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A Mixed-Methods Study of a Poster Presentation Activity, Students' Science Identity, and Science Communication Self-Efficacy under Remote Teaching Conditions

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Disseminating and communicating scientific findings is an acknowledged part of the research experience, but few science programs include explicit undergraduate curricula for practicing oral science communication. Course-based undergraduate research experiences (CUREs) can provide opportunities for students to practice science communication, but few studies describe or assess authentic oral science communication activities within CUREs, and none do so under hybrid conditions. The existing literature lacks substantial evidence for how science communication activities impact students' science identity and science communication self-efficacy, specifically regarding research posters. To address this, we collected students' quantitative and qualitative perceptions of science identity and science communication self-efficacy in a hybrid CURE and collected students' qualitative perceptions of presenting their research remotely at a virtual poster symposium. We found that students' science identity and science communication self-efficacy improved significantly, as well as benefits and complaints about presenting research virtually, namely, reduced stress, a more comfortable atmosphere, but a murkier communication channel. Our results should prove valuable to educators interested in improving students' science identity and science communication self-efficacy, especially when limited to a virtual or hybrid format, as affective factors strongly impact students' persistence in science.

KEYWORDS science communication, hybrid CURE, remote learning, science communication self-efficacy, science identity, virtual poster presentation

INTRODUCTION

To disseminate research effectively, scientists use a variety of media, including conference presentations, research posters, articles in peer-reviewed journals, science cafes, and public outreach events. While each medium requires different skillsets, the main goal of any science communication activity is to communicate effectively. The importance of science communication is highlighted in a call to action from the American Association for the Advancement of Science (AAAS), which includes science communication as a core competency for undergraduate biology majors (1). This core competency underscores providing communication opportunities to students within biology curricula to best develop communication skills students need to effectively communicate within and between scientific and nonscientific disciplines. Additionally, as employers continue valuing excellent communication skills in job candidates (2, 3), there is a substantial need for oral science communication opportunities in undergraduate curricula.

One opportunity in which students might practice oral science communication is in course-based undergraduate research experiences (CUREs). Although the authentic nature of the research experiences has been studied, few studies include descriptions or thorough assessments of oral science communication activities within CUREs (4–6). Brownell et al. (4) described students' oral presentation using research posters in a poster symposium in an introductory biology CURE and its impact on students' thinking like a scientist. Sarmah et al. (5) described oral science communication in a cellular biology CURE, in which students constructed and presented a research poster for a departmental symposium and found increased presenter confidence. Reeves et al. (6) developed a functional genomics CURE and measured oral communication, but the activity consisted only of brief data reports delivered in lab sections at several points in the semester. However, oral communication confidence improved significantly even with the small data updates in the lab (6). No studies examine the effect of oral science communication activities within the increasingly necessary hybrid (combined remote and in-person instruction) environment. In this study, we examined students' oral

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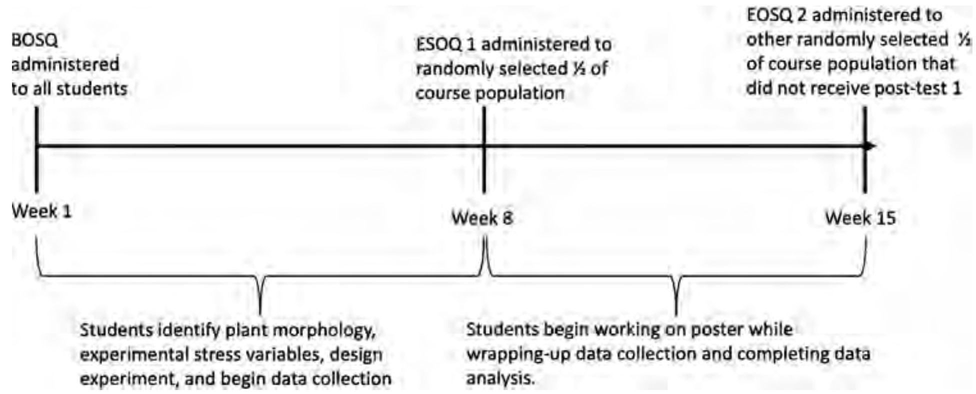

FIG 1. Schematic timeline of course with questionnaire administration.

presentation confidence and its relationship with science identity development within a hybrid-format CURE, using qualitative data and a new instrument focused on science communication (i.e., presentation and conversation) self-efficacy. To this end, we utilized two theoretical frameworks to guide our study and frame our results—self-efficacy development within Bandura's social cognitive theory (7, 8) and Gee's identity development theory (9).

THE CURRENT STUDY

While CUREs, like mentored research experiences (10, 11), provide students with many affective benefits (12, 13), little research exists evaluating students' science communication self-efficacy when presenting research findings orally accompanying posters (5). Furthermore, no known study evaluates student perceptions of a virtual poster symposium during a remote-learning CURE. The purpose of our study is to evaluate how students' science identity and science communication self-efficacy develop in a CURE conducted in a hybrid format, focusing on these research questions (RQ):

RQ 1. How does creating and presenting a research poster relate to students' science communication self-efficacy and science identity in a CURE conducted in a hybrid format?

RQ 2. What are students' perceptions of participating in a virtual poster presentation?

METHODS

Design

We used a convergent mixed-methods approach with institutional review board (IRB) approval (IRB-20-25-STW). We collected students' quantitative self-perceptions of science identity and science communication self-efficacy using a quasi-experimental preinstruction/midinstruction/postinstruction design. We also collected students' qualitative perceptions of participating in a virtual poster symposium at the semester's end.

Course description

We collected data from students enrolled in a process-focused (14) plant biology CURE across two semesters at a large, public, research-intensive university located in the South-Central United States. The CURE involves a long-term examination of plant phenotypes and response to abiotic stress, which is connected to ongoing faculty research. During the pandemic, the course followed a hybrid format in which each research team of four students attended lab in-person every other week, with half the teams present each week. In the first 8 weeks, students attending in-person identified plant morphology, selected abiotic stress variables to test in a plant growth experiment, designed their experiment, and began data collection. On alternate weeks, when students were remote, they completed worksheets covering plant morphology and content vocabulary. In the remaining 7 weeks, students finished data collection and completed data analysis while working on their poster during the in-person sessions and self-determined times during remote weeks. The instructor assessed students primarily through team poster presentations conducted during the last week of the semester. Prior to the semester in which we collected data, presentations were given in a well-attended, public symposium. During the semester in which we collected data, presentations were virtual due to the pandemic.

Data collection

We recruited students ($n = 355$ across two semesters) to complete questionnaires at the beginning (BOSQ) and end (EOSQ) of the semester, with quantitative instruments and open-ended response items administered via Qualtrics, and an end-of-semester semistructured interview via Zoom. After administering the BOSQ, we effectively created two treatment groups by randomly administering EOSQ-1 to half the students before they experienced any poster-related content (what we deem "research only") and EOSQ-2 to the remaining students

TABLE 1
Participant demographic data by treatment

Demographics	% (*n*) of participants in each treatment	
	Research only (*n* = 75)	**Research + poster (*n* = 74)**
Gender[a]		
Male	30.7 (23)	28.4 (21)
Female	69.3 (52)	71.6 (53)
Race		
American Indian or Alaska native	8 (6)	10.8 (8)
Asian	2.7 (2)	5.4 (4)
Black or African American	5.3 (4)	4.1 (3)
Native Hawaiian or other Pacific Islander	0.0 (0)	0.0 (0)
White	80 (60)	74.3 (55)
Other	4 (3)	5.4 (4)
Ethnicity		
Hispanic or Latinx or of Spanish origin	13.3 (10)	8.1 (6)
Not Hispanic or Latinx or of Spanish origin	84 (63)	91.9 (68)
Did not provide	2.7 (2)	0.0 (0)
Classification		
Freshman	25.3 (19)	18.9 (14)
Sophomore	29.3 (22)	27 (20)
Junior	17.3 (13)	25.7 (19)
Senior	28 (21)	28.4 (21)
No. of previous college science courses[b]		
1	14.7 (11)	4.1 (3)
2	14.7 (11)	8.1 (6)
3	10.7 (8)	9.5 (7)
4	4 (3)	16.2 (12)
5	2.7 (2)	8.1 (6)
6	4 (3)	6.8 (5)
More than 6	45.3 (34)	41.9 (31)
No previous college science courses	4 (3)	5.4 (4)
Previous science fair experiences[c]		
1	9.3 (7)	10.8 (8)
2	9.3 (7)	17.6 (13)
3	6.7 (5)	5.4 (4)
4	6.7 (5)	2.7 (2)
5	1.3 (1)	1.4 (1)
6	0.0 (0)	0.0 (0)
More than 6	2.7 (2)	4.1 (3)
No previous experiences with science fairs	64 (48)	58.1 (43)

[a]While we offered seven options for gender (male, female, transgender male, transgender female, gender variant/nonconforming, not listed [please specify], and prefer not to answer) participants only selected male or female.
[b]Students included concurrently enrolled science courses in the number of previous science courses they took.
[c]Science fair experiences include participating as a contest, serving as a content judge, and both.

TABLE 2
Aligned quantitative concepts and instruments with qualitative semistructured interview questions

Topic	Quantitative items	Qualitative interview questions
Science identity	3 science identity items (12)	Describe what a scientist looks like to you.
		How do you see yourself in comparison to the scientist you just described?
		After presenting your research poster, how do you see yourself as part of the scientific community?
Science communication self-efficacy	Modified 10 science communication self-efficacy items (15)	Please describe your confidence about presenting your research before you participated in the poster session.
		Now that you presented your poster, how would you describe your confidence about presenting your research?
		Please describe your confidence in discussing your research with your audience members.

after they presented their poster at the virtual session (what we deem "research + poster"). Each consenting student completed BOSQ ($n=279$) and either EOSQ-1 ($n=103$) or EOSQ-2 ($n=98$). After removing incomplete responses, duplicates, and incorrect responses to a quality control item, the final sample size of matched students' responses was $n=75$ students in the research only (BOSQ-EOSQ1) group and $n=74$ in the research + poster (BOSQ-EOSQ2) group (Fig. 1). We used $n=226$ usable BOSQs to calculate instrument reliability.

Quantitative data sources. We collected measures of science identity and science communication self-efficacy; demographic data including gender, race, ethnicity, class and standing; number of previous college science courses; and number of previous experiences participating in science fairs (as contestant, judge, or both) (Table 1). The BOSQ and EOSQs included the same science identity and science communication self-efficacy scales.

(i) Science identity. We collected students' perceptions of their science identity using three items from the Persistence in the Sciences questionnaire (12), with five options per item anchored from "strongly disagree" to "strongly agree" and a published reliability of α = 0.87. Scores range from, 3 if students answered all items negatively (indicating limited science identity), to 15, if students answered all items positively (indicating high science identity).

(ii) Science communication self-efficacy. We collected students' perceptions of their science communication self-efficacy using 2 subscales, scientific oral presentation (4 items, α = 0.89) and scientific conversation self-efficacy (8 items, α = 0.89) from a previously published instrument (15). The same question stem, "Rate your level of confidence (even if you have never done it yet) in your ability to. . ." preceded all items, followed by five response options per item anchored from "very insecure" to "very confident." Scores range from 12, if students answered all items negatively (indicating low efficacy), to 60, if students answered all items positively (indicating high self-efficacy). The original instrument was designed for graduate and medical student use. Therefore, we modified two items using more appropriate wording for our undergraduate population. For example, we modified, ". . .use the expected scientific style when speaking" to ". . .use the appropriate amount of scientific words."

Qualitative data sources. Students willing to participate in the end-of-semester interview provided contact information on the BOSQ. We only interviewed students after they completed their research and poster presentation experiences. Interviews followed IRB-approved safety guidelines and occurred via Zoom to maintain social distancing. We collected audio files from $n=29$ semistructured interviews, transcribed the interviews using Otter.ai, an automatic transcription service, and reviewed each transcript with its corresponding audio file to correct any transcription mistakes. Table 2 aligns the semistructured interview questions with the quantitative instrument scales.

TABLE 3
Initial EFA eigenvalues and parallel analysis eigenvalue means[a]

Factor	Initial EFA eigenvalue	Parallel analysis eigenvalue mean
1	4.742	1.397
2	1.417	1.288
3	1.144	1.206
4	0.92	1.132
5	0.741	1.071

[a]Factors are only retained if the initial EFA eigenvalue for a factor is larger than the simulated eigenvalue mean created in the parallel analysis. Only the first two EFA eigenvalues are larger than the simulated parallel analysis eigenvalue means, strongly suggesting a two-factor solution.

TABLE 4
Factor loadings for principal axis factoring with direct oblimin rotation after parallel analysis

Item	Factor 1	Factor 2
Rate your level of confidence (even if you have never done it yet) in your ability to. . .		
. . .excel in giving scientific presentations (i.e., you usually receive high praise for your presentations from your mentor or the audience)	0.492	
. . .give a scientific talk to a nonscientific audience (e.g., high school students, cancer patients).	0.776	
. . .give an oral presentation at a scientific conference.	0.75	
. . .require little to no assistance with my speaking and presenting skills.	0.4	
. . .defend your point of view convincingly in a scientific discussion, in spite of a negative response from others.	0.551	
. . .effectively answer questions from the audience at a scientific conference.	0.483	
. . .speak using correct grammar without rehearsing.		0.697
. . .manage worries you have about your pronunciation, accent, vocabulary, grammar, or style of speaking.		0.784
. . .use the appropriate amount of scientific words.	0.463	
. . .introduce yourself and your research briefly and effectively to other professionals.	0.395	

Data analysis

Quantitative. We performed all quantitative analyses using SPSS 26. Because we modified the science communication self-efficacy instrument, we performed exploratory factor analysis (EFA) using principal axis factoring with direct oblimin rotation and parallel analysis (PA) to determine the factor structure and appropriate factor extraction of the modified science communication self-efficacy instrument, respectively (16). PA simulates a fictional data set matching the EFA data set size and is often employed as a robust method to identify appropriate factor extraction and prevents overextraction (16). We also calculated Cronbach's alpha reliability of the modified science communication self-efficacy instrument and unmodified science identity instrument.

We performed parametric or nonparametric, as appropriate, repeated-measure analysis of variance (ANOVA) within treatments on raw, paired-difference scores (EOSQ-BOSQ) to assess how students' science identity and science communication self-efficacy changed. We then calculated normalized change scores (17) between EOSQs and BOSQs and compared those between treatments using the Mann-Whitney U test.

Qualitative. We used NVivo for analysis of interview transcripts. We approached our data inductively and utilized *in vivo* coding for our first-cycle coding scheme to create codes for each interview question response. To establish qualitative validity, we triangulated our data by only including interviews of students who completed a BOSQ and EOSQ. Additionally, the authors discussed the coding scheme until they reached 100% interrater agreement. Subsequently, one author (*E.*A.L.) transitioned the data to second-cycle pattern coding using a coding scheme map (18). Both authors identified and discussed emergent themes from the second-cycle pattern coding until they reached 100% interrater agreement (18).

RESULTS

Quantitative

The EFA of our modified science communication self-efficacy instrument suggested a two- or three-factor model (Kaiser-Meyer-Olkin [KMO] = 0.852, χ^2 = 963.20, df = 66, $P < 0.01$), depending on the scree plot and eigenvalues. PA

TABLE 5
Science communication self-efficacy and science identity scores by treatment[a]

Factor	Treatment	Prescore [mean ± SD (95% CI)]	Postscore [mean ± SD (95% CI)]	Test statistic	*P* value	Effect size
Science identity	Research only	10.35 ± 2.648 (9.74–10.96)	10.97 ± 2.477 (10.4 – 11.54)	χ^2 = 9.618	0.002	Kendall's *W* = 0.128
	Research + poster	10.12 ± 2.449 (9.55–10.69)	11.04 ± 3.004 (10.34 – 11.74)	χ^2 = 20.903	<0.001	Kendall's *W* = 0.282
Science communication self-efficacy	Research only	31.32 ± 7.104 (29.69–32.95)	33.69 ± 6.173 (32.37–35.11)	F = 20.82	<0.001	η^2 = 0.220
	Research + poster	30.69 ± 6.425 (292–32.18)	33.19 ± 6.65 (31.65–34.73)	F = 11.97	0.001	η^2 = 0.141

[a]CI, confidence interval.

TABLE 6
Interviewee scientist descriptions[a]

Theme	Exemplar quote
Does or shares research (16)	I would say a scientist is someone that conducts experiments all the time. *A lot of times someone that's always doing research, or presenting research is what I would consider a scientist to me.*
Physical description (10)	The first thought that always comes to my head is just, like, *a person with big glasses and a lab coat on.*
Gaining knowledge (9)	I guess, really, I think of it more as *someone who asked questions and seeks out the answers, and tried to find out why those answers are the way they are* instead of face value.
Unique to single individual (5)	I think I've realized that, like, not all scientists did well in school. That's been a cool thing to see.

[a]Authors added emphasis to exemplar quotes using italics to showcase the main idea in the quote.

results suggested a two-factor extraction, as only two eigenvalues in the EFA were larger than those produced from the simulated data in PA (Table 3). The final two-factor extraction consists of 10 items (Table 4) and explains 43.590% of the variance. In our study, the science identity instrument reliability was $\alpha = 0.81$, and the modified science communication self-efficacy instrument reliability was $\alpha = 0.84$.

Research question 1. Friedman's repeated measure ANOVA revealed significant improvements in students' science identity in both the research only and research + poster treatments (Table 5). Science communication self-efficacy in each treatment also improved significantly (Table 5). We found no significant differences in normalized change scores between treatments for students' science identity ($U = 3{,}193$, $z = 1.59$, $P = 0.110$) and science communication self-efficacy ($U = 2{,}630$, $z = -0.551$, $P = 0.582$).

Qualitative

The semistructured interview covered three topics—science identity development, science communication self-efficacy development, and perceptions of a virtual poster presentation. We report science identity and science communication self-efficacy here to help answer RQ 1, while the qualitative perceptions of a virtual poster presentation answer RQ 2.

Research question 1. (i) Science identity. Some students described a scientist in multiple ways, which provided more coded responses ($n = 40$) than interviewees. Most responses described a scientist as someone who does or shares research ($n = 16$) or had a certain appearance ($n = 10$) (Table 6). We subdivided the students' comparisons of themselves to their descriptions of scientists as follows: I am a scientist ($n = 14$), developing scientist ($n = 7$), not a scientist ($n = 6$), hesitant to claim scientist ($n = 3$), and mixed response ($n = 2$) (Table 7). When students identified themselves as scientists, most of their responses aligned with their own scientist description. Some students indicated they were still developing their science identity because they were at an entry level or were still learning. Others indicated they were not a scientist because they had yet to reach a "scientist level" (Table 7).

Four major themes emerged regarding students' science identity after they presented their poster: (i) new to, and growing within, the community, (ii) feel official like a scientist, (iii) excluded and questioning contribution, and (iv) affiliate of the community. We subdivided each major theme into subthemes (Table 8). Students who felt new to the science community after presenting their poster indicated they felt like a beginning participant, "like a little fish" in the community. Other students attributed their growing within the community to experience in other research. Some students indicated they felt like a scientist because they used academic language and scientific jargon to discuss their research with academic faculty or presented a professional poster in front of their professors. Conversely, some students felt outside the community because they found the scientific jargon inaccessible; others because their research provided no contribution to the scientific community. Finally, becoming a better collaborator within their lab group made some students feel tangentially affiliated with the community.

(ii) Science communication self-efficacy. When applicable, we coded similar responses using the same code, producing fewer codes than interviewees. Before presenting, about equal numbers of responses indicated that students' science communication self-efficacy developed ($n = 11$) or remained unchanged ($n = 12$) (Table 9). Some students' science communication self-efficacy remained unchanged and low because presenting a poster was a new experience, and thus they could not gauge what to expect. Other students indicated the potential to communicate mistakenly in front of an expert audience shook their confidence. Conversely, some students' confidence remained unchanged because it was already high from prior presentation experience. When students' confidence shifted before their presentation, the reasons included improved understanding and performing the actual experiment ($n = 5$) or compiling and reviewing their poster as a final product ($n = 4$). Other responses indicated a mixed confidence ($n = 3$). For example, one student was confident with poster content but not about discussing the research.

A majority ($n = 18$) of the responses indicated that students' confidence improved after completing the presentation; the remaining responses ($n = 8$) indicated stagnant confidence, needing more practice, or confidence limited to presenting the same project again (Table 10). Students whose confidence improved

TABLE 7
Alignment with scientist description[a]

Theme	Subtheme	Exemplar quote
I am a scientist (14)	Does or shares research (5)	I would think I go out there and I ask questions, and *I conduct research, even if it's on a computer instead of in a lab, informed conclusions, and use those conclusions to do further research*. So I would consider myself a scientist.
	Unique to single individual (3)	*I think I'm very curious*. I don't know if gravity needs to be discovered again. But, I do see myself as a scientist. Someone who just wants to know a little bit more beyond, you know, "Why does this pen fall?"
	Nondescript/holistic (3)	*I see myself as just the same [as a scientist]*. I think I know quite a bit. I think I understand scientific concepts enough that I just see myself as essentially the same.
	Gaining knowledge (2)	I think that I'm a scientist. *I am kind of a life-long learner*. If there's something that's, you know, happening with my kids medically or something like that, I am going to research as best as I can.
	Physical description (1)	I feel like actually, I see myself kind of a perfect mesh of the two. I anticipate working in a lab with human subjects. . . so *you have to wear a lab coat and stuff like that. But I also will be the person that's you know, up in the wee hours of the night on my computer*, like analyzing results and writing up a paper, like writing up a grant proposal or something.
Developing scientist (7)		I would love to be like one of the scientists I imagined someday, and I kind of see myself as an entry level student, you know. . . And so *I think I see myself as, like, developing into one of those scientists, but definitely still learning*.
Not a scientist (6)		I don't think I'm quite at that level. Um, I don't know if a lab is necessarily for me. I'm more of a person-to-person kind of thing. *But, yeah, no, I don't picture myself as a scientist*.
Hesitant to claim scientist (3)		Since I don't have a degree, *I would be hesitant to actually classify myself as a scientist*. But, it was cool to like, be participating in an experiment like that. I felt very scientific.
Mixed response (2)		So, I've done internships before and I really, really, dig research. It's really fun. And. . . I'm still invested in it. So, I want to be one of those problem solvers.

[a]Authors added emphasis to exemplar quotes using italics to showcase the main idea in the quote.

noted their mastering of the experience and that presenting their poster was not as intimidating as they anticipated. Some students' confidence remained unchanged because the experience simply confirmed they could present well. Other students' thought their confidence would have decreased without the opportunity to practice beforehand.

Audience composition impacted students' science communication self-efficacy with four major themes emerging:

TABLE 8
Science identity after presenting the virtual poster[a]

Theme	Subtheme	Exemplar quote
New to, and growing within, the community (9)	Introductory/growing scientist (6)	I would say. . . I'm definitely involved with the scientific community. *But I feel like a little fish, kind of in it. And like, I've just recently entered it.* I definitely wouldn't say I'm like, one of the top dogs in it, but I think I'm a part of it.
	More experience and awareness (2)	*I mean, it's well, I think it's like another experiment that I've done.* So, I would say it's better in my knowledge. So I guess moving forward to that.
	More comfortable (1)	I definitely feel more comfortable. I think it's helped a lot because I wasn't really sure what to expect, because I've never done like a real, genuine poster like that. *But I'd say definitely feel more comfortable now.*
Feel official like a scientist (8)	I feel like a scientist (3)	*I definitely felt like a scientist. Like, I think that sounds kind of, I don't know, cheesy, but after presenting research. . . it felt very academic to present it to [faculty] and [other faculty], who are like, academic intellectuals in this field* and present, like, our little findings from this semester, and I have to speak in academic terms to explain, you know, what was happening, which felt very sort of, like, official.
	I feel more official (3)	*This poster really made me feel more into the scientific community. And now, it looked just the way it looked very professional.* And I think presenting it in front of like, my professors and stuff, they really respected the research that we did. And so that, like, made me feel more you know, accepted into the scientific community.
	I did what a scientist would do (2)	I find myself pretty ingrained in it. I felt kind of that way beforehand, as well. Like, *I know how to compile data. I know how to interpret data. I know how to relay that data in a concise manner.*
Excluded and questioning contribution (7)	Not part of the science community (4)	It's like having to go on Google Scholar and sift through all these like, super wordy articles that I don't even know what they're trying to explain. *And it was really just like, "Dang, I'm not a part of this community" like "I have no idea what y'all are talking about. Good for you. But absolutely not for me."* Like, I can't imagine writing a crazy big article with like, giant words that I don't even know.
	Questioning contribution (2)	I mean, if I was thinking about it logically, I would guess I somewhat contributed to the questions that are asked, like by a scientist, but thinking of like all the science that really happens, *I don't know if it was intentional enough to be counted as a credit towards the*

(Continued on next page)

TABLE 8 (Continued)

Theme	Subtheme	Exemplar quote
		science community. I don't know. And I don't know if it changed my involvement as a scientist.
	More educated but not a scientist (1)	*I feel like, I'm still not completely there yet. But as I mean, I feel better prepared and more educated on the things* so I would consider myself beforehand, kind of a lower middle. And now I would consider myself a higher middle with more experience.
Affiliate of the community (3)	Closer and more connected to community (2)	*I see myself closer to the scientific community now that I've been able to get our. . . I've been able to present information that I've worked on all semester* and been able to get it all in poster format, so everybody else can see it and just see what we did.
	Better collaborator within community (1)	*I think it just helped me be a better collaborator within the scientific community, because I've done a lot of research, but you kind of got to do it with other people*. So it helped me with collaboration within the scientific community.

[a]Authors added emphasis to exemplar quotes using italics to showcase the main idea in the quote.

(i) confident and familiarity with audience members, (ii) nervous with distant and expert audience, (iii) confidence was question-dependent, and (iv) lack of understanding content (Table 11). Students presented to a limited audience (their TA and course faculty) in the virtual format. Confidence largely depended on students' familiarity with their audience ($n = 9$). One student felt fortunate with an expert audience, because they could still understand his poor explanations. Other students were intimidated by the faculty expertise in the audience. Previous lack of interaction with the faculty made some students afraid. Self-efficacy was also question-dependent, as some responses indicated students would become nervous if asked about a part of the project on which they had not worked. A student who was not familiar with the treatment protocol and answered a project-related question incorrectly reported lowered confidence because they lacked enough hands-on experience with the treatments. Other responses ($n = 8$) indicated self-efficacy depended on preparedness or general self-confidence.

Research question 2. We asked students what it was like to present their poster virtually. Based on the first-cycle *in vivo* codes, we coded students' perceptions as either positive or negative, resulting in four emergent themes.

(i) Positive perceptions. Two themes emerged: (i) stress reduction/relaxed environment and (ii) clear communication channel (Table 12). Most responses indicated the virtual aspect either provided students with a relaxing and comfortable space ($n = 7$) or physically removed them from the audience ($n = 7$), thus reducing their presentation anxiety. Other responses ($n = 5$) indicated presenting virtually simply was a lot less scary. "Clear communication channel" encompassed the remaining responses ($n = 8$). Presenting virtually allowed students to read their notes from their screen, reducing anxiety while still maintaining eye contact with their computer camera. Other responses ($n = 2$) suggested familiarity with videoconferencing made the virtual presentation easy.

(ii) Negative perceptions. Two negative themes emerged: (i) murky communication channel and (ii) distractions (Table 13). The majority of responses ($n = 9$) indicated the virtual aspect created a murky communication channel, wherein communication and presentation issues exist. This included complaints about the loss of visual cues, such as hand gestures or body language, or poor Internet connections limiting nonverbal communication. The remaining responses ($n = 3$) indicated students struggled with distractions during the virtual symposium. For example, students became self-conscious seeing themselves on camera. One student noted a parent walked in during the question-and-answer portion of the presentation, which caused communication difficulty between the student and the faculty.

DISCUSSION

Our goal in this study was to determine how poster creation and presentation contributes to students' development of science identity and science communication self-efficacy in a hybrid format. Because of course constraints, we isolated the effect of poster creation and presentation from the rest of the

TABLE 9
Science communication self-efficacy before presenting the virtual poster[a]

Theme	Subtheme	Exemplar quote
Unchanging confidence (12)	Not confident (7)	I'm not too shy of an individual, *but would like maybe the fear, the lack of confidence would come from messing up with someone who knows everything about it.* I know my dad once told me that a couple time he presented on subjects where the author of the book was in the room. And so, he always talks about how you had to have it packed down.
	Pretty confident (5)	*I'm pretty confident presenting. I've done that before.*
Changing confidence (11)	Improved confidence from understanding content knowledge and doing experiment (5)	I don't think I felt that confident, especially before we'd actually done the experiment, *because I didn't really know that much about plant biology and the different things that are, like, impacting plants. And that kind of scared me. But, as we got closer, and I like, actually met with my group mates and we went through it and figured it out, and like, read the articles, I. . . I was a lot more confident going into the actual presentation,* I'd say.
	Improved confidence after reviewing and compiling poster (4)	. . .when [instructor] first told us that we would be presenting I was like, "No way" I just was not confident at all. Um, and then I'd say *the closer we got like maybe the final week before we presented, like once our poster was finalized, and I was looking over it, like I actually understood what we had done.* I definitely felt a lot more confident going into that one. I guess like, as the course progressed, I felt better.
	Improved confidence after doing independent research poster with faculty (1)	. . .the first half of the semester, I was definitely like, "Oh my gosh, I don't even know what to talk about when I'm doing this stuff, like do I just need to read it directly off the poster?" But then, *after submitting my own person poster to a conference, and although I didn't actually talk to anybody about it. . . made me feel more sort of prepared for what it would look like to present the plant biology poster.*
	Decreased confidence (1)	*So, I was honestly, really confident up until like, the week before.*
Mixed statements (4)		I was pretty confident that everything was how it was supposed to be [on my poster]. I was just not confident how I would speak those things.

[a]Authors added emphasis to exemplar quotes using italics to showcase the main idea in the quote.

research process by sampling each of two sets of students at one of two time points (research only and research + poster). Science identity and science communication self-efficacy improved significantly, but not differently, in both treatments. Although students in the research-only treatment neither completed data collection and analysis nor initiated poster creation, they reported gains in science identity. Increased science identity from students participating in activities similar to practicing scientists occurred in other studies (19, 20). Our qualitative data support our findings, as 45% of students' interview

TABLE 10
Science communication self-efficacy after presenting the virtual poster[a]

Theme	Exemplar quote
Improved confidence (18)	*It's a lot higher now. I know that I can do it.* And it's definitely not as hard or intimidating as I thought it would be.
Same confidence as before (3)	*I think this just reiterated I know I can do it.* I just have to set my mind to it, I guess.
Confident, but I need more practice (3)	If I had new research, *I would really have to practice what I was going to say over and over again,* or I would be super nervous again.
Confident if I shared exact same project again (2)	. . .you know, we never really practiced like, just [partner] and I, you know, presenting to people and to do stuff like that. I feel like we would be. . . we would do better a second time around or third time around. The first time you do something, it's always rough. *I feel like if we had a couple more chances to present it, I think our confidence would go up, our understanding of the material would go up.*

[a]Authors added emphasis to exemplar quotes using italics to showcase the main idea in the quote.

responses described a scientist as someone who does or shares research, 35% of which indicated that was a reason they saw themselves as scientists. In 21.8% of responses, students indicated they identified as developing scientists but had not established their science identity. Identity development theory (9) helps frame our results. Students developing their science identity might rely on a discursive development in which discussing science and research with peers and professors contributes to identity development. Conducting research in teams may have provided students a social-professional avenue in which science identity developed from semester-long discussions about research (21). In the research + poster treatment, discursive development of science identity may have developed from the social-professional discussions between students and their TA/faculty audience in the virtual symposium, as the audience asked students various questions about their research. However, not all students developed an identity toward that of a scientist; some grew more distant from a science identity, as about 26% of interviewees indicated they felt excluded or questioned their research contribution to the field. Students in this hybrid-format CURE only attended lab in-person every other week, and storms prevented access to in-person labs for 1.5 weeks. This inconsistent approach to physically manipulating treatments and in-person collaboration might further limit students' developing science identities. We are currently investigating students' science identity and science communication self-efficacy in a face-to-face CURE to compare affect development between hybrid and face-to-face CUREs.

The limited audience during the virtual poster symposium affected students' science communication self-efficacy. Interviews revealed that, during the presentation, more students felt comfortable with their audience, due to familiarity with TAs and course faculty, than felt nervous or intimidated because of the audience's level of expertise. However, some students indicated that lacking prior interaction with their audience, especially with faculty, because of the virtual aspect of this CURE, led to increased nervousness. While nervousness could contribute to a lower science communication self-efficacy, after the presentation, many interviewees (69%) reported increased confidence. Those students shared positive responses to the poster symposium, including having simply survived or confirming that they can indeed present their research. Social cognitive theory (7, 8) explains these responses as resulting from students mastering an experience, i.e., successfully completing their virtual symposium, leading to increased confidence in their ability to communicate science. Our qualitative data converge with our quantitative data, which showed students in both treatments significantly improved their science communication self-efficacy. Interestingly, students in the research-only treatment still reported significant gains in science communication self-efficacy without having yet constructed their poster or present their findings. These reported gains could stem from another aspect of self-efficacy development, vicarious experiences. In this study, students saw peers communicating informally about their research project and shared experiences planning, developing, and implementing data collection up until week 8 of the semester. Future research specifically isolating research aspects from science communication activities will more clearly identify specific sources for science communication self-efficacy improvements.

Students used the Zoom platform to present their research to the TA/faculty audience at the virtual poster session. Using Zoom allowed students to present from anywhere, such as an at-home office or bedroom, which created a sense of comfort and reportedly reduced students' stress. Some students enjoyed being physically absent from an in-person audience, which also played a role in reducing stress. We speculate that physically presenting in front of a live, in-person audience is a source of presentation anxiety for students, which presenting remotely alleviated. However, presenting virtually from a familiar space can also cause distractions, as a student whose father interrupted the question-and-answer session with the audience explained. Noticing one's own facial expressions during a symposium presentation can also distract, as noted by two respondents.

Using Zoom provided some students with clear communication channels and others with what we deemed a "murky" communication channel. Benefits included reading their presentation notes on the same screen to which they

TABLE 11
Science communication self-efficacy with audience during virtual presentation[a]

Theme	Subtheme	Exemplar quote
Confident and familiar with audience members (18)	Confident from audience familiarity (9)	*I had seen [instructor] and [TA], she would always come during our class. So we already knew who they both were*. So I felt pretty comfortable presenting in front of them.
	Fairly confident from preparedness (4)	[TA] asked me a question, and I felt fairly confident answering it. *I didn't feel uneasy about it. I felt pretty prepared.*
	Improved confidence (4)	*I wasn't confident going in. But, when we actually got in there the questions that they asked, I was able to formulate an answer*. Even if you're not 100% confident, you can still be like, "This is what I might propose doing. But I'm not 100% on it."
	Comfortable because expert audience knew what I was trying to say (1)	It was nice, because they actually had way more knowledge on the subject that I was researching than I did. So it was very fortunate for me. Because then *if I explained something not in the best way, they would understand what I was trying to talk about.*
Nervous with distant and expert audience (10)	Nervous/intimidating because audience were experts (5)	*I was probably a little intimidated to know that [faculty] was on there. Because she, you know, she is like, she's a doctor and has been through all this plant biology*. And so if I said something wrong, she would know I was wrong. And so, that was probably a little intimidating.
	Nervous from no prior interaction with professors (5)	So it was a little easy to talk to my lab TA because I've been discussing a majority of my project with her most of the semester. *With [faculty] and [other faculty], I did not have as much interaction with so it made me a little nervous because I didn't know what to expect from them.*
Confidence was question-dependent (3)	Nervous about questions from audience (2)	I know like in lab, [TA] had expressed that she was like, kind of getting frustrated. So *I felt really nervous that she was going to be asking, like, extremely hard questions*.
	Depended on the question audience asked (1)	*It kind of depended on like, the question that I was being asked, because I was super familiar with the data that we took and I had everything on Excel pulled up*. At the end, the person who I didn't know asked something about data that we didn't have on the poster. She asked it to all of us. But I had it. So I was like, "Here, this is this. This is what we got." But. . . then there were some other questions that I was like, wasn't expecting and I didn't know how to answer. Yeah, I think just like, knowing that they could have asked either of us, like a specific question made me nervous.

(Continued on next page)

TABLE 11 (Continued)

Theme	Subtheme	Exemplar quote
Lack of understanding content (1)		I definitely, for this particular project, was a little bit unsteady about some parts of it. *I got asked a question about our methods, and we only actually applied the treatments to our plants once. And so I answered the question wrong because I thought that, like, one of the treatments was being applied way more often than it was* just because we didn't actually do it ourself every time. The TAs did a lot of it.

[a]Authors added emphasis to exemplar quotes using italics to showcase the main idea in the quote.

were presenting, which allowed for a false sense of direct eye contact between the student presenter and the audience. Students commented on the usefulness of reading their notes directly, which they might not have done during an in-person event. Reading notes is one strategy students use to reduce presentation anxiety (22). Students who managed their presentation anxiety via fidgeting or using a stress ball enjoyed the virtual presentation, as they noted their audience could not notice them fidgeting out of their camera's view, providing a sense of comfort and anxiety management without feeling judged. Internet connection issues and students' inability to use their hands to direct audience attention contributed to a murky communication channel. For example, one student commented on their loss of hand gestures to point and instead complained about having to use purely verbal directions for their audience instead of guiding them with hand gestures. Others found it difficult to gauge when to speak during the presentation, because of lagging audio-visual delays.

Limitations and future suggestions

Our treatment groups, research only and research + poster, were limited by the course format in a hybrid model because of the pandemic. We created two treatment groups to isolate the science communication component (including the poster creation/design process) from the research activities component (designing the experiment, collecting and analyzing data) (Fig. 1). However, the events required students to finish data collection and then analyze their data while creating their research poster.

TABLE 12
Positive perceptions of presenting virtually[a]

Theme	Subtheme	Exemplar quote
Stress reduction/relaxed environment (19)	Relaxed and comfortable space (7)	I feel like maybe *being in like, the comfort of your home, like at a desk or something, is a little nice*. It takes the edge off.
	Physically removed from audience (7)	I think *presenting on Zoom was a lot easier than being in front of a group of people and then freezing and not knowing what to say.*
	Less general stress/nondescript (5)	*I felt a lot more confident presenting over Zoom, like it was a lot less scary.* And I think that was like, one of the big plus sides.
Clear communication channel (8)	Virtual presentation benefits (6)	I actually really like [presenting virtually]. Because I, while I'm good at presenting in person, *I was able to have my notes available to me on the same screen, so it was, it was actually a lot more eye contact, as opposed to, you know, presenting in person if I would have to look down at my notes.* So I felt that actually, it was pretty conducive to presenting. And I don't feel like I missed out at all from having to present virtually versus being in person.
	Familiarity with Zoom (2)	*I was pretty familiar with zoom*. So, I think that made it pretty easy.

[a]Authors added emphasis to exemplar quotes using italics to showcase the main idea in the quote.

TABLE 13
Negative perceptions of presenting virtually[a]

Theme	Subtheme	Exemplar quote
Murky communication channel (9)	Communication and presentation issues (7)	It was just kind of hard to gauge. You know, for the two presenters, *it was hard to gauge when one was ending, and the other was starting. And, you know, just not being able to point to things because I'm a very, like when I'm presenting, I like to point and I like to kind of move my hands to move the focus of the room, I guess.* And so, as we presented on Zoom, you don't really have a way to do that. So, you have to keep all your communications really verbal, which kind of takes away from part of my presentations for me.
	In-person preference (2)	*I kind of just like interacting with people in person more.* I feel like we get the point across a little better.
Distractions (3)	Self-conscious from seeing yourself (2)	I thought, "Oh, it'll be easier because it's over Zoom." but really, it's not because you can go back and watch it if you want to. *And you can see yourself speaking, which is nerve-wracking, because I'm like, "Do I really look that stupid? Do I really sound like that?"* I just, I don't want any record of it when I'm done. I just wanted it to be over.
	Outside distractions (1)	And at one point, *my dad walked in when [faculty] was asking my question, and I couldn't hear her. And I was like, "I'm just gonna answer the question I think you asked."* And so, that was really difficult. It's just like, based on just normal zoom problems, I guess.

[a]Authors added emphasis to exemplar quotes using italics to showcase the main idea in the quote.

Thus, we were unable to truly isolate these two aspects. Therefore, it is possible the lack of significant differences between our treatments resulted from the course timeline combining research and communication activities. We recommend future studies attempt to further isolate science communication aspects from research method aspects in a CURE. Some CUREs might require students to complete all research methods, including final data analysis, before designing and creating their research poster—a closer to ideal situation for studying the impacts of science communication activities.

Few undergraduate science programs explicitly include oral communication curricula (23), and although recent literature describes alternative uses for science posters (24–26), instructors might consider including an opportunity for students to communicate their work orally with a broad audience. However, in remote teaching conditions, instructors may find that providing students with opportunities to engage in science practices without a science communication aspect does not hinder students' science identity and science communication efficacy development. Future studies should consider how science identity and science communication self-efficacy develop in a typical face-to-face format without pandemic restrictions and compare these affective factors between hybrid and face-to-face models to identify any significant differences. Future studies should also compare students' perceived skill gains between a hybrid model and face-to-face format. Lastly, an additional research opportunity exists in measuring the impact of alternative scientific poster use on the aforementioned affective factors.

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