Title: Writing for identity? Exploring the motivation of pre-college students to participate in science publication

Abstract:
Over the years, a growing number of students have been participating in research experiences with some seizing the opportunity to further their learning through publication. Scientific publication represents a pinnacle of professional communication in science. While traditional pre-college science classrooms and research programs offer various outlets for scientific communication through lab reports and presentations, access to publication, in particular, remains largely out of reach for these students. Yet, this landscape is beginning to shift as an emerging cohort of young researchers challenge this barrier and choose to extend their research experiences by publishing their work in peer-reviewed journals specifically for pre-college students. Given the rigorous nature of scientific publication, our study investigates why pre-college students voluntarily undertake this challenge, revealing important insights about student motivation and identity development in science. Through analysis of survey responses from student authors using the lens of science identity theory, we discovered that students view publication not merely to share results, but as a transformative process that validates their role in the scientific community. Female students in particular emphasized publication as a pathway to gain recognition as scientists and develop professional writing skills. These findings challenge traditional assumptions about pre-college science communication. They suggest that access to authentic publication opportunities through outreach programs may be a powerful, yet underutilized tool for fostering science identity and expanding participation in STEM fields. Our research provides critical insights for educators and policymakers seeking to create more inclusive and empowering pathways into science careers.

Keywords: science identity, science writing, motivation, disciplinary literacy, science communication

Introduction:
Ten years have passed since the Next Generation Science Standards (NGSS) were released and set the framework of practices meant to prepare students in their 21st century skills and understanding of science (NGSS Lead States, 2013). NGSS emphasizes engaging students in authentic *practices* that help students develop their scientific literacy and transfer skills across disciplines. The eight practices articulated in the Next Generation Science Standards have become key components to science curriculum for the K-12 classrooms. Among these practices, Communicating Information (Practice 8) stands out as particularly crucial, not just for developing scientific understanding, but for fostering scientific identity and inclusion in the broader science community (Kelp et al., 2024).

In a typical out-of-class research experience, communication outputs may be operationalized through lab reports, posters, reflective writing, research proposals, etc. (Jacquez et al., 2020; Baker et al., 2009; Vries et al., 2019; Watts-Taffe et al., 2022). However, a growing number of students are engaging in more complex and professional communication endeavors, including scientific publication. This shift toward authentic scientific communication practices aligns with the goals of STEM outreach programs, which seek to expand access to hands-on research experiences and provide students with platforms to contribute to existing scientific dialogue (Tillinghast et al., 2020). The Journal of Emerging Investigators (JEI) is one such initiative that serves as both a peer review and publication venue and a structured program of STEM outreach, allowing pre-college students to experience all components of the research process. Participation in publishing through JEI represents more than just skill development – it embodies what Correll and Twomey (2018) describe as "scholarship as conversation," where students begin to see themselves as active participants in scientific discourse rather than passive recipients of knowledge.

Over the years, there has been a rise in venues for high school students to submit their research papers, receive peer-reviewed feedback, and publish on platforms designed specifically for the high school science student (Fankhauser & Lijek, 2016; Mattison et al., 2022). The opportunity to write a research paper and experience the peer-review and publication processes may provide students with the chance to integrate several NGSS practices (Fankhauser & Lijek, 2016). Moreover, recent research suggests that engagement in scientific communication activities can significantly predict students' science identity and research career intentions (Cameron et al., 2020). This relationship between communication and identity is particularly important for fostering diversity in STEM fields, as students from underrepresented groups often benefit from opportunities to receive social recognition for their scientific work (Jackson et al., 2019). By participating in STEM outreach programs, like JEI, students are able to gain early access to the often-hidden disciplinary literacy skills used in scientific research. They can experience the process of authentic peer review and publication which play key roles in scientific identity development and consequently long-term trajectories in STEM (Dabney et al., 2012; Deemer et al., 2022; Vennix et al., 2018).

Program Overview: Journal of Emerging Investigators (JEI)

The Journal of Emerging Investigators provides middle and high school students an authentic introduction to scientific publication through a supportive, scaffolded peer review process. Founded in 2011 as an open-access journal, JEI has grown from publishing exclusively biological sciences to now accepting hypothesis-driven research across all STEM fields. The journal's mission centers on making scholarly publication accessible to young scientists by providing necessary tools, mentorship, and community support.

Students typically conduct their research through school programs, science fairs, independent projects, or other out-of-school experiences under the guidance of teachers, parents, or professional scientists. When ready to publish, students prepare manuscripts following standard scientific article formatting, including introduction, methods, results, and discussion sections. The journal provides extensive guides and models through their website to help students navigate this process.
Upon submission, manuscripts undergo a structured review process designed to mirror professional academic publishing while maintaining appropriate support for young authors. Papers first go through pre-review to ensure basic components are present. Then, each manuscript is assigned to 3-4 expert reviewers, typically graduate students, who provide detailed feedback on both scientific content and communication. Reviewers, who must complete training and pass a qualification quiz, are instructed to offer constructive, supportive feedback rather than pure criticism. This approach helps students learn from the process rather than feeling discouraged.

The revision process forms the heart of the learning experience. An editor synthesizes reviewer feedback into a comprehensive editorial letter, guiding students through needed improvements. Students typically go through multiple rounds of revision, receiving ongoing support and guidance. Rather than rejecting papers (except in cases of plagiarism or ethical issues), the process focuses on helping students develop their work to meet publication standards. Once the scientific content meets requirements, manuscripts move to copyediting and final proofing.

This comprehensive approach has yielded impressive results. As of 2024, JEI has published over 1000 student articles. More importantly, research shows that participating students demonstrate increased confidence in scientific writing and stronger science identity (Fankhauser et al., 2021; Mattison et al., 2022). The journal manages this substantial workflow through an online submission portal while maintaining high standards through a network of volunteer graduate students, postdocs, and professionals who serve as reviewers (Fankhauser & Lijek, 2016).

To support broader implementation, JEI provides resources to help teachers integrate publication into their science curriculum (Rodriguez et al., 2022). This creates opportunities for students to engage with professional scientists through the review process, learning firsthand how scientific knowledge is constructed and communicated. By emphasizing learning through revision and scientific discourse rather than gatekeeping, JEI makes scholarly publication accessible to young researchers while maintaining the rigor of the scientific process.

This innovative approach demonstrates how pre-college students can meaningfully participate in scientific publication when given appropriate support and scaffolding. Through careful attention to both process and mentorship, JEI helps develop the next generation of scientists by engaging them in authentic scientific communication early in their academic careers.

Theoretical Framework:
Understanding why pre-college students voluntarily engage in scientific publication requires examining both their motivations and how the publication process shapes their developing scientific identities. While scientists spend a considerable amount of time engaging with scientific literature and communication, these practices are notably absent from pre-college science education. Hence there is a significant gap between classroom science and authentic scientific practice, hinting to the “hidden curriculum” in science. This makes voluntary participation in scientific publication particularly intriguing because despite the lack of education on disciplinary literacy skills, these students still choose to engage in a challenging process that extends far beyond typical academic requirements.

In this investigation, we draw on the theory of science identity development to examine students’ motivations to participate in publication of their research (Figure 1). The theory of science identity has been examined by Carlone and Johnson (2007), who used the concept of identity posited by James Gee to develop their model. According to Carlone and Johnson, science identity is influenced by the three interconnected dimensions of "performance", "competence", and "recognition." By articulating these three dimensions, the authors recognize that identity development includes both the ability *to do* the actions of science and to be seen by others as a "science person."

The science identity framework is particularly relevant for understanding student motivation to publish because the act of scientific publication inherently engages all three dimensions:
Performance: Publication requires students to demonstrate their ability to engage in authentic scientific practices - not just conducting research, but also communicating that research in ways that align with disciplinary norms. Cameron et al. (2020) have shown that engagement in scientific communication activities serves as a key performance indicator that shapes how students see themselves within the scientific community.

Competence: Through the publication process, students develop and demonstrate their understanding of both scientific concepts and the processes by which scientific knowledge is constructed and disseminated. Murphy and Kelp (2023) demonstrate that students' scientific communication skills are intimately connected to their science identity development, suggesting that mastery of scientific writing may be a crucial component of how students assess their own scientific competence.

Recognition: Perhaps most significantly, publication provides students with formal recognition from the scientific community through peer review and eventual publication. Jackson et al. (2019) have shown that such social recognition is particularly important for students' STEM identity development, especially for groups traditionally underrepresented in science. The

public nature of publication makes it a powerful vehicle for recognition, as students' work becomes part of the scientific literature.

In their model, Carlone and Johnson conceptualize identity development as partly situational, i.e. dependent on the social and logistical structures that are present to support a student in developing their scientific skills. In their model, it would be difficult for a student to develop science identity without the opportunity to practice science, for example through conducting experiments. Other researchers have thus used this model of science identity to understand how engagement in authentic science practices helps students develop their science identity (Chapman & Feldman, 2017).

This framework is particularly useful for our study because publication encompasses each dimension of science identity while also highlighting potential gender differences in how students approach and value different aspects of the publication process. Given that academic writing and publication are generally part of the "hidden curriculum" in science (Moradi et al., 2023; Anlar & Phillips, 2023), understanding how students perceive and engage with publication through an identity lens may reveal important insights about why some students choose to pursue publication while others do not. Moreover, this framework allows us to examine whether certain dimensions of science identity (such as recognition) may be more salient motivators for particular groups of students. Do students recognize publication as part of "doing science" (i.e. performance) or do students think that publication is a way to develop scientific skills (competence)? Are students motivated by a perceived public accomplishment (recognition)?

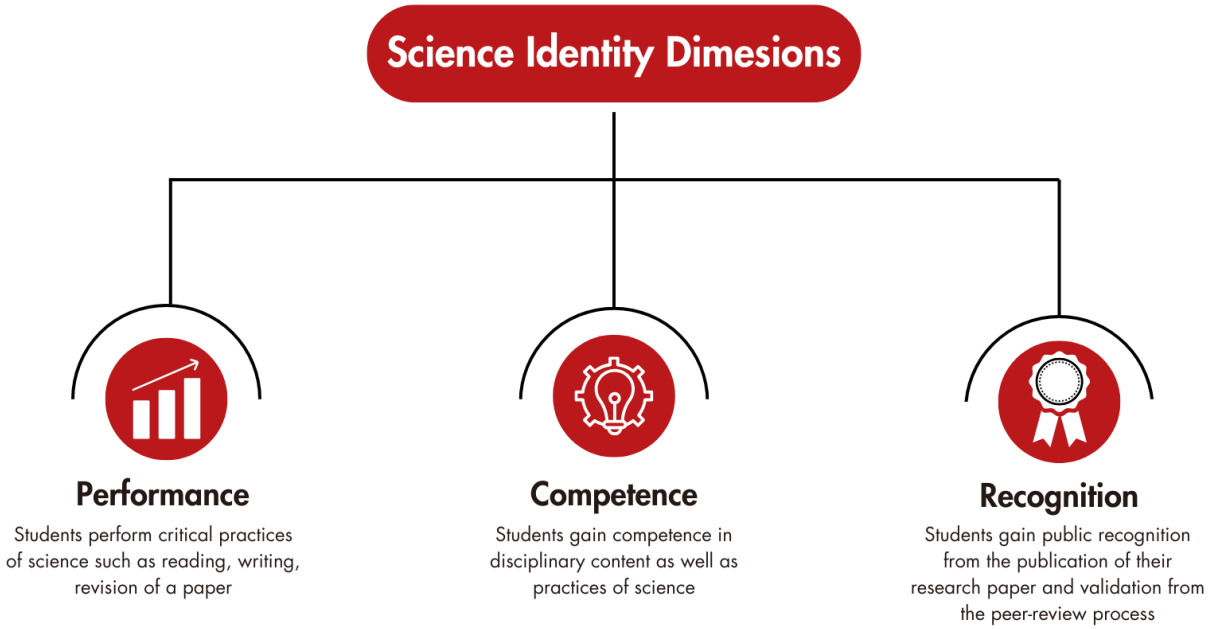

Fig. 1 Three dimensions of science identity (above) paired with the outcomes likely achieved when students participate in the publication of their science research papers (below)

Methods:

Ethics and Consent: This study was approved by the Emory University Institutional Review Board (IRB STUDY00000797). Students provided informed assent to participate in the research. Parental consent was waived by the IRB as the study posed no more than minimal risk to participants.

Survey Development and Administration

We designed a pre-publication survey to assess student authors' backgrounds, perceptions, and motivations regarding scientific publication. The survey was initially developed in 2020 and refined through feedback from a focus group of student authors to ensure clarity and comprehension of the questions. Based on this feedback, we modified the motivation question to be multi-select and adjusted the wording of response options.

The survey was administered through Qualtrics to all student authors who submitted papers to JEI between November 2020 and June 2022. Students received the survey link via email immediately following their paper submission. To incentivize participation, respondents could receive a $5 Amazon gift card upon completion of a subsequent Google form. All survey responses were collected anonymously. Of the students who submitted papers during this period, 254 completed at least part of the survey.

Quantitative Analysis

For this study, we focused our analysis on two key questions related to student motivation for publishing. The first was a multiple-select question asking students to identify their motivation(s) for submitting a paper for publication, which received 174 responses (81 male-identifying, 89 female-identifying). Response options were categorized according to Carlone and Johnson's (2007) science identity framework. Options were categorized based on their primary alignment with the framework's dimensions: Recognition items focused on being seen by or connecting with others in the scientific community, as well as gaining external validation. Performance items centered on enacting core scientific practices, particularly the practice of disseminating research findings. Competence items emphasized learning and skill development within scientific domains. Some items could potentially align with multiple dimensions but were categorized based on their primary emphasis as indicated by the action verbs and intended outcomes in each statement (e.g., "want to learn" indicating competence, "want to connect" indicating recognition).

To determine if there were significant differences in motivation factors between male-identifying and female-identifying students, we conducted Z-tests of proportions for each response option. Statistical significance was set at $p < 0.05$. Non-binary and self-subscribe responses were not included in this comparative analysis due to small sample sizes.

To evaluate the practical significance of gender differences, we calculated Cohen's h as our effect size measure. This statistical approach transforms proportional data to better handle values that are bounded between 0 and 1, making it particularly suitable for comparing the percentage of responses between independent groups (Cohen, 1988; Fritz et al., 2012).

Following Cohen's guidelines, we interpreted effect sizes as small (h=0.20), medium (h=0.50), and large (h=0.80).

Qualitative Analysis

The second question was an open-response item asking students to elaborate on their selected motivations. We received 93 responses to this question. These responses were analyzed using a multi-phase coding approach:

1. Initial Reading: The primary researcher conducted an initial open-reading of all responses. Upon sharing some initial themes that emerged with other researchers, including at a round table presentation at [conference], she was advised to take a deductive approach looking for codes that aligned with Expectancy Value (Eccles & Wigfield, 2002) and science identity (Carlone and Johnson, 2007).
2. Initial Deductive Coding: Two initial independent sets of codes were developed based on the theoretical frameworks of expectancy value and science identity. Through iterative reading and coding, the primary author determined that the open response data fit the codes of science identity more so than expectancy value. In particular, it was challenging to disentangle how student responses may fit into the expectancy value code of “utility” versus “attainment”, but the majority of those responses were coded into “recognition” based on science identity. For example, the student response “I wanted validation on my growth as a scientist, to introduce this great piece of medical equipment, and to share my findings with the scientific and medical community” was initially coded as “attainment” using expectancy value theory and “recognition” using science identity theory.
3. Deductive Coding: Following the theoretical framework of science identity, the primary researcher developed a codebook with three primary constructs:
    - Recognition: Responses indicating desire to make an impact or be seen as a scientist
    - Competence: Responses expressing desire to improve skills or learn
    - Performance: Responses indicating engagement in activities that scientists typically do

The codebook was finalized with clear definitions and example responses for each code (see Table 2 in Results). All open-ended responses were imported into Dedoose qualitative analysis software and coded using this framework. Individual responses could receive multiple codes if they expressed multiple distinct motivations.

To ensure coding reliability, we employed the following measures:

- Clear operational definitions were established for each code
- Example responses were included in the codebook for reference
- Code applications were reviewed and discussed among the research team
- Codes were applied consistently across all responses

To determine interrater reliability, a second researcher who had not coded the data originally analyzed a sample of the responses (24/93 responses). Cohen’s Kappa was performed to evaluate the consistency of coding between the researchers. On average there was 90% agreement across codes and a Cohen Kappa of 0.79, indicating substantial agreement across the coders. The code with the largest area of disagreement was "performance" in which the

original coder had double coded several statements as "performance" and either "competence" or "recognition".

Throughout both quantitative and qualitative analyses, we maintained careful documentation of our analytical decisions and processes to ensure transparency and reproducibility of our findings.

Table 1. Student Motivations for Scientific Publication by Gender Identity: Response Frequencies and Statistical Comparisons

Construct	Response Option	Male-identifying	Female-identifying	Cohen's H
Recognition	I want to connect with other scientists	0.49	0.50	0.02
	I want to share my research with others	0.43	0.55	0.24
	I want to be recognized as a scientist	0.40	0.58*	0.36
	I think others can benefit from my research	0.5	0.48	0.04
	I think a publication will give me a competitive advantage (eg: make my college application stand out)	0.47	.52	0.10
Competence	I want to learn how to write a scientific paper	0.42	0.57*	0.30
	I want to learn about the peer-review process	0.46	0.52	0.12
	I want to improve my scientific skills	0.45	0.54	0.18
	I want feedback on my research project	0.47	0.52	0.10

Notes: N = 174 (81 male-identifying, 89 female-identifying). Values represent proportion of students selecting each motivation factor. Statistical significance determined using Z-test of proportions with $p < 0.05$. Effect sizes calculated using Cohen's h, where h values of 0.20, 0.50, and 0.80 represent small, medium, and large effects respectively between proportions. Respondents could select multiple motivations (average selections: male = 5.8, female = 6.2).

Table 2. Coding Framework for Student Publication Motivations Using Science Identity Theory

Construct	Description	Example Student Quote

Recognition (55 responses)	I want to make an impact/be seen as a scientist"- recognition from public	"I want to be recognized as a scientist in the broader scientific community."
	This will give me an edge for college- recognition by institution	"I think a publication will give me a competitive advantage and make my college application stand out."
Competence (40 responses)	I want to improve my skills/learning	"I want to learn about the peer-review process and improve my scientific skills."
Performance (9 responses)	This is what scientists do so I'm going to do it	"Publications serve as milestones in the scientific journey, otherwise, the process of scientific research would seem like an infinite path with no reward."

Results:

Analysis of our pre-publication survey reveals how pre-college students' motivations for voluntary scientific publication align with Carlone and Johnson's science identity framework (Table 1). Students generally selected multiple motivating factors (male-identifying students averaging 5.8 factors; female-identifying students averaging 6.2 factors), suggesting that they view publication as serving multiple roles in their scientific development. Through analysis of both multiple-select responses (n=174) and open-ended explanations (n=93), we examined how students' motivations aligned with the three dimensions of science identity: recognition, performance, and competence.

Recognition: Seeking Legitimacy in Science

Recognition emerged as a prominent motivating factor across both quantitative and qualitative data. In the multiple-select responses, students frequently selected recognition-oriented factors including "connecting with other scientists" (49-50% across genders, h=0.02), "being recognized as a scientist" (40% male, 58% female, h=0.36), and potential benefits to college applications (47-52% across genders, h=0.10). The gender difference in "wanting to be recognized as a scientist" was both statistically significant ($p<0.05$) and practically meaningful, with the effect size (h=0.36) indicating a small-to-medium difference in how recognition factors into the motivation to publish (Table 1).

This emphasis on recognition was further elaborated in open-ended responses, where it emerged as the most prevalent theme (55 responses). Students explicitly connected publication to gaining legitimacy within the scientific community. As one student expressed: "Conducting a research project is difficult, but it is very important for me that the process... is veritably credible and respected by the scientific community." Another student highlighted the transitional aspect of recognition: "I believe that being successful in publishing a science research paper can be a metric to prove my capabilities... I would like for other scientists to build upon my ideas."

Competence: Building Scientific Skills
Competence-related motivations were featured prominently across both data sources. In the multiple-select responses, "learning how to write a scientific paper" showed both significant gender differences (42% male, 57% female, $p<0.05$) and a meaningful effect size ($h=0.30$), suggesting a small-to-medium difference in how different genders view writing skill development. Other competence factors were selected at similar rates across genders, with effect sizes indicating minimal practical differences: "improving scientific skills" (45% male, 54% female, $h=0.18$) and "learning about peer-review" (46% male, 52% female, $h=0.12$).

Furthermore, in their open-ended responses (40 responses), students elaborated on how they viewed publication as a pathway to developing scientific competence (Table 2). As one student explained: "I want to publish in JEI so that I can improve my critical thinking skills... All of which I think will help shape me into a better scientist." Another student highlighted the learning potential of the review process: "Through that process, you learn your own material a lot better... the reviewers put a lot of feedback on how I should elaborate on that and how I should validate."

Performance: Engaging in Scientific Practice
The performance dimension of science identity was primarily represented in our survey by research dissemination. In the multiple-select responses, "wanting to share research with others" showed notable gender differences (43% male, 55% female, $h=0.24$), with the small effect size suggesting a modest but meaningful difference in how female students view research communication as a core scientific practice.

While performance appeared less frequently in open-ended responses (9 responses), these comments provided valuable insight into how students view publication as authentic scientific practice. One student noted: "It was the next logical step to take. I went through the program over the summer, performed the experiment, and wrote my sections of the paper." Such responses suggest these students view publication not just as an add-on activity, but as an integral part of doing science.

Integration of Identity Dimensions
Many students' responses demonstrated how these three dimensions of science identity interweave in their motivations for publication. For example, one student wrote: "Publishing in a well-known and respected journal would allow me to play a more active role in sharing knowledge within the scientific community and improve my own rigor as an aspiring scientist." This response integrates performance (sharing knowledge), competence (improving rigor), and recognition (being respected within the community).

Notably, even apparently practical motivations like college applications were often framed within the context of scientific identity development. The pattern of effect sizes observed - largest for recognition ($h=0.36$) and writing competence ($h=0.30$), moderate for performance ($h=0.24$), and minimal for general scientific skills ($h=0.12$-0.18) - suggests that female students

may place greater emphasis on formal validation and specific skill development through publication.

Discussion:

Our study reveals how pre-college students view scientific publication as a pathway for developing their science identity across multiple dimensions, with distinct patterns emerging across genders. The findings suggest that publication opportunities may serve as a critical mechanism for students to gain recognition, demonstrate performance, and build competence in science – three key factors that Carlone and Johnson (2007) identify as essential for science identity development.

Recognition and Gender in Science Identity Development

The prominence of recognition-oriented motivations in our findings, particularly among female students, aligns with previous research highlighting recognition as a critical factor in science identity development and persistence (Robnett et al., 2015). Female students were significantly more likely to pursue publication to "be recognized as a scientist," suggesting they may view publication as a formal pathway to legitimate participation in science. This finding is particularly significant given that women remain underrepresented in many scientific fields and often face greater barriers to recognition of their scientific contributions (Lucas & Spina, 2022).

The emphasis on recognition also appeared as a general students' desire to connect with and contribute to the scientific community. Previous research on Course-based Undergraduate Research Experiences (CUREs) has demonstrated that opportunities for students to contribute to public forums are key to scientific development (Dolan, 2016). Our findings suggest that publication might serve a similar function for pre-college students, providing a concrete mechanism for gaining legitimate recognition within the scientific community.

Integration of Identity Dimensions Through Scientific Writing

Scientific writing and publication are not merely auxiliary skills but rather constitute core scientific practices essential to knowledge construction and dissemination in science. As emphasized in the Next Generation Science Standards (NGSS Lead States, 2013), communicating scientific information is a fundamental practice that helps students develop scientific literacy and transfer skills across disciplines. Our findings suggest that students intuitively recognize this, viewing publication as an opportunity to simultaneously enact scientific practices, demonstrate competence, and gain recognition.

The interweaving of these dimensions was evident in students' responses. When students discussed sharing their research (performance), they often connected this to both skill development (competence) and impact on the scientific community (recognition). This integration is particularly powerful because it provides students with a concrete mechanism to engage in authentic science practice through writing while also receiving validation of their scientific capabilities. As one student articulated: "Publishing allows me to contribute real scientific knowledge while developing my abilities as a researcher."

Moreover, the publication process itself reinforces this integration through peer review, where students receive feedback that helps them develop competence while simultaneously engaging in the professional practices of the scientific community. This creates a cycle where performance of scientific practices leads to increased competence, which in turn strengthens their recognition as legitimate participants in science. This cyclic reinforcement may be particularly important for building robust science identities that can persist through challenging academic and career trajectories.

Gender Differences in Science Identity Construction Through Publication

The observed gender differences in motivation patterns reveal important insights about how female students may strategically use publication to build their science identities. Female students' greater emphasis on both recognition and competence suggests that they may view publication as a formal pathway to overcome traditional barriers in science. Their higher likelihood of viewing research sharing as a motivating factor suggests they particularly value the opportunity to actively contribute to scientific knowledge through writing and publication.

The gender differences in competence-related motivations, particularly around scientific writing, may reflect female students' strategic approach to science identity development. By emphasizing skill development in scientific writing, female students may be recognizing writing as a crucial scientific practice that can help establish their legitimacy in the field. This attention to developing competence in scientific communication aligns with research showing that women often need more explicit recognition and validation of their scientific capabilities to develop strong science identities (Carlone & Johnson, 2007).

Limitations

First, our sample represents a self-selecting group of highly motivated students who voluntarily pursued publication and thus likely possess higher levels of science self-efficacy and interest compared to typical pre-college students. This suggests our findings are not generalizable to broader student populations but could have implications for other endeavors, such as science fairs or other competitions, focused on supporting highly motivated student populations.

Second, our reliance on self-reported data through surveys captures students' stated motivations but may not fully reveal underlying factors influencing their decisions to publish. While our mixed-methods approach helps mitigate this limitation, observational studies or longitudinal tracking could provide additional insights into how motivations manifest in actual behaviors and outcomes.

Third, our gender analysis was limited to binary gender categories due to small sample sizes for non-binary and self-identifying students ($n < 10$). This constraint prevents us from understanding the potentially unique experiences and motivations of gender-diverse students in scientific publication. Additionally, the intersection of gender with other identity factors (e.g., race, socioeconomic status) could not be meaningfully analyzed due to sample size limitations. Finally, our study's focus on a single journal (Journal of Emerging Investigators) may not capture variation in student experiences across different publication venues or formats. The journal's

specific support structures and review processes could influence student motivations in ways that might differ in other publication contexts.

Despite these limitations, our findings provide valuable insights into how pre-college students approach scientific publication and its role in science identity development, particularly regarding gender differences in motivation patterns.

Implications for Science Education and Scientific Community Engagement

Our findings suggest the need to fundamentally reimagine how we integrate scientific communication opportunities into pre-college education. Rather than treating student research as purely educational exercises, educators and those involved in science outreach could create authentic connections between students and the scientific community. This could manifest through student research symposia, school-university partnerships, and mentorship programs that connect students with working scientists. Such opportunities provide scaffolded experiences that help students develop both confidence and competence in scientific communication while gaining recognition from the broader scientific community. Additionally, platforms like the JEI can serve as critical avenues for students to extend the impact of their research beyond science fairs and summer programs. By engaging in the peer review and publication process, students not only refine their scientific communication skills but also receive authentic and meaningful results as well as the opportunity to contribute to the broader scientific dialogue. Thus, this engagement reinforces the idea that the work they are doing through STEM outreach programs is valued and important.

The development of systematic support structures is crucial for making these opportunities sustainable and equitable. This includes professional development for educators in guiding student research and scientific writing. It also involves partnerships between K-12 schools and scientific institutions, as well as the recognition of communication and publication within science education standards.

Creating more opportunities for authentic scientific communication could have broader impacts on diversity in science by providing formal pathways for recognition and community entrance. Moreover, it could enhance scientific literacy through a deeper understanding of how scientific knowledge is constructed and communicated. This approach aligns with NGSS Science Practice 8, Communicating Information, by providing students concrete opportunities to develop their scientific identities through meaningful communication practices.

Future Directions

While our study focused on highly motivated students who voluntarily pursued publication, future research should examine how publication opportunities might support science identity development in broader student populations. Additionally, longitudinal studies could investigate how early publication experiences influence long-term persistence in science, particularly for underrepresented groups. Understanding these relationships could help design more effective interventions to support diverse students' science identity development and persistence in scientific fields.

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Science Identity Dimesions

Performance

Students perform critical practices of science such as reading, writing, revision of a paper

Competence

Students gain competence in disciplinary content as well as practices of science

Recognition

Students gain public recognition from the publication of their research paper and validation from the peer-review process