editors offer constructive and supportive feedback that will not deter young scholars from the field.

JEI currently engages in the above points. For example, JEI provides a variety of resources to help teachers engage their middle and high school students in the publication process which include exercises based on previous JEI publications as well as links to outside resources for students and teachers. JEI also serves as a space where the earliest-career scholars can publish and read the work of their immediate peers. Finally, JEI has instituted resources to support reviewers and editors by providing training for new volunteers that emphasizes providing

constructive and supportive feedback across all manuscripts. JEI is not alone in these endeavours. Other organizations, such as PreReview and the Genetics Society of America, are also providing opportunities for ECRs to participate and receive training in the peer-review process. The positive outcomes of engaging young scholars in the publication process that we, and others, have observed suggest that including and supporting ECRs in this aspect of scientific discovery can be accomplished through increased and earlier access to education and opportunities.

Limitations to our study

While our results show largely positive outcomes of exposing grade school students to scholarly publication, there are limitations to our study. First, we noted a high level of representation from student authors of Asian descent. During the study period, about 20% of manuscripts submitted to JEI came from California which has a large population of people of Asian descent. Another ~20% of submitted manuscripts came from countries in Asia. While we do not have information regarding the demographic breakdown of all submissions, these manuscript origins may explain at least some of the overrepresentation we see from Asian populations in our survey results. Second, because the post-survey was only administered to students who completed the publication process after receiving rounds of reviewer feedback, we may have inadvertently selected for exceptionally motivated or well-supported students. It remains possible that students who do not resubmit a revised manuscript may not see the value of spending their time on revisions, particularly if the revisions were substantial. These students may have different perceptions of the feedback received from the peer-review process.

However, even without the act of revision, experiencing the peer-review process could be an important learning opportunity and community-engagement experience for students. Therefore, evaluating the impact of peer-review independent of revision will provide new insight into how the benefits of peer-review can be provided to a larger and more diverse student population at earlier opportunities than previously attempted. Through such opportunities, students can gain the experience of engaging with their peers and acquire tools to better understand the scientific process while increasing their senses of confidence and belonging in the STEM community. Ultimately, our findings suggest that instituting a supportive peer-review and publication process can contribute to the development of young scholars by increasing their sense of inclusion in the scholarly community and fostering an understanding of research as a social enterprise.

AUTHOR CONTRIBUTIONS

Sarah C. Fankhauser conceived the project, developed methodology, analysed data, and contributed to writing the article. Kari A. Mattison, Scott T. Wieman, Stephanie Zimmer, contributed to methodology, analysis, and writing the article. Andrea R. Merchak contributed to methodology, figures, analysis, and writing the article.

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CONFLICT OF INTEREST

Andrea R. Merchak, Stephanie Zimmer, Scott T. Wieman serve as Editors of the Journal of Emerging Investigators, they receive no compensation for their service. Sarah C. Fankhauser serves as the chair of the Board of Directors of the Journal of Emerging Investigators and receives no compensation for her service. Kari A. Mattison serves as the Editor-in-Chief of the Journal of Emerging Investigators and receives compensation for her role.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Appendix S1 JEI Editor Handbook

Appendix S2 Example Editorial Letter to Student Author. Identifying information has been removed.

Appendix S3 Supporting Information

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