SCIENCE IDENTITY AND COMMUNICATION EFFICACY AS A FUNCTION OF PARTICIPATION MODALITY IN UNDERGRADUATE RESEARCH

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MODALITY IN UNDERGRADUATE RESEARCH

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Abstract: Effective science communication is a common goal scientists share, but explicit science communication curriculum is lacking in undergraduate science programs. Although course-based research experiences (CUREs) can provide opportunities for students to practice their communication skills, the literature lacks consistent investigations of oral communication activities and their impact on student outcomes. Furthermore, the emergence of COVID-19 has added a sudden challenge, about which little is known, to improving student outcomes in CUREs.

This dissertation evaluates the role research posters play in students' self-perceptions of science identity, science communication self-efficacy, value, and skills gained in two different course modalities: hybrid and face-to-face. Using a convergent mixed-methods design, I collected quantitative and qualitative self-perceptions across two hybrid semesters and one face-to-face semester from an introductory plant biology CURE. I used a repeated measures posttest approach to isolate poster design and presentation experiences from research aspects, and to collect quantitative perceptions of science identity and communication self-efficacy. I also collected qualitative perceptions of science identity and communication self-efficacy in one-on-one semi-structured student interviews, and qualitative perceptions of value and skills gained from the poster experience from open-ended survey responses.

Within both modalities, I found students' science identity and communication self-efficacy significantly improved even without an oral science communication activity. However, students' communication self-efficacy improved significantly more during the face-to-face modality when they experienced research aspects and presented at a face-to-face poster symposium. In the hybrid modality, students described benefits and complaints regarding a remote virtual research presentation, namely, reduced stress, a more comfortable atmosphere, but a murkier communication channel. In the face-to-face semester, students indicated face masks were a barrier for audio and visual communication. However, students' comments were consistent with the view that research posters were an authentic and engaging experience that improved their science presentation and conversation skills. Students gained science communication efficacy from the research experience under both modalities but presenting a poster did not enhance their efficacy further under the hybrid modality. Faculty should consider this when designing courses under the constraints imposed by the delivery format.

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CHAPTER I

INTRODUCTION

The recent call to action from the American Association for the Advancement of Science (AAAS) included science communication as one of its core competencies for undergraduate biology majors (AAAS, 2011). However, few programs include explicit curricula for practicing science communication at the undergraduate level. Chan (2011) recognized the need for graduates of science programs not only to improve science communication skills in general but specifically improve how scientists orally communicate their research. In addition to providing a review of science communication initiatives, Chan (2011) stressed the importance of training undergraduate students in oral communication skills early before they reach postgraduate levels or enter the workforce. As employers continue valuing excellent communication skills in job candidates (Crosling & Ward, 2002; Dekay, 2012), there is a significant need for science communication opportunities in undergraduate curricula.

A common element of the scientific research experience is the dissemination aspect in which established scientists and emerging professionals, e.g., graduate students and post-doctoral students, participate. This dissemination often takes the form of oral presentations and poster presentations at scientific conferences, but scientists can also disseminate their findings to the general public in the form of science cafes and outreach initiatives. One recent attempt to include science communication training to undergraduate students required neurobiology students to communicate primary literature they read in class to a general audience using a science journalism format (Brownell et al., 2013). However, Brownell et al. (2013) stress the goal was to improve science communication in students, not prepare students for science journalism. Regardless of the audience, disseminating research is an accepted norm of the scientific research experience (Brownell and Kloser, 2015).

One opportunity to embed these research experiences within undergraduate curriculum is through course-based undergraduate research experiences (CUREs). CUREs can offer students a wide range of research experiences including peer collaboration, discovery and relevance, and iteration (Auchincloss et al., 2014; Corwin et al., 2015a). Students experiencing CURE courses can practice their science communication with their peers, as CUREs often require students to collaborate for group projects or one project between all class members (Jordan et al. 2014). However, few studies include descriptions or assessments of science communication within CUREs (Kloser et al., 2013; Sarmah et al., 2016). The few studies that describe and assess science communication activities tailor their assessments to the course, suggesting a need for a standardized science communication assessment instrument for CUREs.

A recent CURE assessment developed by Corwin et al. (2015a) includes criterion based on CURE aspects described Auchincloss et al. (2014). However, science communication was not included as an aspect of CUREs nor in the popular CURE assessment Corwin et al. (2015a) developed. While the goal of my study is not to create a science communication assessment instrument for CUREs, the existing literature gap highlights a need to assess the impact science communication has on students' self-perception.

Research posters can serve as a form of authentic assessment and provide students a way to disseminate their work in an authentic way – i.e., a way that mirrors how professional scientists disseminate their work. In a CURE at a large Midwestern, research-intensive university students had the opportunity to disseminate their research through a poster session (Sarmah et al., 2016). Students reported positive experiences with the poster process and showed gains regarding effective oral presentation skills using the CURE survey developed by Lopatto (2009). Gardner et al. (2010) allowed students to make scientific posters after an introductory neurobiology CURE, but the posters were not created modeling the standard scientific poster format (introduction, methods, results, and discussion) and instead were a condensed version of their results only. Students reported satisfaction with the posters, however Gardner et al. (2010) did not provide a citation or appendix for their 37-item attitudinal survey they used to measure student satisfaction, making comparisons challenging. Using posters as an assessment method continues gaining popularity (Moule et al., 1998) and aligns with the AAAS (2011) call to include science communication as an undergraduate core competency. Therefore, a need exists to measure how students benefit from presenting research posters as an authentic assessment within the context of CUREs.

Purpose

CUREs can provide a myriad of benefits to students, which can in-turn benefit higher-education institutions with increased retention and persistence in STEM courses. While many of these benefits, including science identity and self-efficacy (one's belief in oneself to successfully perform certain tasks to achieve a specific outcome, Bandura, 1977), are measured with different quantitative instruments, recent attempts to condense and standardize these measures neglect assessing science communication self-efficacy. Additionally, research posters as an authentic assessment technique continue growing in popularity, but much of the current research lacks quantitative and qualitative student perceptions of this oral communication activity. Furthermore, the COVID-19 pandemic has forced higher education instructors to consider alternative course deliveries (i.e., modalities). As a result, there is no literature that yet assesses the impact of a science communication activity in hybrid modality on students' self-perceptions, nor is there a comparison of science communication self-efficacy between hybrid and face-to-face (F2F) modalities. The purpose of my dissertation is to identify and evaluate the role research posters as an authentic assessment technique in different modalities can play in shaping students' self-perceptions in an introductory CURE. Specifically, my study is guided by the following research questions:

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

2. How does creating and presenting a research poster affect students' science communication self- efficacy and science identity in a CURE conducted in a face-to-face format?

3. How does students' science communication self-efficacy and science identity development compare between hybrid and CURE modalities?

4. How do students' perceptions of value and skills gained from a science communication activity compare between CURE modalities?

Literature Review

CUREs as research opportunities

Course-based undergraduate research experiences (CUREs) are scalable initiatives that provide research experiences to students within their courses (Hanauer & Dolan, 2014). Scalability is an important aspect of CUREs because CUREs can provide many more students with access to research experiences than the standard apprentice-based model, which relies on a selective one faculty to one (or a few) student relationship. As literature continues to highlight the positive impact of undergraduate research experiences on retention (Lopatto, 2004, Corwin et al., 2015b), CUREs are increasing in popularity. A well-known CURE is the Science Education

Alliance Phage Hunting Advancing Genomics and Evolutionary Science (SEA-PHAGES) program aimed at introductory biology students (Jordan et al., 2014). This program is a year-long research experience providing introductory biology students the opportunity to isolate phages from local soil samples, extract and purify DNA, then send their results to be sequenced. Although this CURE lasts an entire year, Jordan et al. (2014) have developed a useable SEA-PHAGES program model that can be implemented across numerous institutions. As a result, this program is often cited throughout CURE review literature as a popular CURE (Corwin et al., 2015b) for its scalability and its direct contribution to a larger, national phage database useable by faculty for novel research. However, the SEA-PHAGES program does not provide students with a dissemination component. While a dissemination component has not been considered an essential aspect of CUREs (Auchincloss et al., 2014), one might argue that not including a dissemination opportunity removes a degree of authenticity from CUREs.

Aspects of CUREs

While large-scale CUREs and recommendations for future CUREs persist in the literature, biology education researchers began developing criteria for what constitutes course research experiences as CUREs (Auchincloss et al., 2014). CUREs must involve students in the use of scientific practices, discovery, contributing to scientific literature, collaboration, and iteration (Auchincloss et al., 2014). While research attempts to link these aspects with formal definitions of authentic research (Spell et al., 2014), these five CURE aspects can provide a myriad of benefits to students including increased science self-efficacy, enhanced science identity, and increased persistence in science (Auchincloss et al., 2014).

Building from the work of Auchincloss et al. (2014), Corwin et al. (2015a) developed the Laboratory Course Assessment Survey (LCAS) which measures quantitatively the design features that distinguish CUREs from other laboratory experiences. During their instrument development, their exploratory factor analysis suggested the five design features originally posited by Auchincloss et al. (2014) actually condensed to form three features: collaboration, discovery and relevance, and iteration. These three features are best understood to distinguish CUREs from traditional "cookbook" laboratories, and as expected, each feature the LCAS measures factored into its respective construct – i.e., items measuring iteration grouped together, as did items that measured discovery and relevance and iteration with reliability of $\alpha \geq 0.80$. While the LCAS attempts to standardize the features of undergraduate research experiences, and other research attempts to describe these features as an authentic research experience (Spell et al., 2014), no published scales exist that measure science communication skills in students in CUREs. Those studies that publish how students' research is communicated after they participate in authentic research experiences are mostly qualitative, which provides opportunities for developing quantitative science communication assessments.

CUREs and authentic research

A wealth of literature exists which attempts to define authentic research experiences. In addition to providing a thorough review of different authentic research approaches, Spell et al. (2014) attempted to define *authentic research experiences* and found faculty respondents primarily emphasized scientific process as the main theme of authentic research. The working definition of *scientific processes* in their study included forming hypotheses, designing experiments, collecting and analyzing data, and presenting or publishing findings, which aligns closely with the aspect of scientific practices that Auchincloss et al. (2014) use to define CUREs. However, few studies exist which describe and directly assess science communication opportunities in CUREs. Kloser et al. (2013) assessed students in an introductory biology CURE which focused on ecological aspects of yeast. In addition to forming hypotheses and collecting and analyzing data, students were required to present their findings in a conference-like oral presentation to their class peers and course instructors as well write a scientific paper. Using a pretest/posttest design, Kloser et al. (2013) found students reported significantly higher confidence in their ability to orally present their work to their peers. Students also reported higher confidence in their ability to write an accurate, full-length lab report, but the difference between pretests and posttests were not significant. In their development of a conceptual framework for CURE assessment, Brownell and Kloser (2015) mention a CURE they both observed which used posters as a science communication exercise for students. However, they failed to provide a citation for their claim and a search through their references did not produce a study which included the CURE they observed. This limited research suggests that CUREs may not provide a truly authentic research experience to students if the CURE excludes science communication opportunities. Because few studies explicitly describe and assess science communication opportunities within CUREs, my study aims to fill this literature gap by identifying the role scientific posters play in shaping students' self-perception.

CUREs and psychosocial measures

As CUREs continue to gain popularity, numerous constructs have emerged throughout the literature to assess different psychosocial constructs related to authentic research experiences including: self-efficacy (Chemers et al. 2011; Estrada et al. 2011), science motivation (Glynn et al. 2011), grit (Duckworth and Quinn, 2009), ownership (Hanauer and Dolan, 2014), experimental design (Sirum and Humberg, 2011; Deane et al., 2014), science literacy (Gormally et al., 2012), and general presentation skills (Kishbaugh et al., 2012). In an attempt to condense and formalize CURE assessment instruments, Hanauer et al. (2016) developed the Persistence In The Sciences (PITS) instrument. The PITS, in its finalized format, is a 36-item instrument consisting of six factors with overall reliability of α=0.96. According to Hanauer et al. (2016), the goal of the PITS is to accurately measure the psychosocial constructs which previous literature suggests strongly relate to persistence. The six factors within the PITS instrument include project ownership-emotion, science community values, self-efficacy, networking, project ownership-content, and science identity. With each factor's reliability at $\alpha \geq 0.85$, it is not surprising that the PITS is widely used throughout the science persistence literature.

Psychosocial measures and persistence

Once research began to show how students' science self-efficacy and science identity were strongly related to their persistence in science (Lopatto, 2004; Auchincloss et al., 2014; Corwin et al., 2015b), more studies have explored the relationship between those affective constructs (Sawtelle et al., 2012; Larson et al., 2014; Findley-Van Nostrand & Pollenz, 2017). Sawtelle et al. (2012) investigated the role of self-efficacy, along with course type and conceptual understanding, in introductory physics students and found that self-efficacy was a significant predictor of course success in all students. They further investigated how self-efficacy impacted males and females independently and found different aspects of self-efficacy predicted success depending on gender. For Males' master experience in physics was a strong predictor of course success, while for females' social persuasion and vicarious learning significantly predicted course success. Sawtelle et al. (2012) then posited that course success can extend to student persistence in physics. Larson et al. (2014) investigated how undergraduate students' mathematics/science self-efficacy in an introductory biology course predicted their college graduation. After measuring both mathematics and science self-efficacy in 280 undergraduate students, Larson et al. (2014) found that mathematics self-efficacy and science self-efficacy during a students' first semester not only contributed to their ultimate graduation, but self-efficacy significantly contributed more to student persistence than any other measure of prior achievement and aptitude. Recently, Findley-Van Nostrand and Pollenz (2017) evaluated how academic self-efficacy and science identity predicted first-year persistence after a pre-semester engagement program. They also compared program participants to non-participants and found program participants had higher academic self-efficacy and science identity. While Findley-Van Nostrand and Pollenz (2017) found program participants entered with higher reported self-efficacy, they also found program participants persisting in their major at a higher rate than their non-participating counterparts. Overall, recent studies continue to support the phenomenon that self-efficacy and identity positively impact persistence in science.

Research posters as authentic assessments

After students participate in a CURE, one might argue that assessing students should also include an element of authenticity. While different definitions of *authentic assessment* exist throughout the literature, a common definition from Wiggins (1990) suggests authentic assessment requires students to effectively perform with their acquired knowledge and mirror closely the "ill-structured" challenges students will face in the real world (p.1). Using research posters as an assessment technique has been a growing trend since the mid 1990s in different disciplines (Moule et al. 1998). Research posters as a form of authentic assessment began in nursing programs to better prepare nurses' science literacy skills (Moule et al. 1998) and are now used throughout different fields. In a case study about research poster use in social work education, students reported positive benefits from presenting posters over writing assignments as they felt it was easier to communicate their knowledge (Akister et al. 2000). However, some students from the case study still experienced enough performance anxiety to discourage them from presenting posters and instead choose to communicate in writing. Kinikin et al. (2012) tested whether poster presentations improved students' knowledge of information sources in library searches and their ability to find research tools in an introductory library science course. They found students preferred the poster format rather than preparing annotated bibliographies and completing take-home essay exams because students felt they learned more from the course. Ohaja et al. (2013) interviewed 14 nursing students in a midwifery diploma cohort who presented posters as an assessment form. They found students enjoyed presenting posters but did not enjoy the peer-evaluation process because they felt unprepared and intimidated to realistically rate their peers. Lastly, Goldey et al. (2012) used research posters as an authentic assessment in a transformed introductory biology course in addition to online quizzes and student-managed laboratory notebook assessments. The original course format was a standard didactic lecture, but Goldey et al. (2012) transformed the course to include only guided inquiry techniques. Over 600 mixed-major students participated in this freshman level reformed-course study across three years. Students were required to construct and present their posters in teams to their peers. Overall, students reported frustration, but ultimately appreciation, for the poster as they reported more perceived knowledge on their presentation subject than before. Students also had higher perceived gains in writing abilities, using evidence, and developing logical arguments. However, these gains might not be a direct result from the poster independently, but a result of the reformed course format overall.

Science communication self-efficacy

Clearly students perceive value from presenting research posters, but few studies provide quantitative data (Gardner et al., 2010; Kloser et al., 2013; Sarmah et al., 2016) and only one study (Anderson et al., 2016) developed an instrument to assess science communication self-efficacy (SCSE). Anderson et al. (2016) developed that instrument to measure SCSE, career outcome expectations, and interest in science communication activities. Using doctoral students and post-doctoral trainees in biomedical science (n=411), the instrument includes three constructs measuring SCSE in writing, oral presentation, and conversation with reliabilities of ≥ 0.89 for each. Anderson et al. (2016) suggested future studies use their instrument to measure the effect of science communication interventions for job trainees and students alike.

Theoretical Frameworks

My dissertation uses two conceptual frameworks: Bandura's self-efficacy expectations within his larger Social Cognitive Theory (Bandura, 1977; Bandura, 1997) and identity development described by Gee (2000). These frameworks help me interpret students' quantitative and qualitative science communication self-efficacy and science identity scores and interview responses, respectively. Bandura (1977) describes self-efficacy as one's belief in oneself to successfully perform certain tasks to achieve a specific outcome. Situated in my dissertation, science communication self-efficacy is one's belief in their ability to successfully communicate their science. One's perceived self-efficacy can be developed from a single, or combination of, four sources: performance accomplishments, vicarious experiences, verbal persuasion, and/or emotional arousal. Briefly, performance accomplishments (later termed *mastery experiences*, Bandura, 1997) are the most reliable source of self-efficacy development and can significantly raise or lower one's self-efficacy as the individual is directly performing a behavior for a specific outcome. If one performs well, their self-efficacy improves while performing poorly can lower it. Vicarious experiences can also develop one's self-efficacy when an individual compares themselves and their abilities to others', especially when others are most like oneself. Think, "If they can do this, so can I." One can develop self-efficacy via verbal persuasion – i.e., when a significant individual expresses their confidence in one's own abilities. In a biology lab, verbal persuasion might occur when a teaching assistant or lab coordinator expresses confidence or encouragement in a students' ability to perform a certain task. Finally, one's emotional arousal (also termed *physiological state*, Bandura, 1997) can develop one's self-efficacy as people often self-evaluate their physiological response (e.g., stress) to situations. Regarding science communication self-efficacy, one might read one's physiological response (e.g., perspiration, trembling hands) as signs of anxiety or dysfunction before a communication activity. An individual might also read their stress response as a vulnerability (Bandura, 1997), which can lower self-efficacy.

While one can develop their identity in different ways (see Le et al., 2019 for a thorough description of identity production frameworks), the identity framework I use in my dissertation originated with Gee (2000) which describes identity as a "'kind of person' in a given context" (p.

99). Gee (2000) describes four ways to view identity: Nature Identity, Institutional Identity, Discourse Identity, and Affinity Identity. Briefly, Nature Identity refers to an identity one achieves from natural forces (i.e., identical twin) and over which one has no control. Institutional Identity refers to an identity determined by a set of authorities (i.e., the position of professor or research scientists by way of degree). Discourse Identity refers to an identity one achieves from the interactions, dialogue, and/or treatment one experiences with other people (i.e., people recognizing someone as "talkative," "charismatic," or "scientific"). The power of Discourse Identity originates in recognition from others through discourse. Finally, Affinity Identity refers to an identity achieved from sharing practices and experiences with others (i.e., Trekkies or fans of Star Trek). Affinity groups rely on shared participation, access, and allegiance to specific practices (Gee, 2000). Regarding my dissertation, science identity may develop through active discourse in a poster session between undergraduate presenters and faculty scientists and/or other students and scientists at various levels (undergraduate through post-doctoral scientists).

Dissertation Style

My dissertation is structured in a portfolio style (Maxwell & Kupczyk-Romanczuk, 2009) with three individual publications serving as their own chapters guided by different research questions (Table 1). This atypical dissertation style showcases my tangible deliverables and contributions to knowledge and practice (Maxwell & Kupczyk-Romanczuk, 2009) within the field of biology education research. My dissertation project, including the three individual publications as their own chapters, was approved and conducted in accordance with Oklahoma State University IRB guidelines (IRB-20-25-STW; Appendix A).

Chapter 2 contains my first publication (Leone & French, 2022) guided by my first research question and is a convergent mixed-methods study of how two psychosocial factors develop in a hybrid CURE using a virtual poster presentation science communication activity.

Chapter 3 contains my second publication (in review) guided by my second research question. Like Chapter 2, Chapter 3 is a convergent mixed-methods study of how two psychosocial factors develop, but the study context exists in a F2F CURE using a masked, in-person poster presentation science communication activity. Chapter 4 contains my third publication, guided by my third and fourth research questions, which compares two quantitative psychosocial factors and qualitative perceptions of value and skills gained as a function of two CURE modalities. Chapter 5 concludes my dissertation with a discussion of my results for practical implications in STEM education, and suggestions for future research.

Table 1

Data sources for each research question.

Research Question	Identity and Self-Efficacy Questionnaire	Semi-structured interviews	Perceived Value and Skill-gain Questionnaire
1. How does creating and presenting a research poster affect students' science communication self- efficacy and science identity in a CURE conducted in a hybrid format?	X	X	
2. How does creating and presenting a research poster affect students' science communication self- efficacy and science identity in a CURE conducted in a face-to-face format?	X	X	
3. How does science communication self-efficacy and science identity development compare between CURE modalities?	X		
4. How do students' perceptions of value and skills gained from a science communication activity compare between CURE modalities?			X

CHAPTER II

A MIXED-METHODS STUDY OF A POSTER PRESENTATION ACTIVITY, STUDENTS' SCIENCE IDENTITY, AND SCIENCE COMMUNICATION SELF-EFFICACY UNDER REMOTE TEACHING CONDITIONS

Abstract

Disseminating research and communicating scientific findings is an acknowledged part of the research experience, but few science programs include explicit curricula for practicing oral science communication at the undergraduate level. Course-based undergraduate research experiences (CUREs) can provide opportunities for students to practice oral science communication, but few studies describe or assess authentic oral science communication activities within CUREs, and none do so under hybrid conditions. 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 & qualitative perceptions of science identity and science communication self-efficacy in a hybrid CURE and collected students' qualitative perceptions of remotely presenting their research at a virtual poster symposium. We found students' science identity and science communication self-efficacy improved significantly, and benefits and complaints regarding a remote and virtual research presentation. Namely, reduced stress, a more comfortable atmosphere, but a murkier communication channel. Our results will be valuable to educators interested in improving students' science identity and science communication

self-efficacy, especially when limited to a virtual or semi-virtual format, as affective factors strongly impact students' persistence in science.

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 (AAAS, 2011). This core competency underscores providing communication opportunities to students within biology curricula to best develop communication skills students need to effectively communication within and between scientific and non-scientific disciplines. Additionally, as employers continue valuing excellent communication skills in job candidates (Crosling & Ward, 2002; DeKay, 2012), 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 (Brownell et al., 2015; Sarmah et al., 2016; Reeves et al., 2018). Brownell et al. (2015) 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. (2016) 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. (2018)

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 lab (Reeves et al., 2018). 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 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 (Bandura, 1977; Bandura, 1997) and Gee's identity development theory (Gee, 2000).

The Current Study

While CUREs, like mentored research experiences (Corwin et al., 2015; Cooper et al., 2019), provide students with many affective benefits (Hanauer et al., 2016; Esparza et al., 2020), little research exists evaluating students' science communication self-efficacy when presenting research findings orally accompanying posters (Sarmah et al., 2016). 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 (Cresswell & Plano-Clark, 2018) with IRB approval (Appendix A). We collected students' quantitative self-perceptions of science identity and science communication self-efficacy using a quasi-experimental pre-instruction/mid-instruction/post-instruction 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 (Spell et al., 2014) 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 a short-term activity in which they practiced measuring and recording plant characteristics, a literature review of their abiotic stress treatments, and worksheets covering plant morphology and content vocabulary. In the remaining 6 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 semi-structured 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 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 *research only* (BOSQ-EOSQ1) and n=74 in *research + poster* (BOSQ-EOSQ2) groups (Figure 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 standing; number of previous college science courses; and number of previous experiences participating in science fairs (as a contestant, judge, or both) (Table 1). The BOSQ and EOSQs included the same science identity and science communication self-efficacy scales.

Science Identity. We collected students' perceptions of their science identity using three items from the Persistence In The Sciences questionnaire (Hanauer et al., 2016) (see Appendix B), with five options per item anchored from "Strongly Disagree" to "Strongly Agree" and a published reliability of $\alpha = 0.87$. 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).

Science Communication Self-Efficacy. We collected students' perceptions of their science communication self-efficacy using 2 subscales: scientific oral presentation (4 items, $\alpha = 0.89$) and scientific conversation self-efficacy (8 items, $\alpha = 0.89$) from a previously published instrument (Anderson et al., 2016). 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" (see Appendix C).

Qualitative Data Sources

Students willing to participate in the end-of-semester interview (see Appendix D) 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 semi-structured 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 semi-structured interview questions with the quantitative instrument scales.

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 (O'Connor, 2000). PA simulates a fictional dataset matching the EFA dataset size and is often employed as a robust method to identify appropriate factor extraction and prevents over-extraction (O'Connor, 2000). We also calculated Cronbach's alpha reliability of the modified science communication self-efficacy instrument and unmodified science identity instrument.

We performed parametric or non-parametric, as appropriate, repeated-measures 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 (Marx & Cummings, 2007) between EOSQs and BOSQs and compared those between treatments using Mann-Whitney U.

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 student interviews who completed a BOSQ and EOSQ. Additionally, the authors discussed the coding scheme until they reached 100% interrater agreement. Subsequently, one author (EAL) transitioned the data to second-cycle pattern coding using a coding scheme map (Saldaña, 2013).

Both authors identified and discussed emergent themes from the second-cycle pattern coding until they reached 100% interrater agreement (Saldaña, 2013).

Results

Quantitative

The EFA of our modified science communication self-efficacy instrument suggested a two or three factor model (KMO = 0.852, $\chi^2 = 963.20$, df = 66, $p < 0.01$), depending on the scree plot and eigenvalues. PA 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 measures 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 ($U = 3193$, $z = 1.59$, $p = 0.110$) and science communication self-efficacy ($U = 2630$, $z = -0.551$, $p = 0.582$).

Qualitative

The semi-structured 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 *Research*

Question 1, while the qualitative perceptions of a virtual poster presentation answer *Research Question 2.*

Research Question 1

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 sub-divided 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 1) *New to, and growing within, the community*, 2) *Feel official like a scientist*, 3) *Excluded and questioning contribution*, and 4) *Affiliate of the community*. We sub-divided each major theme into sub-themes (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.

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 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, 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 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 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: 1) *Confident and familiarity with audience members*, 2) *Nervous with distant and expert audience*, 3) *Confidence was question-dependent*, and 4) *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.

Positive Perceptions. Two themes emerged: 1) *Stress reduction/Relaxed environment* and 2) *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.

Negative Perceptions. Two negative themes emerged: 1) *Murky communication channel* and 2) *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 non-verbal 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 & presentation from the rest of the 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 (Mraz-Craig et al., 2018; Cooper et al., 2020). Our qualitative data support our findings, as 45% of students' interview responses described a scientist as someone who does or shares research, of which 35% 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 (Gee, 2000) 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 (Carlone & Johnson, 2007). 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 they can indeed present their research. Social Cognitive Theory (Bandura, 1977; Bandura, 1997) 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, like 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 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 (Sari, 2016). Students who managed their presentation anxiety via fidgeting or 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 on 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 & 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 experiment, collecting and analyzing data) (Figure 1). However, the events required students to finish data collection and then analyze their data while creating their research poster. 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 methods 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 more ideal situation for studying the impacts of science communication activities.

Few undergraduate science programs explicitly include oral communication curricula (Chan, 2011), and although recent literature describes alternative uses for science posters

(Stanton, 2013; Gruss, 2018; Mayfield et al., 2018), 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. A concern that science educators have is that the value of involving students in CUREs is negatively affected by the need for remote instruction. We have shown that a hybrid experience contributes to gains in science communication self-efficacy and science identity, and that if the opportunity to present material remotely is unavailable, the gains are not negatively affected. 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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Table 1

Participant demographic data by treatment.

Demographics	% (n) of Participants	
	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)
Number 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)

Demographics	% (n) of Participants	
	Treatment	
	Research Only (n=75)	Research + Poster (n=74)
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/non-conforming, not listed (please specify), and prefer not to answer) participants only selected male or female.

[b] Students included concurrently enrolled science courses into the number of previous science courses they took.

[c] Science fair experiences include participating as a contest, serving as a content judge, or both.

Table 2

Aligned quantitative concepts and instruments with qualitative semi-structured interview questions.

Topic	Quantitative Items	Qualitative Interview Questions
Science Identity	3 Science Identity items (Hanauer et al., 2016)	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 (Anderson et al., 2016)	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.

Table 3

Initial EFA eigenvalues and parallel analysis eigenvalue means.

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

Note. 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	
Rate your level of confidence (even if you have never done it yet) in your ability to…	1	2
...excel in giving scientific presentations (i.e., you usually receive high praise for your presentations from your presentations from your mentor or the audience)	0.492	
...give a scientific talk to a non-scientific 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.	0.40	
...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	

Note: We suppressed factor loadings < 0.3, as any loading under 0.3 indicates weak loading.

Table 5

Science communication self-efficacy and science identity scores by treatment.

Factor	Treatment	Pre-Score (mean ± SD & [95% CI])	Post-Score (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]	$\chi 2 = 9.618$	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]	$\chi 2 = 20.903$	<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**	η2 = 0.220
	Research + Poster	30.69 ± 6.425; [292 - 32.18]	33.19 ± 6.65; [31.65 - 34.73]	F = 11.97	0.001*	η2 = 0.141

**p* < .05. ***p* < .001

Table 6

Interviewee scientist descriptions.

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.

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 7

Alignment with scientist description.

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?'
	Non-descript/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.*

Theme	Subtheme	Exemplar Quote
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.

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 8

Science identity after presenting the virtual poster.

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.

Theme	Subtheme	Exemplar Quote
	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 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.

Theme	Subtheme	Exemplar Quote
	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.

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 9

Science communication self-efficacy before presenting the virtual poster.

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 & doing experiment (5)	I don't think I felt that confident, especially before we'd actually don't 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.

Theme	Subtheme	Exemplar Quote
	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 confidence 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.

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 10

Science communication self-efficacy after presenting the virtual poster.

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.*

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 11

Science communication self-efficacy with audience during virtual presentation.

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.*

Theme	Subtheme	Exemplar Quote
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.
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.

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 12

Positive perceptions of presenting virtually.

Themes	Subthemes	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/Non-descript (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.

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 13

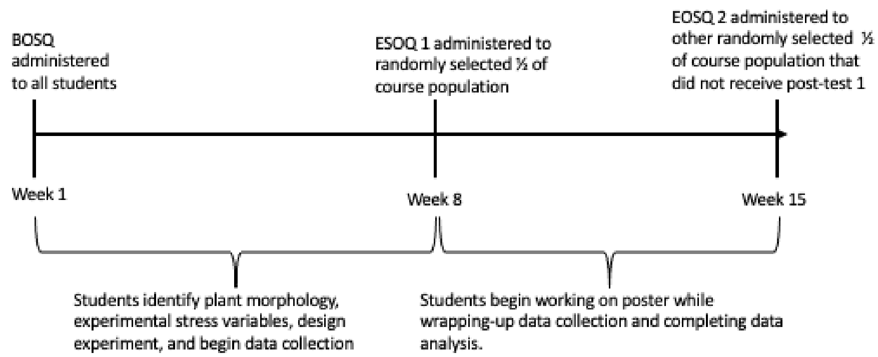
Negative perceptions of presenting virtually.

Themes	Subthemes	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.

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Figure 1

Schematic timeline of course with questionnaire administration



CHAPTER III

A MIXED-METHODS STUDY OF A POSTER PRESENTATION ACTIVITY, STUDENTS' SCIENCE IDENTITY, AND SCIENCE COMMUNICATION SELF-EFFICACY IN FACE-TO-FACE TEACHING CONDITIONS

Abstract

Communicating scientific findings is an accepted part of the research experience, but few science programs include explicit undergraduate curricula for developing or practicing oral science communication. Course-based undergraduate research experiences (CUREs) can provide opportunities to practice science communication, but few studies describe or evaluate authentic oral science communication activities in CUREs. Existing literature lacks considerable evidence for how science communication activities impact students' science identity and science communication self-efficacy regarding research posters. Therefore, we collected students' quantitative & qualitative perceptions of science identity and science communication self-efficacy in a face-to-face (F2F) CURE during the COVID-19 pandemic. We also collected students' qualitative perceptions of participating in a poster symposium and of wearing a face mask while engaging their symposium audience. We found significant improvements in science identity and science communication self-efficacy, as well as benefits and barriers to presenting in a F2F symposium while wearing a face mask. Our results can help educators interested in improving students' science identity and science communication self-efficacy, especially when deciding if a F2F poster symposium in a CURE is appropriate, as affective factors strongly impact students'

persistence in science.

Introduction

Scientists communicate their findings through platform talks, research posters, published articles, science cafes, and public outreach events. Although each communication approach requires its own nuanced skillset, all address a common goal: communicating effectively with an intended audience. The American Association for the Advancement of Science (AAAS) includes science communication as a core competency for undergraduate biology majors in a call to action (AAAS, 2011). The call emphasizes that undergraduate science curricula should provide opportunities for students to develop their skills at communicating effectively within and between scientific and non-scientific disciplines. Furthermore, employers value for excellent communication skills in employees (Crosling & Ward, 2002; DeKay, 2012), bespeaks the need for oral science communication opportunities in undergraduate curricula.

One way students may practice their oral science communication exists in course-based undergraduate research experiences (CUREs). While the benefits of research experiences are well documented in the CURE literature (Hanauer et al., 2016; Esparza et al., 2020), few studies include descriptions or assessments of oral science communication activities (Brownell et al., 2015; Sarmah et al., 2016; Reeves et al., 2018; Liu et al., 2021). Brownell et al. (2015) described students' oral presentation using research posters in a poster symposium for an introductory biology CURE and measured its impact on students' thinking like a scientist. Sarmah et al. (2016) reported gains in students' presentation confidence after students presented their research from a cellular biology CURE at a departmental research symposium. Similarly, Liu et al. (2021) reported gains in students' general self-confidence and skills giving an effective oral presentation after presenting a research poster in an introductory cell and molecular biology CURE. Reeves et al. (2018) also found significant improvement in students' oral communication confidence, but approached oral communication differently by requiring students to provide brief data reports within their respective lab sections at several points throughout the semester. While these studies report gains in students' oral communication confidence, they use diverse quantitative measures and do not account for students' qualitative perceptions. Additionally, most of these studies occurred before the COVID-19 pandemic required that CUREs be modified to include additional safety protocols. Thus, there is also a need to revisit how CUREs, operating with safety protocols, impact students' oral communication confidence. Only one known study (Leone & French, 2022) investigates how students' science communication self-efficacy and science identity developed in a hybrid CURE, which found no significant differences in communication self-efficacy and science identity between students who completed research tasks without a communication activity and research tasks coupled with a virtual communication activity. This study is the first to report affective development related to oral communication in a CURE with mask protocols. and a masked poster symposium event.

The Current Study

The purpose of our study is to evaluate how students' science identity and science communication self-efficacy develop in a F2F CURE which used a masked F2F poster symposium as an authentic assessment. Our study was guided by the following 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 F2F CURE using a masked poster symposium as an authentic assessment?

RQ 2) What are students' general perceptions of participating in a F2F poster symposium?

RQ 2a) What are students' perceptions of the impact of wearing a face mask during a F2F poster symposium?

Methods

Study Design

Our study was classified as an exempt project per IRB approval (IRB-20-25-STW). Upon approval, we used a convergent mixed-methods approach (Creswell & Plano-Clark, 2018) to analyze quantitative and qualitative self-perceptions of science identity and science communication self-efficacy. We used a quasi-experimental pre-test and multiple post-test design to collect quantitative self-perceptions; we used semi-structured one-on-one interviews to collect qualitative perceptions of science identity, science communication self-efficacy, and perceptions of participating in a masked poster symposium at the semester's end.

Course Context

We gathered data from students at a large, public, research-intensive university located in the South-Central United States enrolled in a process-focused (Spell et al., 2014) introductory plant biology CURE. The CURE involves a semester-long investigation of plant phenotypes' response to abiotic stress, which is connected to ongoing faculty research. We collected data from this CURE during a semester in which the university allowed instructors to resume full F2F instruction with expectations that students wear face masks in class. The plant biology CURE met F2F once weekly for 14 weeks. In the first 6 weeks, research teams of four students were introduced to the scientific method and plant microscopy, completed a literature review for the semester-long project, and planted their experimental organism. They also completed a short-term activity in which they practiced measuring plant characteristics and used excel to practice entering data into a spreadsheet. In the following 8 weeks, students created their research poster while completing data collection and analysis. Students received iterative feedback from their teaching assistant (TA) for each of the research poster sections (Introduction, Methods, Results, & Discussion) before finalizing the poster for printing in week 14. Students presented their posters, which TAs assessed as part of their laboratory grade, at a public, F2F, masked presentation in week 16.

Data Collection

We recruited students (n=167) 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 semi-structured interview via Zoom. After we administered the BOSQ, we effectively created two treatment groups by randomly administering the EOSQ-1 to half the students after they submitted their finalized poster for printing (what we deem *Poster Design*), and EOSQ-2 to the remaining students after they presented their poster at the masked face-to-face symposium (what we deem *Poster Presentation*). Each consenting student completed the BOSQ (n=95) and either EOSQ-1 (n=48) or EOSQ-2 (n=60). After removing incomplete responses, duplicate attempts, and incorrect responses to a quality control item, the final sample size of matched responses was n=30 in *Poster Design* (BOSQ-EOSQ1) and n=36 in *Poster Presentation* (BOSQ-EOSQ2) groups (Figure 1). We used n=66 usable BOSQs to calculate instrument reliability.

Quantitative Data Sources

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

Science Identity. We used three science identity items from the Persistence In The Sciences questionnaire (Hanauer et al., 2016) (see Appendix B), with five optional responses anchored from “Strongly Disagree” to “Strongly Agree” and a published reliability of $\alpha = 0.87$. Scores range from 3 to 15. Lower scores indicated a limited science identity; higher scores indicated a high science identity.

Science Communication Self-Efficacy. We gathered students’ perceptions of their science communication self-efficacy using two subscales: scientific oral presentation (4 items, $\alpha = 0.89$) and scientific conversation self-efficacy (8 items, $\alpha = 0.89$) from a previously published instrument (Anderson et al., 2016). An identical question stem, “Rate your level of confidence (even if you have never done it yet) in your ability to…” preceded all items, which contained five response options anchored from “Very Insecure” to “Very Confident”. The original subscales are intended for graduate and medical student use, so we used a version of this instrument modified for an undergraduate audience (Leone & French, 2022). Thus, the modification resulted in a combined reliability score $\alpha = 0.84$, with potential scores range from 10 to 50. Lower scores indicated lower self-efficacy; higher scores indicated higher self-efficacy (see Appendix C).

Qualitative Data Sources

Students indicated their willingness to participate in the end-of-semester interview (see Appendix D) by providing contact information on the BOSQ. We only interviewed students after they completed their poster presentations. Interviews via Zoom followed IRB-approved, social-distancing, safety guidelines. We collected audio files from n=15 semi-structured interviews, transcribed the interviews using Otter.ai, an automatic transcription service, and reviewed each transcript with its corresponding audio file to correct transcription errors. Table 2 aligns the interview questions with the quantitative instrument scales.

Data Analysis

Quantitative

We performed all analyses using IBM SPSS 26. We calculated Cronbach's alpha reliability for science identity and science communication self-efficacy using the n=66 completed BOSQ responses. We performed parametric or non-parametric, as appropriate, repeated-measures analysis of variance on (ANOVA) within treatments on raw, paired scores to determine how students' quantitative perspectives changed. We then calculated normalized change scores (Marx & Cummings, 2007) between EOSQs and BOSQs and compared those between treatments using Mann-Whitney U tests.

Qualitative

We used NVivo for analysis of interview transcripts. We utilized an inductive approach employing in-vivo coding for our first-cycle coding scheme to create codes for each interviewee's question responses. To establish qualitative validity, we triangulated our data by including only student interviews (n=14) who completed a BOSQ and EOSQ in our analyses. Additionally, the authors discussed the coding scheme until they reached 100% interrater agreement. One author (EAL) transitioned the data to second-cycle pattern coding using a coding scheme map (Saldaña, 2013). Both authors identified and discussed emergent themes from the second-cycle pattern coding until they reached 100% interrater agreement (Saldaña, 2013).

Results

Quantitative

Research Question 1

Reliability for our science identity and science communication self-efficacy instruments were $\alpha = 0.76$ and $\alpha = 0.88$, respectively. Friedman's repeated measures ANOVAs revealed significant increases in students' science identity and science communication self-efficacy within the *Poster Design* and *Poster Presentation* treatments (Table 3). Science identity did not differ significantly between treatments (U = 590, z = 0.64, p = 0.516), but treatments differed significantly in their science communication self-efficacy development (U = 689.50, z = 1.93, p = 0.054).

Qualitative

The interview covered four topics: science identity development, science communication self-efficacy development, perceptions of presenting at a F2F symposium, and perceptions of wearing a mask while engaging the audience. We report science identity and science communication self-efficacy development to answer *RQ 1*, while the qualitative perceptions of the F2F symposium and masks answer *RQ 2*, and *RQ2a*, respectively.

Research Question 1

Science Identity. Students described a scientist in multiple ways, with 42.8% describing scientists as someone who gains knowledge and 28.5% describing scientists as having a specific personality trait. The remaining response (28.5%) described a scientist with either a physical description (e.g., white lab coats) or as someone with general interest in any science field (Table 4). When students compared themselves to their scientist description, half identified themselves as a developing scientist, while the other half was split between other identity themes: *I am a scientist* (21.4%), *Partly a scientist, partly not* (14.2%), *Still exploring* (7.1%) and *Not a scientist* (7.1%) (Table 5).

Four themes emerged when students described their science identity after presenting their poster: 1) *New to the community*, 2) *Improved belonging*, 3) *Part of the community*, and 4) *I don't belong yet*. When applicable, we subdivided themes into sub-themes (Table 6). Students feeling new to the community felt as though their "…foot's in the door to a degree" indicating an emergence into the scientific community. Some students reported improved belonging, citing more involvement in the community, while others attributed improved belonging to feeling more accepted and comfortable in the scientific community. One student did not see themselves as part of the community because they had yet to "earn their spot", citing their need to expand their scientific understanding to consider their community participation.

Science Communication Self-Efficacy. Before they presented, most students (64.3%) reported improved confidence. Conversely, the remaining students (35.7%) reported unchanging confidence with either zero confidence (n=3) or existing confidence (n=2) (Table 7). Some students' science communication self-efficacy improved from gaining content knowledge and completing the research experience (n=3) while others' confidence improved from seeing, "our whole poster together" (n=2). Some students attributed their existing confidence to their work ethic before they presented their poster, as one student noted, "…we worked pretty hard on it [poster]. And so I knew that when we did present, we're doing pretty good."

Students also reported improved confidence after they presented their poster, with a majority (71.4%) indicating improvement (Table 8). While some students did not attribute their improvement to any specific experience (n=3), others specifically attributed their improved confidence to multiple presentations during the symposium (n=2), the experience of presenting their research (n=2), and the length of their research experience (n=1). A minority of students (n=2) reported their confidence depended on circumstances. For example, one student shared, "…with the right team around me, and a clearer picture of what I needed to do, I feel like I could do it [present] again." Finally, some students (n=2) indicated high confidence without mentioning confidence changes.

The diverse audience impacted students' science communication self-efficacy which resulted in three emergent themes: 1) *Conditional confidence*, 2) *Confident*, and 3) *Improved* *confidence* (Table 9). Although a diverse audience attended the symposium, 64.3% of students reported their confidence depended on whom they engaged. Particularly, three students indicated feeling nervous with faculty, but more confident with other audience members, which included the course's TAs and both graduate and undergraduate students unassociated with the course. In addition to student presenters feeling more confident with undergraduate attendees, some presenters (n=2) also reported improved confidence speaking with their instructors after presenting to their TA. Different presenters (n=2) were confident with all audience members, with their confidence reportedly increasing with the number of interactions. Finally, 28.6% of presenters reported general confidence engaging their audience.

Research Question 2

We asked students to share their general perceptions of presenting at the F2F symposium, which resulted in three major themes: 1) *Emotionally charged*, 2) *Over or under stimulated*, and 3) *Relating to the unknown* (Table 10). One student described their experience in multiple ways, which resulted in more coded responses (n=15) than interviewees. Most responses (n=8) indicated students were emotionally charged during the symposium, describing the experience as "nerve-wracking" and "fun". Other responses (n=5) indicated the symposium was over or under-stimulating. The crowd density in the small symposium space was overstimulating to some students, who described their experience as "hectic" and "…people walking in and out, and conversations constantly going on." Under-stimulated responses indicated other students were annoyed with how frequently they repeated their project information or simply, "standing there and waiting". Finally, n=2 responses suggest students were differentially surprised by their symposium experience. One response suggested the symposium reminded the student of a previous presentation experience in high school, while the other response suggested the entire experience was surprising and "took me [the student] off guard."

Research Question 2a. The F2F symposium required presenters and attendees wear face coverings. Therefore, we asked student presenters to share their perceptions of wearing a face mask while engaging their audience, which resulted in three major themes: 1) *Communication barrier*, 2) *Mask adaptation*, and 3) *Positive barrier/Mardi Gras effect* (Table 11). One student described their experience in multiple ways, which resulted in more coded responses (n=15) than interviewees. Most responses (n=9) indicated masks acted as a communication barrier, citing visual issues (n=5) or vocal issues (n=4). Students described visual issues as the inability to read lips and mouths, while other students stated the mask muffled their voice in an already loud room, forcing them to step closer to their audience and speak louder. *Mask adaptation* encompassed (n=5) responses which described masks as a non-issue because, "I'm used to it. I mean I've been doing it for two years." The final response suggested a positive interaction with masks, as a particular student felt "It [the mask] helps me calm my nerves down. Okay, you couldn't see my face."

Discussion

Our goal was to determine how poster creation and presentation contributed to students' science identity and science communication self-efficacy development in a F2F format. Due to course limitations, we isolated the poster presentation aspect from the research and poster creation processes by evaluating each of two sets of students at one of two time points (*Poster Design* and *Poster Presentation*). We found science identity improved significantly, but not differently, in both treatments. This suggests participating in a F2F poster symposium does not significantly improve students' science identity if they previously participated in other research aspects (i.e., experimental design, collecting and analyzing data, creating a research poster) in the same semester. Improved science identity in our *Poster Design* treatment aligns with literature which suggests students' who participate in activities similar to scientists develop a science identity (Mraz-Craig et al., 2018; Cooper et al., 2020). Qualitative descriptions explain students' science identity development, as 42.8% of interviewees described a scientist as someone who gains knowledge, and 50% of interviewees identified as a developing scientist. Although not explicitly stated, we speculate our interviewees implied “research” or “research methods” as a means of gaining knowledge when they described scientists as someone who gains knowledge.

Identity development theory (Gee, 2000) helps frame our science identity findings. Science identity development may rely on a discursive experience (Gee, 200) in which students discussing their science with peers and professionals improves their science identity. Students worked in teams of four, which may have provided avenues for semester-long discussions about their research project in our *Poster Design* treatment (Carlone and Johnson, 2007). Although we did not find significant differences in science identity between treatments, we speculate science identity also significantly developed in the *Poster Presentation* treatment through social-professional discourse at the symposium between presenters and the audience. Most of our interviewees (92.8%) indicated positive perceptions with the scientific community after they presented their F2F poster – either being new to the community with “my foot in the door” or having an improved sense of belonging, whereas 7.2% of interviewees felt they did not belong to the community due to their perceived lack of science content knowledge. Our science identity findings align with those from Leone and French (2022) who found science identity did not significantly differ between students in a hybrid CURE who presented a poster virtually, and students who completed research activities without designing or presenting a poster. Therefore, we posit that significant science identity development relies more on students participating in research activities similar to a scientist than communicating research findings.

Students presented to a diverse audience at the F2F symposium, which included course personnel (course faculty and TAs), institutional administration, and unassociated faculty, graduate and undergraduate students. We found the diverse audience differentially impacted students’ science communication self-efficacy, as our interviews revealed presenters’ confidence depended upon with whom they discussed their research. Presenters felt particularly nervous discussing their research with faculty, because they perceived faculty as experts. While interacting with faculty may have inhibited self-efficacy development, engaging with other audience members such as TAs, graduate, and undergraduate students increased science communication self-efficacy because "[my TA] helped walk me through the whole process" and "it felt like we were in the same playing field." Our findings partially align with those in Leone and French (2022), who found that students' presenting to only course faculty and TAs in a virtual symposium felt nervous and intimidated by the course personnel's content expertise. We recommend future studies investigate how students navigate their anxiety with perceived content experts during an oral presentation.

Interviewees reported improved science communication self-efficacy both before and after the symposium. Before their presentation, interviewees attributed their improvement to knowledge gain, progressing through their project, and seeing their poster develop into a final product. Our qualitative data supports our quantitative self-efficacy results, which showed significant science communication self-efficacy improvement in both treatments. However, students in the *Poster Presentation* treatment reported significantly higher self-efficacy development compared to the *Poster Design* treatment. Social Cognitive Theory (Bandura, 1977; Bandura, 1997) contextualizes our results, which explains improved self-efficacy develops from mastering an experience, i.e., successfully completing their F2F symposium, which led to improved confidence in students' ability to communicate science. We speculate that students in the *Poster Design* treatment reported significant science communication self-efficacy development from another aspect of self-efficacy development: vicarious experiences, i.e., seeing someone similar to oneself complete a task (Bandura, 1977; 1997). Throughout the semester, students saw their group peers communicating informally about their project while they engaged in research activities. We speculate vicarious experiences and social group dynamics in small research teams played a role in students' developing their science communication self-efficacy, as suggested by Leone and French (2022), who found similar improvements in students who completed research activities without presenting their research poster.

The extant literature lacks student perceptions of participating in a poster symposium, especially in a F2F format during the COVID-19 pandemic. Therefore, we asked students to share their general perceptions of participating in the F2F poster symposium and their perceptions of wearing a face mask while engaging their audience. Most students navigated multiple emotions, describing their symposium experience as "nerve-wracking," "fun," and "excited about everything." We speculate navigating these different emotions created a source of physiological stress for students (Lea et al., 2019). Bandura (1977; 1997) explains monitoring one's physiological state impacts self-efficacy development, which may have contributed to differential self-efficacy development in our study. Others attributed the large crowd density in the small symposium space to difficulty hearing and distractions, which over-stimulated some students, while others felt under-stimulated from "…just standing there and waiting." Our findings slightly align with those in Leone and French (2022), who found students presenting posters virtually felt comfortable because they presented from a comfortable space like an at-home office or bedroom, but still experienced distractions such as interruptions from family members.

Face masks were required for student presenters and audience attendees, which created visual and vocal communication barriers for students. The perceived small space, which presenters described as too crowded, placed greater importance on verbal and non-verbal communication. Presenters indicated masks inhibited their ability to read lips, a communication tactic one might use in a loud environment. A loud environment might also require more vocal effort to raise voice volumes, which masks impeded according to students. Although limited research investigating mask perceptions exists, it contextualizes our results. In recent studies, Saunders et al. (2021) and Karagkouni (2021) found negative impacts on hearing and understanding, and increased perceptions of voice discomfort and intelligibility in the general public, respectively. Our findings relate to the limited literature, as students indicated vocal and visual issues associated with wearing a face mask. However, not every student reported concerns with masks, as some indicated they adapted to wearing masks because, "…I've been doing it for two years." Interestingly, one student described the mask experience as positive because the mask hid their face which calmed their nerves about presenting.

Limitations & Future suggestions

We created two treatment groups to isolate the oral science communication component from the research activities component (Figure 1). However, one may argue poster development is itself a science communication activity, as creating effective visuals for a poster requires representational competence (Halverson & Friedrichsen, 2013; Daniel et al., 2018). Therefore, it is possible students' science communication self-efficacy in the *Poster Design* treatment increased during poster development. We recommend future studies isolate research activities, poster development, and oral communication aspects in CUREs to test how each individual aspect impacts affective development. We also recommend future studies investigate how science communication self-efficacy predicts persistence in undergraduate science programs, as extant literature establishes a strong relationship between general science self-efficacy and science program persistence (Hanauer et al., 2016).

Conclusion

Research posters are one popular approach scientists, regardless of discipline, use to communicate their work. In fact, recent literature promotes new creative ways to use posters in the classroom (Stanton, 2013; Gruss, 2018; Mayfield, et al., 2018). We have shown that a CURE using a F2F poster symposium in the COVID-19 pandemic improves science identity and science communication self-efficacy, and if the opportunity to present research F2F is inaccessible, science identity improvements are not negatively impacted. Our results are useful to interdisciplinary STEM course instructors who are considering a F2F science communication poster activity, especially during the pandemic.

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Table 1

Participant demographic data by treatment.

Demographics	% (n) of Participants	
	Treatment	
	Poster Design (n=30)	Poster Presentation (n=36)
Gender [a]		
Male	30 (9)	19.4 (7)
Female	66.7 (20)	80.6 (29)
Prefer not to answer	3.3 (1)	0.0 (0)
Race		
American Indian or Alaska Native	13.3 (4)	5.6 (2)
Asian	3.3 (1)	11.1 (4)
Black or African American	6.7 (2)	0.0 (0)
Native Hawaiian or Other Pacific Islander	0.0 (0)	0.0 (0)
White	73.3 (22)	72.2 (26)
Other	3.3 (1)	11.1 (4)
Ethnicity		
Hispanic or Latinx or of Spanish Origin	3.3 (1)	16.7 (6)
Not Hispanic or Latinx or of Spanish Origin	96.7 (29)	83.3 (30)
Classification		
Freshman	33.3 (10)	5.6 (2)
Sophomore	30 (9)	44.4 (16)
Junior	20 (6)	25 (9)
Senior	16.7 (5)	25 (9)
Number of previous college science courses[b]		
1	13.3 (4)	5.6 (2)
2	13.3 (4)	8.3 (3)
3	10 (3)	11.1 (4)
4	6.7 (2)	8.3 (3)
5	3.3 (1)	8.3 (3)
6	6.7 (2)	13.9 (5)
More than 6	40 (12)	41.7 (15)
No previous college science courses	6.7 (2)	2.8 (1)
Previous science fair experiences [c]		
1	13.3 (4)	36.1 (13)
2	16.7 (5)	5.6 (2)
3	6.7 (2)	0.0 (0)
4	3.3 (1)	2.8 (1)

Demographics	% (n) of Participants	
	Treatment	
	Poster Design (n=30)	Poster Presentation (n=36)
5	0.0 (0)	2.8 (1)
6	0.0 (0)	0.0 (0)
More than 6	0.0 (0)	2.8 (1)
No previous experiences with science fairs	60 (18)	50 (18)

[a] While we offered seven options for gender (male, female, transgender male, transgender female, gender variant/non-conforming, not listed (please specify), and prefer not to answer) participants only selected male, female, or prefer not to answer.

[b] Students included concurrently enrolled science courses into the number of previous science courses they took.

[c] Science fair experiences include participating as a contestant, serving as a content judge, or both.

Table 2

Aligned quantitative concepts and instruments with qualitative semi-structured interview questions.

Topic	Quantitative Items	Qualitative Interview Questions
Science Identity	3 Science Identity items (Hanauer et al., 2016)	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 (Anderson et al., 2016; Leone & French, 2022)	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.

Table 3

Science communication self-efficacy and science identity scores by treatment.

Factor	Treatment	Pre-Score (mean ± SD & [95% CI])	Post-Score (mean ± SD & [95% CI])	Test statistic	p-value	Effect Size
Science Identity	Poster Design	10.33 ± 2.383; [9.44 - 11.22]	11.17 ± 2.306; [10.31 - 12.03]	$\chi 2$ = 6.00	0.014*	Kendall's *W* = 0.20
	Poster Presentation	9.94 ± 2.378; [9.14 - 10.75]	11.36 ± 2.206; [10.61 – 12.11]	$\chi 2$ = 12.46	<0.001**	Kendall's *W* = 0.346
Science Communication Self-Efficacy	Poster Design	33.47 ± 7.811; [30.55 – 36.38]	36.03 ± 6.651; [33.55 – 38.52]	F = 5.38	0.028*	η2 = 0.156
	Poster Presentation	30.33 ± 6.787; [28.04 - 32.63]	35.83 ± 7.137; [33.42 – 38.25]	F = 40.25	<0.001**	η2 = 0.535

$^{*}p < .05.$ $^{**}p < .001$

Table 4

Interviewee scientist descriptions.

Theme	Exemplar quote
Gaining knowledge (6)	A scientist, to me looks like *somebody who is constantly working to figure out something that hasn't been figured out before. … They're just trying to further the knowledge.*
Personality trait (4)	To me, a scientist is someone who, like, *thinks in like terms of, like, scientific procedures. Professional. Some of the words that comes to my mind. Intelligent.* Someone who's willing to fail to find the correct answer. That's all I got.
General interest/curiosity (2)	To me, a scientist, I think has many different forms. It's just *someone who, um, just kinda is more into biology or chemistry or like psychology or pretty much any -ology It's just anyone who takes an interest in science*, I feel, like me. Like, it just has many different forms.
Physical description (2)	It's just about *anyone in a white lab coat, probably with some goggles on,* maybe

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 5

Alignment with scientist description.

Theme	Subtheme	Exemplar Quote
Developing Scientist (7)	Scientist in training (4)	I see myself as a learner. I wouldn't necessarily call myself a scientist, I do do research on my own. But in terms of like, research it's not my primary thing. I like just learning in classes. *Um, I would say, I see myself as, like a scientist in training, I guess.*
	Novice, need more experience (3)	I think I'm definitely in the very beginning stages. I think as I learned more about science, I'll hopefully get a little bit better. *But I definitely think I'm like a baby scientist in a way of I definitely haven't learned everything or scratched the surface, but I'm slowly getting there.*
I am a scientist (3)		I mean, as someone who enjoys science, *I guess I would consider myself a scientist.* You know, I took a very heavy course load in high school about science. So and I'm undergrad in biology. So I guess I would look at myself as a scientist.
Partly a scientist, partly not (2)		I would say I'm also a scientist, too, but like, not as much, because we did do our experiment and did our research over... ours was over mung beans…*So I would say I'm also a scientist, but not as much as some of those other people who are their whole job is just to research and to learn more about science. I just did it for a class.*
Still Exploring (1)		I see myself well, I'm going towards what I want to do what I'm happy with. And... but I haven't reached the moment of, like, "I found the research that I want to do for the rest of my life". But I have found the topics that I'm like, "This is really good. I like this. *This is a good starting point". But I haven't even begin to get towards the end of it.*

Theme	Subtheme	Exemplar Quote
Not a scientist (1)		*I mean, I'm just not a scientist, I don't compare myself to them.* You know, just because I really can't, you know, I do field stuff.

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 6

*Science identity after presenting the face-to-face poster***.**

Theme	Subtheme	Exemplar Quote
New to the community (5)	My foot’s in the door/on the right track (4)	Um, so I would say, like, *I can kind of understand that, like, my foot's in the door to a degree of it, but it's definitely not like, I'm not all the way in there.* And like, going to be doing research and stuff, but it's going to be kind of in the field aspect of science.
	Still a scientist in training (1)	Um, I don't think it necessarily, like, changed my view [of scientist in training]. But I do think that it was nice to get that experience, because I know we're all a little bit nervous, as most people are before they present, but it was nice to know that it was kind of a chill environment. And the questions that were asked were respectful.
Improved belonging (5)	More involved in the community (3)	*I actually felt more involved*. I would, I would agree with that… I started out in a group of four, and then I ended up in a group of two. So I had kind of a majority of the work and I did figure out what exactly I was doing. And I kind of had to know what I was doing to be able to present it. *So yes, I would feel more involved after doing a poster.*
	More accepted and comfortable (1)	*I feel more… more comfortable, more accepted.* I didn't get a lot of harsh criticism when presenting my poster, which was really nice. Because that's you got a lot of that in engineering - harsh criticism. And when I was presenting my poster, was more like, "Hey, why did you do this? Can you help me understand? Can you answer my questions, maybe we can work together to figure out a future problem.”? I had one person come up to me, and they were kind of like, suggesting why our research was good. You know, it's nice to have that kind of like feedback. *So it does make me feel comfortable to be a part of the scientific community in that sense.*

Theme	Subtheme	Exemplar Quote
	More confident (1)	*I definitely feel more confident now that I've had some experience within the scientific community*. And I feel like that whole experience with presenting a scientific poster will definitely help me as I pursue a degree in science and throughout the rest of my college and university career.
Part of the community (3)	Part of the scientific community (2)	Um, after presenting the poster*, I would say I definitely am a part of the scientific community.* Because the poster made you delve into your topic, which was ours was mung beans, how light, and daylength affects them. So it really makes you connected to the greater scientific community as a whole, because they make you research and study and use the scientific method to find out more about mung beans. And then the presentation also helps you connect with scientific community because it shows like this is what we learned and then presenting it to others. *It like connects them to what you learned about your poster. So it makes you like, immersed into the scientific community.*
	Fairly grounded in it (1)	*I think I'm pretty fairly grounded in it*. There is no doubt that as a psychology and so I'm a psychology major with a minor in biology, that I'm going to be looking into the future and doing papers and poster presentations and PowerPoint presentations, just based on the fact that where I'm planning to settle at involves research on the biology, you would call it behavioral health. It's on the on the biology and on mood disorders. So kind of finding out what's actually triggering these problems for some people.
I don’t belong yet (1)		*Um, I don't really see myself as like, part of the scientific committee community, yet. I'm working on it. But um, I… I don't know. It's like I'm working on being part of the scientific community, but I don't necessarily feel like I belong there yet.* I feel like I haven't really earned my spot. I feel like I definitely need to practice a few things and like, expand my

Theme	Subtheme	Exemplar Quote
		knowledge before I can consider myself part of the scientific community.

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 7

*Science communication self-efficacy before presenting the poster***.**

Theme	Subtheme	Exemplar Quote
Improved Confidence (9)	Improved confidence from knowledge gain and research experience (3)	Well, … *putting this poster together, getting the abstracts, the discussion, the results, everything necessary to have a scientific poster made me very nervous.* … we formulated a good quality poster by the end of the semester, *when that was finished, my confidence levels rose a lot, because not only did I gain the knowledge of doing the research and putting together the poster, but also I was more comfortable with the actual contents on the poster as a result of putting those things together.*
	Improved confidence from seeing it all come together (2)	But I don't know, *my confidence grew as it got closer, because I saw our whole poster together. And I thought it looked really good.* And like I had read through it all I've like I had practiced. So my confidence was pretty low until like the week before.
	Improved confidence over time (2)	Um, at first, I was not very confident…, *but I think as the day approached, I got, like, more confident, I felt like I knew more about our project, and like, the reasoning behind what we did and what we saw. And then, of course, like, you know, a couple days before, although I knew what I was gonna say, and, you know, I kind of had the spiel down….*. But yeah, *I was like, I got more confident as the semester went on*.
	Improved confidence from reading and practicing poster (1)	*I was very nervous at first because we all focused on different parts of the poster.* And we all had our own variables. So presenting on someone else's data that they did hands on, I was very nervous about that. *As I started reading and practicing, I definitely became more confident in it.*

Theme	Subtheme	Exemplar Quote
	Improved confidence after seeing progress on project (1)	*So, as the project progressed, and I started to see more progress being made towards the end product, I started to feel more confident,* you know, at the sort of felt very daunting.
Zero confidence (3)		Um, it was *zero until I actually started presenting.*
Confident already (2)		Um, I was very confident I knew our research. Like we worked pretty hard on it. And so I knew that when we did present, we're doing pretty good. We looked over the poster, we all knew what we were supposed to say. *So I felt pretty confident in it.*

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 8

*Science communication self-efficacy after presenting the poster***.**

Theme	Subtheme	Exemplar Quote
Improved confidence (10)	Improved confidence, nondescript (3)	And I am actually… I'm really glad they set up the class like this, because I feel better about presenting after. *So, I am more confident than I was before, basically.*
	Improved confidence after multiple presentations during the symposium (2)	I feel a lot more confident. The first time we presented it was toward our TA… I was definitely a little shaky on the research and we didn't quite have a flow yet of how we were all presenting it. *And after we did that first time and more people started coming up to us. I definitely feel a lot more confident about presenting it to others.*
	Improved confidence from the experience (2)	*I would say I'm, like, very confident now presenting research because we have that initial practice.* Because before, it was just like, I never presented before. So, you didn't know how to present your research. But now that you have presented research, it's like, "Oh, I've already done that, so it's not going to be hard next time with presenting research." *So, I would say the confidence of presenting research went up because of the presentation.*
	Improved confidence from long research experience (1)	*I say it was, it's definitely higher than it was before.* I feel like I can adequately present my research. *Because, like, if I've worked on it for as long as I have, I'm going to know what's going on*. I got understand it.
	Slight improvement (1)	Much greater? *Now it's not anything atmospheric, but it's, it's higher*. Just because I've done it before. I know sort of the questions that are kind of going to be asked…If you asked me to do one again, I would be able to do it in a much faster timeframe than my initial project.

Theme	Subtheme	Exemplar Quote
	Higher but still nervous (1)	Um, I'm… *I'm confident, but I'm not. I, I'm still nervous.* But I feel like that's just a natural thing to be. But I feel like if I, if I could present my research, again, I wouldn't change very many things, which is good. *So I would say my confidence after is a lot higher*.
Conditional confidence (2)		Yes, I would I, *with the right team around me, and a clearer picture of what I need to do. I feel like I could do it again.*
Confident (2)		Oh, I'm like, totally dead-on with it. Because I don't think… I didn't have a single moment's hesitation when I was asked questions, and I was able to answer them concisely. So, yeah. Pretty confident in it.

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 9

Science communication self-efficacy with audience during face-to-face poster session.

Theme	Subtheme	Exemplar Quote
Conditional confidence (9)	Nervous with professor/faculty, but more confident with other audience types (3)	*Um, confidence with the professors is a little iffy, because I'm like, "they know what this is. Maybe I'm saying it wrong. Maybe I have the wrong information for it."* Um *confidence with the TAs was a whole lot better, because they helped me walk through the whole process of the... of the experiment that I did. And then they kept on encouraging me* like throughout the whole thing be like, "it's okay, you can be nervous. You got this." I'm like, thank you. And then the people that were just looking for extra credit. Some of them it was a little difficult to present to them, because they didn't know what they know, some basic things.
	More confident and relaxed around students, gained confidence with their instructors (2)	*For me, it was less nerve racking. I feel like with students, I'm just because it felt like we were in the same playing field of, we're both students here, it's a lot more relaxed.* But definitely felt also confident once we presented to our TA, when ever professors would come around, felt more confident as she gave us tips and said, Okay, I would try to focus on this area more. So a little bit more nerves for professors to come around, because they know they're talking about and I was making sure, I wanted to say the right things, but definitely became more competent.
	Comfortable with all audience; increased with interactions (2)	But as we kept on presenting to more and more people our confidence grew, because we had already done it many times before. *And so for the scientific community that we were doing, even though they were like very scholarly people who knew their stuff, we felt very comfortable because we had practice.* And because we knew what our research meant and what it was talking about.

Theme	Subtheme	Exemplar Quote
	Pretty confident but nervous with TA (1)	*Definitely felt pretty confident. Um, I was a little a little more nervous when we presented to our TA.* But when we were presenting to people that were kind of like our age, like peers, I felt pretty confident like explaining, like the premise of our research and then like going through the methods and the results and the discussion. Just because I felt like they were kind of on a similar level.
	Somewhere in the middle (1)	*I say it was like, somewhere in the middle because sometimes they ask questions that were really bizarre* like, we got one question about, like, the chemical makeup of our acid rain, and we were like, but… But, there are some questions that we could just like, straight up… we got it because we've been researching it.
Confident (4)		*I was pretty confident I didn't really... like I said, I didn't hesitate when asked a question.* And I'm a little different than the rest of my teammates. And that is I am a person who is very introverted most of the time. But when it comes to knowledge, I am a total extrovert. *Didn't have an issue.*
Improved confidence (1)		Okay, um, I would say that it was a little bit scary presenting to some of the faculty because they're obviously more well versed in these areas than we are because it's not necessarily everyone's like, my, it's not my specialty. And it's not a lot of people's who are in the class, but I would say, *my confidence level changed. So, after the first faculty member that we presented to, I think I felt a lot more confident. So I would that's how I would describe it*, I guess.

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Table 10

General perceptions of face-to-face poster session

Theme	Subtheme	Exemplar Quote
Emotionally charged (8)	Nerve wracking at first, but grew more confident with time (4)	Nerve wracking, but fun. It was. *At first, we were all very nervous, because this was the first time I'd ever presented before* and especially in front, like in person was someone where you had to dress nice and look nice and so a little nerve wracking. *But after that, I felt great. And I felt a whole lot more confident and just excited about everything.*
	Fun (4)	It was, I don't know how to describe it in like a few words, it was... *it was fun, I guess I'd say. Just like, having the, like, science fair kind of feel around it* with, like going around and seeing everybody else's, as well as ours and seeing how their results stood up to ours. I'd say it was a lot of fun, but was also kind of like, kind of a little bit... A little bit nervous about it.
Over or under stimulated (5)	Crowd density (3)*	I have a 30% deficit in this year. *So with that major group of people in that small location, and then having people walking in and out, walking in and out, and conversations constantly going on,* sometimes I couldn't hear… *Hectic there was a lot of people there…* you couldn't tell when a person was going to walk up to you could be from any direction, or, or any, any timeframe.
	Annoyed with repetition (1)	Um, so at the very beginning, especially when I was getting graded, It was a little nerve wracking but it was also like I got like I can do it. I I've been I had some practice I can I can get an A. And then after that, since I was graded early on, I just got tired. *I was like, you're making me do this for an hour and 15 minutes? I'm a little tired now just having to repeat over and over what I've said. So I got annoyed at the end.*

Theme	Subtheme	Exemplar Quote
	Just waiting (1)	*So basically, we're just standing there and waiting, either waiting your turn to say your point or you're saying your point* and like explaining what your specific point meant to the audience member.
Relating to the unknown (2)	Familiarity (1)	Um, well, it kind of took me back to where… because in high school, I competed at stuff like this, like for Star events and FCCLA. I don't know if you've ever heard of it or not. But I did that a lot. *And that's kind of what it reminded me of, because you have a big poster, you put all your information on, and then you present it to a panel of judges. So that's kind of what it's like to me.*
	Surprised (1)	*Um, I was kind of taken off guard.* Most of the time, they were talking to, like, one person directly, like normal conversation. And then, like, other people would chime in if they had something to say. *So, yeah, that definitely took me off guard. Like… pretty sure we told the dean that our hypothesis was completely wrong and it wasn't supposed to happen.*

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme. *We used quotes from two different student interviewees to convey the Crowd Density sub-theme.

Table 11

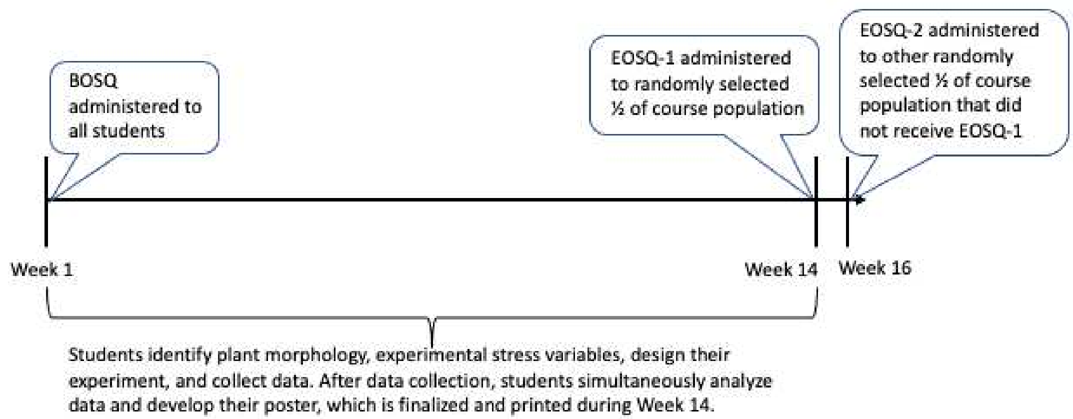
Perceptions of wearing a face mask at face-to-face poster symposium

Theme	Subtheme	Exemplar Quote
Communication barrier (9)	Visual issues (5)	Yeah, so it was kinda difficult. *It'd been, it'd been more difficult than if we didn't [use masks], because they can't really read our lips.* And we can't really read theirs, so we had to, like, talk louder, and project our voice more.
	Vocal issues (4)	*It was pretty difficult. Just because for one, there's so many people in the room is loud already. And then the face mask, muffle your voice a lot.* So, whoever was talking would have to step closer to and you would have to like look at her and talk pretty close and loud.
Mask adaptation (5)		Um, honestly, that wasn't like…it wasn't that bad. I have quiet voice, and sometimes I stutter… *but I'm used to it. I mean, I've been doing it for two years.*
Positive barrier/Mardi Gras effect (1)		Super easy, super, super easy. *It helps me calm my nerves down. Okay, you couldn't see my face.*

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme & subtheme.

Figure 1

Schematic timeline of F2F course with questionnaire administration.



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CHAPTER IV

COMPARING STUDENTS' PERCEPTIONS OF SCIENCE IDENTITY AND SKILLS GAINED IN A CURE UNDER HYBRID AND FACE-TO-FACE CONDITIONS

Abstract

The COVID-19 pandemic caused higher education to shift instruction, including in course-based undergraduate research experiences (CUREs), from face-to-face (F2F) to alternative approaches. To date, few studies compare student outcomes among different CURE modalities, and none compare student perceptions of value and skills-gained from the presentation of research posters, a common assessment activity in CUREs. We collected students' quantitative perceptions of science identity and science communication self-efficacy in F2F and hybrid modalities of the same plant biology CURE. We also collected students' qualitative perceptions of value and skills gained from a research poster science communication activity. While we found no significant differences between modalities for science identity, we found significant differences in science communication self-efficacy. We also found differences in emergent themes and theme frequencies between modalities. Our results can help educators plan approaches to CUREs under different instructional modalities, as certain affective factors strongly predict students' persistence in science.

Introduction

Over a decade ago, the American Association for the Advancement of Science published a call, *Vision and Change*, to reform undergraduate science education (AAAS, 2011). One important aspect of their call was the emphasis on undergraduate research experiences in higher education. While traditional research apprenticeships models between faculty and undergraduates address this need, multiple barriers prevented students from accessing apprenticeships (Wayment & Dickson, 2008). Course-based undergraduate research experiences (CUREs) broaden research opportunities for students by embedding research aspects in courses, and provide similar benefits to apprentice-based research models (Corwin et al. 2015). These benefits include improved science identity (Hanauer et al., 2016) and science self-efficacy (Esparza et al., 2020), increased graduation and completion of science, engineering, and mathematics degrees (Rodenbusch et al., 2016), and a more inclusive research environment (Bangera & Brownell, 2014). While a wealth of literature describes CURE development and outcomes across undergraduate science, technology, engineering, and math (STEM) programs, research on outcomes in alternative CURE modalities (i.e., hybrid and online) in response to the COVID-19 pandemic is limited.

The COVID-19 pandemic forced higher education to consider alternative course delivery formats to ensure student and faculty safety. This created a natural opportunity to describe and assess hybrid or remote approaches to CUREs. Fey et al. (2020) described a fully remote, intermediate-level ecology CURE in which upper-division students completed a five-week independent research project in their ecology course. Each student presented their research virtually at a symposium at the end of the semester. Although the course instructors emphasized access to existing datasets for student analysis, every student collected new data, implying a preference for a “hands-on” (p. 12530) experiences despite material and travel limitations. Students reported an increased ability in their science communication skills on a post-project survey. Unlike Fey et al. (2020), Leone and French (2022) used valid and reliable quantitative instruments in a mixed-methods design to evaluate a hybrid introductory plant biology CURE in which students attended their F2F portion every other week, and presented their work virtually at the end of the semester. Leone and French (2022) found students' science identity and science communication self-efficacy significantly increased, even when isolating students' poster creation and virtual presentation activities from the research process. A recent study investigating a fully remote high school plant biology research experience also found significant improvement in quantitative self-efficacy measures (Stainbrook, 2022). Although recent literature describing hybrid and remote CURE modalities are emerging, even fewer studies compare outcomes between different CURE modalities.

The shift in course delivery created a natural experiment by which to compare face-to-face (F2F) and alternative modalities. In a qualitative study comparing F2F and fully remote summer undergraduate research experiences, Jensen-Ryan et al. (2021) collected and compared student interview and faculty focus group responses. They found students in the remote experience reported gains in learning to conduct research, data analysis skills, and positive outcomes from virtual networking. Both students and faculty agreed Zoom and Slack, virtual communication platforms, provided positive networking opportunities between student groups and faculty. Students noted drawbacks to their remote experience, namely, the need for detailed daily schedules so students could work around outside commitments. In the only quantitative study comparing three CURE modalities (F2F, hybrid, and full remote), DeChenne-Peters et al. (2022) described how students' affective factors developed between all modalities. Their introductory molecular biology CURE, primarily consisting of freshmen and sophomores (81.9% of the course population), required students to isolate DNA and identify the presence of *Wolbachia* bacteria in insect systems. Students communicated their results in a final presentation. Using a pre/post-test design, DeChenne-Peters et al. (2022) found significant improvement in science identity across all modalities, regardless of student ethnicity. Science self-efficacy also significantly improved across all three modalities, but some underrepresented students had significantly less improvement than their white or Asian peers, regardless of modality (DeChenne-Peters et al., 2020). Although few studies describe an oral communication activity during a hybrid or remote CURE (Fey et al., 2020; DeChenne-Peters et al., 2022), even fewer evaluate the impact of oral science communication activities on students' science communication self-efficacy (Leone and French, 2022), an outcome inconsistently and largely understudied even before the emergence of COVID-19.

The *Vision and Change* call emphasizes providing opportunities in curricula for students to develop communication skills they need to communicate effectively within and between scientific and non-scientific disciplines. However, even before the pandemic, few studies described and assessed oral communication activities in the CURE literature (Brownell et al., 2015; Sarmah et al., 2016; Reeves et al., 2018). Brownell et al. (2015) described students' oral presentation using research posters in a poster symposium for an introductory biology CURE and measured its impact on students' thinking like a scientist. Sarmah et al. (2016) utilized a departmental research poster symposium in which students presented their research from a cellular biology CURE and reported gains in students' presentation confidence. Reeves et al. (2018) also found significant improvement in students' oral communication confidence but approached oral communication differently by requiring students to provide brief data reports within their respective lab sections at several points throughout the semester. Although these studies report gains in students' oral communication confidence, they use diverse quantitative measures for different approaches to oral communication activities. Thus, there is a clear need to investigate science communication self-efficacy outcomes with an appropriate instrument, not only in a F2F format, but among different modalities of the same CURE with the same oral communication activity.

The main goal of this study was to compare two quantitative affective outcomes, science identity and science communication self-efficacy, from the same plant biology CURE delivered in different modalities. To our knowledge, this is the second study which quantitatively evaluates student affective factors of the same CURE in different modalities, the first to parse quantitative affective outcomes by class standing, and the first to compare qualitative perspectives of value and skill gain from a research poster activity in different modalities. While previous research disaggregates affective factors by ethnicity between modalities (DeChenne-Peters et al., 2022), our study provides insight to a unique situation wherein a near equal representation of class standings (e.g., Freshman, Sophomore, Junior, and Senior) in the same CURE existed in different modalities. Two research questions guided our study:

> RQ 1) How does science communication self-efficacy and science identity development compare between CURE modalities?
>
> RQ 2) How do students' perceptions of value and skills gained from a science communication activity compare between CURE modalities?

Methods

Study Design

We used a two-group pretest-posttest design (Allen, 2017) to analyze quantitative self-perceptions of science identity and science communication self-efficacy. We also collected students' qualitative perceptions of their poster activity at the end of the semester through their written responses to open-ended items on the posttest.

Course Description

We recruited students from an introductory process-focused (Spell et al., 2014) plant biology CURE at a large, research-intensive university located in the south-central United States from two different modalities: hybrid and F2F. This course does not have any prerequisites, is required for many life-science and agricultural-science majors, and fulfills a natural science requirement for non-science majors. The CURE involves long-term examination of plant phenotypes in response to abiotic stress, which is connected to ongoing faculty research. Students worked on their research project in teams of four.

Hybrid modality

This modality involved students' full research team alternating between in-person and remote meetings. In the first 8 weeks, teams attending in-person identified plant morphology, selected their abiotic stress variables to test plant growth, designed their experiment, and began data collection. When teams were remote on alternate weeks, each member completed a short-term activity in which they practiced measuring and recording plant characteristics, a literature review of their abiotic stress treatments, and worksheets covering plant morphology and content vocabulary. In the remaining 7 weeks, teams completed their data collection and analysis while simultaneously working on their posters during the in-person sessions and self-determined times during remote weeks. The instructor and teaching assistants (TAs) assessed students through the team poster presentations conducted virtually via Zoom during the last week of the semester.

F2F Modality

The F2F modality occurred during the pandemic after the institution allowed instructors to resume full F2F instruction with expectations that students wear face masks during their instructional periods. In the first 6 weeks, students were introduced to the scientific method, plant microscopy, completed a literature review for the semester-long project and planted their experimental organism in a community grow room accessible by the students and their TAs. They also completed a short-term activity in which they practiced measuring plant characteristics and used excel to practice entering treatment and control data into a spreadsheet. In the following 8 weeks, teams simultaneously created their research poster and completed data collection and analysis. Teams printed their posters at the end of week 14 and presented their work while masked in a public symposium in week 16, during which TAs assessed students through the team poster presentations.

Data Collection

We recruited n=98 and n=60 students from the hybrid and F2F modalities, respectively. After removing duplicate attempts, incomplete responses, and participants who incorrectly answered a quality control item, the final sample size of quantitative matched response values for the hybrid modality was n=74, and n=36 for the F2F modality.

Quantitative Data Sources

We used the same quantitative items as established in Leone and French (2022).

Qualitative Data Sources

Three open-ended responses on the post-test served as our qualitative data sources: "What skills, if any, did you gain from the entire poster process (making AND presenting)? "In what ways do you think the poster presentation benefited you?" and "What reasons would you have for choosing a poster over other major assignments, or vice versa?" (see Appendix E). We collected n=76 and n=50 usable responses from the hybrid and F2F CURE respectively.

Data Analysis

Quantitative

We performed all quantitate analyses in IBM SPSS 26. We calculated Cronbach's alpha reliability for science identity and science communication self-efficacy using pre-test responses in each modality. We calculated normalized change (Marx and Cummings, 2007) between scores (posttest-pretest) for both science identity and science communication self-efficacy in each modality. We divided class standing into two levels - i.e., Lowerclassman (Freshman and Sophomore) or Upperclassman (Junior and Senior). We used the normalized change scores in separate two-way analysis of variances (ANOVAs) to assess the impact of, and interaction between, modality and class standing on students' science identity and science communication self-efficacy, respectively. We utilized two-way ANOVAs instead of a single two-way multivariate analysis of variance (MANOVA) because our science communication self-efficacy and science identity normalized change scores were weakly correlated with one another. Moderately correlated dependent variables are an important assumption for performing MANOVAs (Cole et al., 1994), which our data did not meet. We also performed Levene's test for equality of variances for each two-way ANOVA, and if scores in initial ANOVAs were significant, Bonferroni post-hoc comparisons using estimated marginal means.

Qualitative

We used NVivo software to analyze responses to each open-ended question by modality. Analyzing responses by modality independently allow themes to emerge independently from each modality (Lindsay, 2019). We approached our data inductively and utilized in-vivo coding for our first-cycle coding scheme to create codes for each open-ended question. To establish coding reliability, both authors discussed the generated in-vivo codes, and a co-author analyzed a 10% sample of open-ended responses using the in-vivo codes to calculate overall percent agreement and Cohen's kappa (k). Authors discussed the codes until they reached agreement. The first author then analyzed the remaining data and transitioned the data to second-cycle pattern coding using a code map. We identified emergent themes within each question using the generated pattern codes (Saldaña, 2013).

Results

Research Question 1

Science Identity

Cronbach's alpha reliability for our science identity instrument was $\alpha = 0.79$. We used normalized change scores (Table 2) for science identity in a two-way ANOVA, which did not violate Levene's test ($p = 0.32$), and found no significant main effects of modality, $F(1, 106) = 0.08$, $p = 0.78$, or class standing, $F(1, 106) = 0.07$, $p = 0.79$, on science identity development. We also found no significant interaction between modality and class standing on science identity development, $F(1, 106) = 1.08$, $p = 0.30$ (Table 3).

Science Communication Self-Efficacy

Cronbach's alpha reliability for our science identity instrument was $\alpha = 0.83$. We used normalized change scores for science communication self-efficacy in our second two-way ANOVA, which did not violate Levene's test ($p = 0.22$), and found a significant main effect of modality on science communication self-efficacy development, $F(1, 106) = 8.92$, $p = 0.004$, with a medium to large effect size (Table 4). Bonferroni pairwise comparisons of marginal means revealed science communication self-efficacy developed significantly higher in the F2F modality than the hybrid modality (Mean Difference = 0.16, $p = 0.004$) (Figure 1). There was no significant main effect of class standing, $F(1, 106) = 0.50$, $p = 0.48$, and no significant interaction between CURE modality and class standing, $F(1, 106) = 2.03$, $p = 0.18$, on science communication self-efficacy development.

Research Question 2

Percent agreement between both coding authors ranged from 90% to 100% while Cohen's kappa ranged from k = 0.86 to k = 1.00. While n=76 and n=50 students responded from each modality, respectively, some responses were double-coded, while others were excluded from our analyses because the responses did not answer the question. Therefore, the number of responses does not align with the number of participants. Responses were only excluded from analyses when both authors agreed the response did not answer the question. Furthermore, our in-vivo coding approach, which relies on using students' own language choice in their responses for theme generation, led to some themes sharing similar content but having a slightly different theme name. A detailed description of shared and distinct themes by each open-ended question follows. We designated themes as *Shared* when similar emergent themes arose in both modalities, while *Distinct* themes only emerged in one modality.

What skills, if any, did you gain from the entire poster process (making AND presenting)?

Shared. Both modalities shared themes regarding personal development, quantitative process skills, research aspects, presenting science communication/oral communication, and the aspects of poster creation (Table 5 and Table 6). The hybrid modality had a larger percentage of responses for each of these shared themes except for presenting science communication/oral communication, which was more frequently described as a skill gain in the F2F modality (Table 6).

Distinct. Only one distinct theme arose between modalities: *Synthesizing science content for communication*, which emerged only in the F2F modality and comprised 8.7% of responses. These responses suggested students gained skills summarizing their own research in verbal and written mediums. These responses also indicated students gained a skill in, "how to give a 'spiel' about our work," referencing the brief research summary presenters provide their audience at poster symposiums.

In what ways do you think the poster presentation benefited you?

Shared. Both modalities shared themes regarding benefits to communication about science, expanded or improved knowledge, trappings and aspects of scientific research, interpersonal and personal development, and a positive impact on future science/my future (Table 7 and Table 8). Thematic frequency coverage was similar between modalities, indicating similar proportions of students identified similar benefits in each modality. Responses suggesting the poster presentation benefited students with improved communication about was the most frequent response in each modality (Table 7 and Table 8).

Distinct. Only one distinct theme arose between modalities: *Hands-on experience*, which emerged only in the F2F modality and comprised 3.2% of responses. These responses suggested the poster presentation benefited students with a hands-on experience.

What reasons would you have for choosing a poster over other major assignments, or vice versa?

Shared. Both modalities shared themes regarding posters facilitating knowledge and content better than other assignments, and posters being more authentic, fun, and engaging than other assignment types (Table 9 and Table 10). Responses to this open-ended question had the fewest number of shared themes, but response frequencies were similar between the shared themes.

Distinct. Multiple distinct themes arose in each modality. For the hybrid modality, *Posters are more focused and straightforward*, *Posters are too time consuming and difficult*, and *Strong emotion about non-poster assignments* were distinct. These themes represented 31.5%, 17.5%, and 12.3% of responses, respectively. Regarding the F2F modality, *Posters are easier and less stressful than other assignments* and *More comfortable with other assignment types* emerged as distinct themes with 24% and 7.4% of responses, respectively. While the themes *Posters are more focused and straightforward* and *Posters are easier and less stressful than other* *assignments* overlap in their both containing responses noting how posters were less stressful than other assignments, hybrid modality responses for its theme noted how posters only covered one topic and, "…focuses on just one thing throughout the semester."

Discussion

Quantitative Comparisons

We used the unique opportunity the COVID-19 pandemic provided as a natural experiment to compare various self-perceptions in two modalities of the same introductory plant biology CURE. We found no significant impact of modality, class standing, or interactions therein on students' science identity development. Our science identity findings align with the only study quantitatively comparing science identity using the same survey in our study (DeChenne-Peters, 2022), which found no significant effect of modality on science identity when comparing three different modalities of the same CURE. While DeChenne-Peters (2022) attributed their science identity findings to small sample sizes, we speculate our results are not significant because both modalities required students to complete work similar to scientists (Mraz-Craig et al., 2018; Cooper et al., 2020). Each modality required students' complete literature reviews, design and execute their experiments, collect and analyze data, then present their findings. A recent study which isolated poster creation and presentation aspects from research aspects in a hybrid CURE found no significant differences in science identity development (Leone and French, 2022). We posit that, regardless of modality, students' science identity will significantly improve in CUREs when they engage in research activities similar to scientists, as performative actions are an additional avenue for identity development (Cobb et al., 2009).

Although we found no significant impacts on science identity, we did find the F2F modality significantly impacted science communication self-efficacy development. Science communication self-efficacy has been largely understudied during the pandemic except for one study (Leone and French, 2022) which found no significant differences in a hybrid CURE between students who presented their research poster virtually and students who completed research activities without a presentation. Leone and French (2022) speculated students' discussing their research within their team of four peers significantly contributed to communication self-efficacy development in the hybrid CURE. Here, we speculate their self-efficacy developed from mastering either the poster creation experience, which includes a social discussion component of teamwork to create a research poster, or the poster presentation experience, which included a social component between student teams and their audience. Therefore, the significant improvement we found in science communication self-efficacy in the F2F modality could be confounded by unmeasured peer group interactions.

Before the pandemic, Kloser et al., (2013) investigated an ecology CURE where students worked with partner peers and found significant improvement in self-reported confidence presenting to lab members after presenting findings in an oral presentation to the class. However, Kloser et al. (2013) did not consider peer interactions as a source of self-confidence improvement. Said interactions could be an avenue through which students developed their self-efficacy, as Bandura's (1997) Social Cognitive Theory describes seeing someone similar to oneself succeed in a task (i.e., vicarious experiences) builds self-efficacy. We also speculate that students interacting with their audience in the F2F symposium played a significant role, as Leone and French (2022) found the presence of expert audience members in a virtual poster session impacted some students' science communication self-efficacy. In a study before the pandemic, Gardner et al. (2010) required students to present results-only research posters to a diverse audience comprised of faculty and graduate students, and found students reported satisfaction with their posters, but did not account for the impact of audience diversity on student development. We recommend studies investigate student perceptions of audience diversity and its relationship with self-efficacy development.

In addition to analyzing both quantitative affective measures, we disaggregated affective outcomes by class standing because we had an equal representation of upperclassmen and lowerclassmen in our F2F modality (Table 1). Our institution contains multiple life-science programs among five departments, and only two departments require the CURE we evaluated as a pre-requisite. While the introductory CURE is designed for lowerclassmen, students enrolled in programs for which the CURE is not a pre-requisite commonly delay this course until their junior or senior year. While no previous study disaggregated affective outcomes by class standing between CURE modalities, we hypothesized lowerclassmen would experience greater affective development than upperclassmen because class standing serves as proxy for maturity and prior experience. We found no significant impact of class standing on science identity or science communication self-efficacy, which suggests introductory CUREs can still impact students' affective development regardless of their class standing.

Qualitative Comparisons

Skill Gains

More participants in the F2F modality described gains in their oral communication and presentation development skills (35%) than participants in the hybrid modality (21.4%). Additionally, a distinct theme emerged in the F2F modality responses: *Synthesizing science content for communication*. We speculate our findings highlight the importance of both modality and audience diversity, as students in the F2F modality presented to a heterogenous audience consisting of faculty, students, and institutional administrators, whereas students in the hybrid modality presented virtually to a limited audience consisting of only their TA and course faculty. Furthermore, we speculate audience diversity played a role in how students synthesized and communicated science content during the F2F symposium. During the F2F symposium, students could encounter a heterogenous audience at their poster at any given moment, requiring students to synthesize their information in ways their heterogenous audience members could all understand. While audience diversity and delivery method are confounded in our study, Leone and French (2022) investigated the delivery methods by interviewing students who communicated their research via Zoom after participating in a hybrid CURE, and found they enjoyed presenting virtually because their physical absence from an audience provided a sense of comfort. Leone and French (2022) speculated presenting remotely alleviated students' presentation anxiety; here we speculate presenting F2F also provides a positive anxiety from which students benefit and develop personally, as one student in the F2F presentation described a benefit as, "It helped me get out of my comfort zone." However, we found a larger percentage of responses indicating gains in personal development from the hybrid modality (22.9%) than the F2F modality (15%). This could result from the hybrid modality requirement which forced student groups to work on their poster virtually outside of the designated lab time without TA oversight and moderation. We speculate that TA absence, and thus, the required self-moderation of groups in the hybrid modality, resulted in more hybrid participants reporting interpersonal and personal development than F2F participants who were not required to work on their poster outside of designated instructional time. Recent literature supports the impact CURE instructors have on student development, as Esparza et al. (2020) found interactive behaviors between students and instructors significantly impacted students' perceptions of their laboratory experience. We recommend future studies investigate how TA presence might moderate group dynamics and thus, perceptions of personal development in difference CURE modalities.

Poster Presentation Benefits

In both modalities, students reported improved communication skills about science, improved knowledge, learned aspects of science, personal and interspinal development, and impactful skills for the future as benefits of the poster presentation. Only one distinct theme emerged between modalities, which originated in the F2F modality: *Hands-on experience*. We think that the responses from which the themes emerged resulted from the extra time students had to work on posters during the F2F modality, instead of benefits of the poster presentation itself. Additionally, students may be noticing the fact that a physical poster was present in the F2F modality.

Preferences for Posters or Other Assignments

In both modalities, students described posters as authentic, engaging, and an assignment which better facilitated learning content compared to other assessments. Our findings align with Goldey et al. (2012), who found introductory biology CURE students reported more perceived knowledge on their presentation subject after presenting a research poster. While students' positive descriptions of the poster assignment overlapped between modalities, students also provided reasons for choosing other assignment types. Students in the F2F modality indicated more comfort preparing for an exam and written assignments than creating or presenting a poster. Speaking with others in a formal public setting is known to cause public speaking anxiety (Pull, 2012). We speculate the F2F poster presentation caused presentation anxiety in some students, which consequently impacted their consideration of posters as a future assessment. Our speculations are supported by findings from Akister et al. (2000), who found some students experienced enough performance anxiety from presenting posters in a social work course to discourage them from future poster presentations, and instead choose written communication activities. Because, public speaking is a common source of anxiety (Pull, 2012), it is not surprising responses from the F2F modality signified a preference for other assessments which do not require a public speaking aspect.

Conversely, responses from the hybrid modality did not signify preferences for other assignments but did provide strong emotions to non-poster assignments and negative perceptions to completing research posters. The most common non-poster assignment to which students had a strong negative response was writing. We speculate our respondents suffered from writing anxiety, as prior research shows undergraduate students suffer from both writing anxiety and low writing self-efficacy (Woodrow, 2011). Students were required to write information on their poster, which contradicts their strong negative emotional response to writing. Future research should compare science writing self-efficacy between research posters and written assignments (i.e., reports or manuscripts) to elucidate different perspectives of written communication. Students in the hybrid modality also described posters as too time consuming and difficult. We speculate these responses were a consequence of students having three fewer weeks than the F2F modality to create and design their poster. Furthermore, students who were new to the poster experience may have underestimated the work required to complete a research poster, resulting in perceptions of posters being difficult and time consuming.

Limitations

Although we found a significant main effect of modality on science communication self-efficacy development, we could not isolate aspects of the F2F CURE to identify which aspects directly impacted science communication self-efficacy. Our pre/post-test design did not include additional repeated measures throughout the semester to isolate activities, unlike the repeated measures in Leone and French (2022). Therefore, we can only speak to these modalities, as an entire semester experience, regarding their impact on science communication self-efficacy. An additional limitation is the small sample size of from the F2F modality. Completing the pre-test and post-test were not required but incentivized with extra credit from the instructor only if a student completed both surveys. While the variance was similar among modalities for each affective factor, we accounted for our smaller sample sizes using conservative post-hoc comparisons.

Future Suggestions and Conclusions

Science communication self-efficacy is inconsistently understudied as a CURE outcome. While we provide evidence that a F2F CURE significantly improves science communication self-efficacy development, future studies should isolate aspects of F2F CUREs to identify what, if any, aspects impact science communication self-efficacy. Additionally, we recommend future studies investigate CUREs which use a different science communication activity, for example, a written manuscript, as we found students had a strong emotional aversion to science writing. Finally, we recommend future studies identify relationships between group dynamics and science communication self-efficacy development, as group dynamics could serve as a source of vicarious experience through which self-efficacy developed. Should instructors have an option for their CURE modality, we recommend providing a F2F CURE with an oral science communication activity if the instructor aims to improve students' science communication self-efficacy. However, given safety precautions, limitations, and the unpredictability of the pandemic, instructors could also utilize a hybrid modality with no science communication activity to improve science identity, communication self-efficacy, and perceived skill gains with quantitative data management and interpersonal development among their students.

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Table 1

Participant demographic data by CURE modality.

Demographics	% (n) of Participants	
	Modality	
	Hybrid (n=74)	F2F (n=36)
Gender [a]		
Male	28.4 (21)	19.4 (7)
Female	71.6 (53)	80.6 (29)
Race		
American Indian or Alaska Native	10.8 (8)	5.6 (2)
Asian	5.4 (4)	11.1 (4)
Black or African American	4.1 (3)	0.0 (0)
Native Hawaiian or Other Pacific Islander	0.0 (0)	0.0 (0)
White	74.3 (55)	72.2 (26)
Other	5.4 (4)	11.1 (4)
Ethnicity		
Hispanic or Latinx or of Spanish Origin	8.1 (6)	16.7 (6)
Not Hispanic or Latinx or of Spanish Origin	91.9 (68)	83.3 (30)
Classification		
Freshman	18.9 (14)	5.6 (2)
Sophomore	27 (20)	44.4 (16)
Junior	25.7 (19)	25 (9)
Senior	28.4 (21)	25 (9)
Number of previous college science courses [b]		
1	4.1 (3)	5.6 (2)
2	8.1 (6)	8.3 (3)
3	9.5 (7)	11.1 (4)
4	16.2 (12)	8.3 (3)
5	8.1 (6)	8.3 (3)
6	6.8 (5)	13.9 (5)
More than 6	41.9 (31)	41.7 (15)
No previous college science courses	5.4 (4)	2.8 (1)
Previous science fair experiences [c]		
1	10.8 (8)	36.1 (13)
2	17.6 (13)	5.6 (2)
3	5.4 (4)	0.0 (0)
4	2.7 (2)	2.8 (1)
5	1.4 (1)	2.8 (1)

Demographics	% (n) of Participants	
	Modality	
	Hybrid (n=74)	F2F (n=36)
6	0.0 (0)	0.0 (0)
More than 6	4.1 (3)	2.8 (1)
No previous experiences with science fairs	58.1 (43)	50 (18)

[a] While we offered seven options for gender (male, female, transgender male, transgender female, gender variant/non-conforming, not listed (please specify), and prefer not to answer) participants only selected male or female.

[b] Students included concurrently enrolled science courses into the number of previous science courses they took.

[c] Science fair experiences include participating as a contest, serving as a content judge, or both.

Table 2

Affective scores and normalized change by modality.

Factor	Modality	Pre-Score (mean ± SD & [95% CI])	Post-Score (mean ± SD & [95% CI])	Mean Normalized Change, ± SD
Science Identity	Hybrid	10.12 ± 2.449; [9.55 - 10.69]	11.04 ± 3.004; [10.34 - 11.74]	0.263 ± 0.404
	F2F	9.94 ± 2.378; [9.14 - 10.75]	11.36 ± 2.206; [10.61 -12.11]	0.287 ± 0.319
Science Communication Self-Efficacy	Hybrid	30.69 ± 6.425; [292 - 32.18]	33.19 ± 6.65; [31.65 - 34.73]	0.135 ± 0.263
	F2F	30.33 ± 6.787; [28.04 - 32.63]	35.83 ± 7.137; [33.42 - 38.25]	0.290 ± 0.247

Table 3

Science Identity ANOVA results.

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Effect size (partial eta squared)
Corrected Model	0.17	3	0.57	0.39	0.76	0.01
Intercept	7.364	1	7.364	51.01	0	0.33
CURE Modality	0.01	1	0.01	0.08	0.78	0.001
Class Standing	0.01	1	0.01	0.07	0.79	0.001
CURE Modality*Class Standing	0.18	1	0.16	1.08	0.3	0.1
Error	15.3	106	0.14			
Total	25.53	110				
Corrected Total	15.47	109				

Note: Alpha = 0.05

Table 4

Science Communication Self-Efficacy ANOVA results.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Effect size (partial eta Squared)
Corrected Model	0.72	3	0.24	3.62	0.02	0.09
Intercept	4.33	1	4.33	65.04	0	0.38
CURE Modality	0.59	1	0.59	8.92	0.004*	0.08
Class Standing	0.03	1	0.03	0.5	0.48	0.01
CURE Modality*Class Standing	0.14	1	0.14	2.03	0.16	0.02
Error	7.052	106	0.07			
Total	11.56	110				
Corrected Total	7.77	109				

Note. Significant main effect highlighted in red. *p < .05.

Table 5

Emergent themes to perceived skills gained in the hybrid CURE.

Theme	Exemplar quote	Proportional response coverage (%)
Personal Development (14)	Group work is not my specialty because I like to take over the project, so I would say that *my team working ability improved over making the poster.*	22.9
Quantitative Process Skills (14)	From making the poster *I learned about the p-values and how to do those calculations in excel,* which I think will be useful in the future.	22.9
Conversing & Presenting about Science (13)	As for presenting, *it helped me with paraphrasing and giving a general overview of data rather than regurgitating what we had on the poster.*	21.4
Research Aspects (11)	I learned the process of *how to conduct and present an experiment* where I didn't really know how before.	18
Mechanical Poster Qualities (9)	*How to create a poster and what does into it.*	14.8

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme.

Table 6

Emergent themes to perceived skills gained in the F2F CURE.

Theme	Exemplar quote	Proportional response coverage (%)
Oral communication and presentation development (28)	*I gained better presenting skills* and became *confident answering questions about what I was presenting.*	35
Quantitative process skills (13)	*Learning to organize* and present *scientific data* was a big skill I learned during this process.	16.3
Research aspects (13)	A lot – like research and a *better understanding of how to approach a question.*	16.3
Personal development (12)	I learned that *it's okay to ask others for help when needed*, and that *it's okay if you mess up a few times as long as you fix it.*	15
Synthesizing science for communication (7)	I think I have a *better understanding of summarizing the results of research* and presenting them in an innovative way which *others can clearly see trends and take-home messages.*	8.7
Poster creation (7)	I gained a new experience in *learning how to craft a scientific poster.*	8.7

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme.

Table 7

Emergent themes to perceived benefits of the poster presentation in the hybrid CURE.

Theme	Exemplar quote	Proportional response coverage (%)
Improved communication, presentation, and conversations about science (20)	I think the poster presentation *helped me hone my scientific communication skills*.	52.6
Expanding knowledge (8)	*I was able to grasp the material and gain some knowledge on effects of our treatments* that could be implemented in real life.	21
Interpersonal interaction and belonging (5)	*I think it taught me very valuable lessons on how to work well with a group* because not many of my classes involve school group work.	13.2
Trappings of lab science work (3)	It helped me comprehend and *understand more about what we actually did in lab*.	7.9
Positive impact on future science (2)	*I learned about a growing environmental issue and now know there's scientific outlets I can use to make a difference.*	5.3

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme.

Table 8

Emergent themes to perceived benefits of the poster presentation in the F2F CURE.

Theme	Exemplar quote	Proportional response coverage (%)
Improved communication skills and presentations about science (34)	*I am now more confidence speaking about results to a group of scientists.*	54
Improved experimental understanding (8)	*It helped me see the differences and treatments not just on a piece of paper, but actually knowing the knowledge.*	12.7
Learned aspects of scientific research (8)	*It…taught me how to answer questions about the science world.*	12.7
Personal and interpersonal development (8)	It *helped me get out of my comfort zone* and also *gave me something to be proud of at the end of the semester.*	12.7
Provided skills for other courses and my future (3)	*It… helped me gain skills that I will use in the future with research.*	4.7
Hands-on experience (2)	Allowed me the opportunity to get some *hands-on experience with the instructional period.*	3.2

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme.

Table 9

Emergent themes to choosing posters over other assessments in the hybrid CURE.

Theme	Exemplar quote	Proportional response coverage (%)
Posters are more focused and straightforward (18)	I like that I get to choose one topic and *really go in depth and then relate it to what I'm learning in class.* I feel like it's more real life than an exam.	31.5
Authentic and engaging (13)	I find making the poster *more related to what I'll be doing in the future than writing a paper*.	22.8
Posters are too time consuming and difficult (10)	I can *obtain information quicker* by reading a paper. Making a *poster is an overwhelming process*.	17.5
Posters facilitate learning content (9)	It's [the poster] 100 [percent] *better and promotes learning over memorizing and cheating.* You cannot cheat on a poster but must learn and build it. The poster in this class is a million times better than an exam.	15.9
Strong emotion about non-poster assignments (7)	*I hate writing papers* (one of the reasons I went into STEM so I did not have to write as many). If I had the option between the poster and a paper, I would choose the poster any day of the week.	12.3

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme.

Table 10

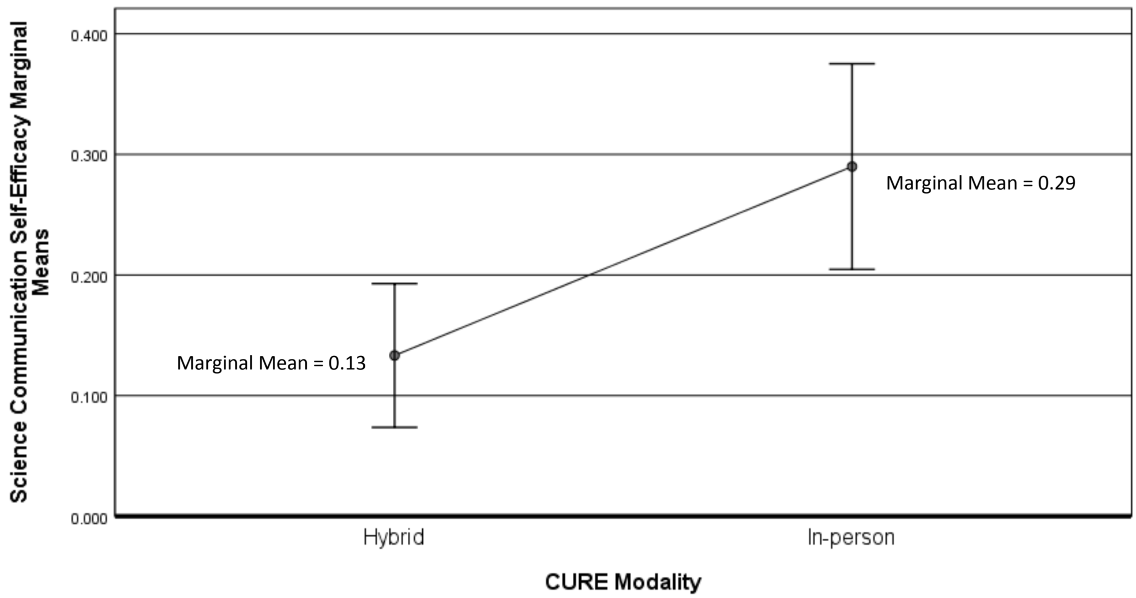
Emergent themes to choosing posters over other assessments in the F2F CURE.

Theme	Exemplar quote	Proportional response coverage (%)
Posters are more fun and engaging (15)	*I would choose the poster because it's fun to make* and we get to collaborate with others.	27.8
Posters are authentic (14)	I prefer a poster because it *applied real life experiences and skills to be used later on*.	26
Posters are easier and less stressful than other assignments (13)	A presentation is *less stressful to me compared to a major assignment like a paper or lab practical*.	24
Posters facilitate learning (8)	*It requires a deeper level of understanding in the topic* because if you don't know anything it will show.	14.8
More comfortable with other assessments (4)	The only reason I would pick an exam over a poster is because *I am more comfortable and confident in preparing for an exam than creating and presenting a poster.*	7.4

Note: Authors added emphasis to exemplar quotes using italics to showcase main idea in quote; numbers in parenthesis are number of coded responses which developed the theme.

Figure 1

Marginal means of science communication self-efficacy in both modalities



Note. Error bars represent 95% confidence intervals.

CHAPTER V

IMPLICATIONS FOR FUTURE RESEARCH AND PRACTITIONERS

The purpose of this research was to identify and evaluate the role research posters, as an authentic assessment technique, can play in shaping students' self-perceptions in an introductory CURE conducted in different modalities. In Chapter 2, I found students' science identity and communication self-efficacy significantly improved in a hybrid modality when students focused on research aspects with or without a virtual science communication activity. In Chapter 3, I found students' science identity significantly improved in a F2F modality, with significantly more improvement in communication self-efficacy when students engaged in research aspects with a F2F poster symposium. In Chapter 4, I found that a F2F modality had significantly higher communication self-efficacy gains than a hybrid modality of the same CURE, and minimal differences in students' perceived value and skills gained between modalities. Because science communication self-efficacy is inconsistently, and largely during the pandemic, understudied, there are multiple avenues for future research to expand communication outcomes in CUREs

Opportunities for Future Research

CUREs are well documented to provide outcomes related to STEM persistence and retention (Lopatto, 2007; Corwin et al., 2015b; Hanauer et al., 2017; Gin et al., 2018), specifically regarding science identity and science self-efficacy (Hanauer et al., 2016; Hanauer et al., 2017, Gin et al., 2018). Thus, one area of future research includes investigating the relationship between science communication self-efficacy and STEM persistence. I found science identity and oral communication self-efficacy were weakly correlated, suggesting students can develop their identity independently from their confidence to communicate their work orally. Furthermore, science communication is but one aspect of the scientific process, and I found students significantly develop their science communication self-efficacy without an oral communication activity. Based on my findings, I speculate oral science communication self-efficacy does not significantly predict STEM persistence. However, future research should investigate my hypothesis, and include a second form of science communication: written communication.

Science communication can occur in multiple formats, which underscores the importance for researchers to evaluate how students develop self-efficacy in multiple communication media. Previous research highlights the strong inverse relationship between writing self-efficacy and writing anxiety in students (Martinez et al., 2011), as writing anxiety plays a significant role in writing self-efficacy development (Anderson et al., 2016). While CUREs can include a writing communication activity (e.g., a lab report or manuscript), science writing self-efficacy in CUREs is largely understudied. Although my dissertation focused on oral science communication self-efficacy, I received qualitative responses which indicated mixed preferences for science writing assessments. Students reported a strong negative emotion to other assessments, especially writing, as evidence for preferring a research poster activity. However, I also received responses indicating preferences for assessments requiring an individual approach (e.g., exams and written assignments) instead of a poster activity. Therefore, another area for future research includes evaluating written science communication activities in CUREs and their impact on science writing self-efficacy. One might also extend this research to investigate relationships between science writing self-efficacy and STEM degree persistence.

In addition to investigating relationships between science writing self-efficacy and STEM persistence, future research should consider evaluating relationships between science identity and science writing self-efficacy. I was interested in how science identity developed in the context of a poster session (i.e., discourse between students and their audience), which Gee (2000) describes as discourse identity development. However, students' descriptions of their science identity indicated both performing actions similar to scientists and acquiring scientific content knowledge as identity development sources. These two sources of identity development are better contextualized in frameworks described by Cobb et al. (2009) and Carlone and Johnson et al. (2007), respectively. I also found students perceived their audience as experts because of their institutional identity, another aspect of identity development described by Gee (2000). Because individuals constantly re-evaluate their identities (Robinson et al., 2018), especially in different contexts (Gee, 2000), based on actions (Cobb et al., 2009) and acquired knowledge (Carlone & Johnson, 2007), future science identity research should be guided by multiple identity frameworks.

In Chapters 2 and 3, I speculated group dynamics served as a source of communication self-efficacy development, as student teams that engaged in research aspects without a communication activity still reported significant improvement in communication self-efficacy. Social network analysis of group dynamics and group composition is an emerging interest in education research literature. Recent studies show that group composition (e.g., demographics and competency) impacts learning outcomes and attitudes in nonmajors biology courses (Donovan et al., 2018), and self-perceptions of group dynamics can predict individual performance behaviors (Theobald et al., 2017). Literature also shows self-efficacy predicts course success differently depending on gender (Sawtelle et al., 2012). Thus, another area for future research includes investigating how group dynamics, including group gender demographics, relate to self-efficacy development in CUREs, as I speculated the vicarious experience aspect of self-efficacy (Bandura 1997) improved science communication self-efficacy among group members. Evaluating group dynamics frequently involves coding behaviors among group members (number of members on-task, number of agreement statements between members, etc.)

which can be quantitively analyzed to compare frequencies or performance durations, or qualitatively analyzed to derive emergent themes (Paine & Knight, 2020). These approaches to collecting and analyzing group dynamic data may provide robust results to improve student outcomes and experiences in course-based research.

Finally, one other area for future research includes measuring science communication self-efficacy in middle and high school student science fair participants. Previous research suggests parental support, pressure to succeed, and science self-concept predict success in science fair competitions in grades 7-12 (Czerniak, 1996). Furthermore, literature suggests science fair participants experience increased understanding in science inquiry, and positive attitudes towards STEM courses and careers (Schmidt & Kelter, 2017). However, only a few studies investigate the psychosocial outcomes on which I have focused. Reis et al. (2015) found students experienced anxiety in all stages of the science fair process, but anxiety was reduced if students had repeatedly engaged in science fair processes. Forrester (2010) found college freshman who had previous science fair experience showed higher science self-efficacy and were more likely to pursue an engineering degree. Science communication self-efficacy is just as understudied in secondary education as it is in higher education. Therefore, future studies should consider investigating science communication self-efficacy in science fair participants, and the relationship between career choice and communication self-efficacy development.

Implications for Practitioners

While my findings provide multiple avenues for future research, they also inform evidence-based implications for biology educators in higher education. Science communication is an important aspect of the research process and is necessary if educators are to prepare successful future scientists (Chan, 2011). While CUREs provide benefits similar to the classic research apprentice model (Corwin et al., 2015b), they can also provide opportunities to practice science communication. For faculty interested in developing a CURE in either a hybrid or F2F modality, my research shows students' science identity will significantly improve regardless of modality without an authentic oral science communication activity. However, if faculty are interested in developing students' science communication self-efficacy, my findings suggest incorporating an authentic oral communication activity in a F2F modality will yield significantly higher self-efficacy gains than incorporating said activity virtually in a hybrid modality.

Regarding science identity, modalities do no harm (DeChenne-Peters et al., 2022) given the CURE provides opportunities for students to engage in research activities similar to scientists, such as experimental design, reviewing literature, collecting data, and completing data analysis (Mraz-Craig et al., 2018, Cooper et al., 2020). However, given the inconsistent approaches to studying science communication self-efficacy in the literature (Gardner et al., 2010; Kloser et al., 2013; Brownell et al., 2015; Sarmah et al., 2016), and the scarce understanding of how student characteristics interact with science communication self-efficacy, faculty may consider students' diverse personalities while developing a science communication activity. To my knowledge, no previous studies describe interactions between student personalities and susceptibility to change from an oral communication experience. While I did not explicitly measure student personality, I found improvement in students' confidence from the beginning to end of the semester in Chapters 2 and 3, and mixed reasonings to choosing (or not choosing) an oral presentation assignment in Chapter 4. Faculty may consider measuring students' anxiety to both written and oral communication to make informed decisions before developing an authentic communication experience. Overall, faculty should first consider the goal of their CURE before determining the modality, as I found modality does not negatively impact science identity or science communication self-efficacy.

Contribution

The Covid-19 pandemic provided an unexpected challenge and opportunity to this research. While the original goal of my dissertation was to evaluate the impact of a science communication activity on self-perceptions in an introductory CURE, my goal additionally included the impact of modality on self-perceptions after the emergence of COVID-19. This provided a unique opportunity to be one of the first to evaluate science identity, and the first to evaluate science communication self-efficacy, during the pandemic. At the time of writing, cases and transmission of COVID-19 are declining during the pandemic's second year after two emergent variants. Given the unpredictability of future variants and the unknown future impact of the pandemic on instruction within higher education, my dissertation presents three timely and unique studies relevant to course-based research instructional strategies in biology curriculum. My goal in producing these three publications is to better inform both the biology education research and practitioner communities, so their future decisions may have lasting positive impacts on future generations of scientists.

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APPENDICES

Appendix A

IRB Approval Letter

Oklahoma State University Institutional Review Board

Date:	01/24/2020
Application Number:	IRB-20-25
Proposal Title:	Evaluating the impacts of research posters on students' self-perceptions in biology Course-based Undergraduate Research Experiences (CUREs)
Principal Investigator:	Austin Leone
Co-Investigator(s):	
Faculty Adviser:	Donald French
Project Coordinator:	
Research Assistant(s):	
Processed as:	Exempt
Exempt Category:	

Status Recommended by Reviewer(s): Approved

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in 45CFR46.

This study meets criteria in the Revised Common Rule, as well as, one or more of the circumstances for which continuing review is not required. As Principal Investigator of this research, you will be required to submit a status report to the IRB triennially.

The final versions of any recruitment, consent and assent documents bearing the IRB approval stamp are available for download from IRBManager. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be approved by the IRB. Protocol modifications requiring approval may include changes to the title, PI, adviser, other research personnel, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3. Report any unanticipated and/or adverse events to the IRB Office promptly.
4. Notify the IRB office when your research project is complete or when you are no longer affiliated with Oklahoma State University.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact the IRB Office at 405-744-3377 or irb@okstate.edu.

Sincerely,
Oklahoma State University IRB

Appendix B

Science Identity Instrument

Rate the degree to which you agree or disagree with the following statements concerning your sense of yourself as a scientist who undertakes research activities.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1. I have a strong sense of belonging to the community of scientists					
2. I have come to think of myself as a 'scientist'.					
3. I feel like I belong in the field of science.					

Appendix C

Modified Science Communication Self-Efficacy Instrument

Rate your level of confidence (even if you have never done it yet) in your ability to…

	Very Insecure	Insecure	Neither Insecure nor Confident	Confident	Very Confident
…excel in giving scientific presentations (i.e., you usually receive high praise for your presentations from your mentor or the audience).					
...give a scientific talk to a non-scientific audience (e.g., high school students, cancer patients).					
...give an oral presentation at a scientific conference.					
...require little to no assistance with my speaking and presenting skills.					
...defend your point of view convincingly in a scientific discussion, in spite of a negative response from others.					
...effectively answer questions from the audience at a scientific conference.					
...speak using correct grammar without rehearsing.					
...manage worries you have about your pronunciation, accent, vocabulary, grammar, or style of speaking.					
...use the appropriate amount of scientific words.					

	Very Insecure	Insecure	Neither Insecure nor Confident	Confident	Very Confident
...introduce yourself and your research briefly and effectively to other professionals.					

Appendix D

Semi-structured Interview Protocol

1. Describe what a scientist looks like to you
    a. Why?
2. How do you see yourself in comparison to the scientist you just described?
3. Before taking this class, what previous experiences do you have presenting and/or communicating scientific research? What previous experience do you have presenting research posters?
4. After presenting your poster, how do you see yourself as part of the scientific community?
5. Looking back to before you presented your poster, describe your confidence about presenting your research before you participated in the poster session.
    a. Now that you presented your poster, describe your confidence about presenting your research after you presented your poster.
6. Who was the main audience of your poster session? Other students in your class? Professors?
7. Describe your confidence discussing your research with your audience members.

7b. **F2F Semester Only:** How did you engage with people who came up to you at your poster during the poster session?

8. Describe what it was like to present your poster at the (virtual or F2F, **choose based on type of modality**) poster session last week.
9. **F2F Semester Only:** Tell me what it was like to wear a face mask while talking to your audience about your research.
10. Briefly tell me about your research.

Appendix E

Open-ended Items for Perceived Value and Skill Gain from the Poster Process

1. What skills, if any, did you gain from the entire poster process (making AND presenting)?
2. In what ways do you think the poster presentation benefited you?
3. If given the option in the future, how likely would you be to choose the poster over other exams and other major assignments?

VITA

Edward Austin Leone

Candidate for the Degree of

Doctor of Philosophy

Dissertation: SCIENCE IDENTITY AND COMMUNICATION EFFICACY AS A FUNCTION OF PARTICIPATION MODALITY IN UNDERGRADUATE RESEARCH

Major Field: Integrative Biology

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Integrative Biology at Oklahoma State University, Stillwater, Oklahoma in May, 2022.

Completed the requirements for the Master of Science in Biology at Texas State University, San Marcos, Texas in 2017.

Completed the requirements for the Bachelor of Science in Zoology at University of Oklahoma, Norman, Oklahoma in 2014.

Experience:
Teaching Assistant, *Dept. of Integrative Biology, Oklahoma State University* (2017-2022)
Graduate Research Assistant, *Dept. of Integrative Biology, Oklahoma State University* (2018 – 2020)
Introductory Biology Course Development, *Dept. of Integrative Biology, Oklahoma State University* (2019)

Professional Memberships:

National Association of Biology Teachers

National Science Teachers Association