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Identity Trajectories of Faculty Members through Interdisciplinary STEAM Collaboration Paired with Public Communication

Renee M. Desing [1], Renee Pelan [2], Rachel L. Kajfez [3], Cassie Wallwey [4,*], Abigail M. Clark [5] and Sathya Gopalakrishnan [6]

[1] Department of Mechanical Engineering, University of Washington, Seattle, WA 98195, USA; desing@uw.edu
[2] Community, Access, Retention, and Empowerment Office, The Ohio State University, Columbus, OH 43210, USA; pelan.5@osu.edu
[3] Department of Engineering Education, The Ohio State University, Columbus, OH 43210, USA; kajfez.2@osu.edu
[4] Department of Engineering Education, Virginia Tech, Blacksburg, VA 24061, USA
[5] Dr. Carl D. Clay and H. Jane Clay Department of Mechanical Engineering, Ohio Northern University, Ada, OH 45810, USA; a-clark.5@onu.edu
[6] Department of Agricultural, Environmental, and Development Economics, The Ohio State University, Columbus, OH 43210, USA; gopalakrishnan.27@osu.edu
* Correspondence: cwallwey@vt.edu

Abstract: Faculty members in science, technology, engineering, and mathematics (STEM) fields are accustomed to presenting their research findings through journal publications, conference presentations, textbooks, and other academic mediums. However, the audience for these traditional forms of communication are other researchers, which raises concerns about how science research and knowledge are communicated to audiences who have less expertise on these topics. We sought to understand how faculty members develop their identities through collaborative professional development opportunities aimed at growing communication skills to communicate with audiences less familiar with research through interdisciplinary science, technology, engineering, arts, and mathematics (STEAM) activities. We conducted a qualitative, longitudinal study with sixteen STEAM faculty members to explore their identity trajectories as their interdisciplinary cohorts participated in various collaborations to engage with public audiences about their research. Through our analysis, we found that each faculty member's dominant identity played a significant role in their identity trajectory through their professional development. We observed a significant growth in faculty members' communication skills, such as learning new presentation techniques to engage others in their research areas of expertise and in their understanding of interdisciplinary STEAM collaboration. Our results provide insights into the identity trajectories of faculty members and how their identity development through these interdisciplinary STEAM collaborations will impact their formal education roles as researchers and teachers moving forward.

Keywords: interdisciplinary collaborations; faculty development; identity trajectory; science communication

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1. Introduction and Background

Effective STEM teaching and learning is dependent on effective science communication. The communication of science knowledge often occurs in classrooms, laboratories, and museums, facilitated through lectures, textbooks, and scientific publications. However, science teaching and learning has broken through traditional barriers into innovative dissemination areas (e.g., [1]) and informal learning settings in public spaces. In particular, interactive science centers (e.g., [2–4]), community programs (e.g., [3,5,6]), and extracurricular events for students (e.g., [7–9]) have started expanding where, when, and to whom

STEM learning is communicated and practiced. Given the increasingly complex challenges facing society [10,11], there is a growing need to increase public awareness and engagement on important and impactful science topics, including adjacent fields such as technology, engineering, and mathematics, which come together to form STEM. One such avenue for the public's engagement with STEM knowledge and education is informal settings, as significant science learning occurs external to formal learning environments [12]. For these STEM informal learning experiences to be impactful and educational, the communication of STEM content must be understandable and accessible to the public.

Researchers and scholars in universities who are at the forefront of advancements in STEM disciplines are well-accustomed to communicating their research topics and findings within their specific areas of expertise, but the public remains largely uninformed regarding new scientific discoveries. A study by Durant et al. found that while many members of the public in the United States and the United Kingdom professed an interest in science, study participants performed poorly in terms of measures of scientific knowledge [13]. In the last two decades, there have been numerous calls for increased science literacy (e.g., [14–17]), but there continues to be widespread concern regarding a lack of public understanding of science knowledge and innovation (e.g., [13,18–21]). Working toward a solution to this STEM communication gap outside of classroom environments is necessary, as there exists a growing need for faculty members to communicate their research to the public to share the research process, intermediate and preliminary findings, and potential applications for those new findings. This communication can help engage the public in the scientific process and promote a broader understanding of cutting-edge research [22]. However, faculty members are often not professionally trained to communicate their specialties to the public. While professional development opportunities exist to support faculties in this way, many remain underprepared [23].

To address the growing need for improved science communication with the public, we designed a research project that studied faculty researchers from divergent science, technology, engineering, arts, and mathematics (STEAM) disciplines who expressed interest in collaboration and communicating their research with others outside of their disciplines. Most of the literature on STEM teaching and learning communication has stayed in the science, technology, engineering, and math fields, but the landscape of 'STEM' has expanded to include 'Arts' given the importance of arts in societal advances and in engaging and motivating STEM learners [24]. For these reasons, in our research, we considered interdisciplinary STEAM faculty members rather than just STEM faculty members. We explored STEAM faculty members' identity trajectories as they participated in training and public outreach activities in which they communicated their research to broader audiences. In this manuscript, we answer the research question: In what ways do STEAM faculty members' identities as professionals develop from collaborative informal science communication experiences?

1.1. Project Background

The goal of the project was to bring together researchers with diverse disciplinary expertise to develop learning content around convergent themes and develop a program to inform and engage public audiences of all ages with STEM in unstructured and semi-structured learning environments. Faculty members worked with four informal venues to engage with the public: a science museum, a science pub, a community hackathon, and a community art walk. Our study took place in a large state capital city (population of about 905,000) in the Midwest United States and leveraged collaborations between the public land-grant university located in this city, the city's science museum, the university's hackathon program, and a university organization focused on STEAM community engagement and faculty development. Within these settings, faculty members engaged with the public individually and with other members of their interdisciplinary cohort. When the participants presented or engaged with the community individually, they focused on their individual disciplines and research topics. When the cohorts presented as a group, they

were challenged to create a convergent presentation that integrated all their disciplines and discussed how their seemingly disparate disciplines were connected. Table 1 describes the public engagement venues and activities.

Table 1. Description of Participant Engagement at Events by Community Partners.

Event	Event Description	Participant Engagement
Science Museum Exhibit	An adult 21 + event in which attendees explore the museum and stop by exhibit tables at their leisure	At tables, cohort members would engage with the attendees by providing an activity to teach the public about an application of their research.
High School Hackathon	A high school hackathon that gives students an opportunity to learn about computer science	Cohort participants created an integrated, interdisciplinary challenge for hackathon attendees, served as mentors to student teams throughout the day, and judged the final products.
Community Art Walk	A community event in the form of a gallery walk that showcases art, theater, food, science, and other exhibits	Cohort participants gave an informal talk about their research.
Science Pub	A monthly event that invites scientists to present their research to the public to improve science literacy	Cohort participants gave an online presentation to a community audience about their research topics.

1.2. Identity

Identity research rooted in the work of Erikson seeks to understand how people view themselves [25]. Currently, identity is viewed in a range of ways, including who people see themselves becoming through frameworks such as Possible Selves Theory [26] or "the kind of person one is seeking to be and enact in the here and now" [27] (p. 99). Additionally, identity might be viewed as simply the answer to the question "Who are you?" [28] or through the lens of how one views oneself as part of a group, including the social dynamics of identity [29]. Related to groups, these include nationalities (e.g., [30]), family groups (e.g., [31]), and careers (e.g., [32–34]), among others. While some elements of identity remain relatively stable over time, identity does change in response to experiences, context, personal goals, and other factors [28]. It is this shift in identity, related to faculty members' views of the self, that is of particular interest in this study.

1.3. Conceptual Framework

We used the identity-trajectory framework [35] to guide our analysis. Through their body of work, McAlpine and Amundsen define identity trajectory as a "developmental perspective on identity; it incorporates how individuals represent the (a) continuity of stable personhood through life and, at the same time, (b) experience a sense of ongoing change in perceptions, emotions, knowledge, and abilities; identity-trajectory is attentive to individual agency, conceives of work as one aspect of a broader personal life, and highlights continuity of experience—how the past influences the present and the future" [36] (p. 215). This framework provides a developmental perspective on identity and has been used to examine career development and decision-making by incorporating learning and development through time, individual agency, and affect; personal aspects of individuals that influence motivation for work, the workplace, and its contribution to career development; and the intersection of the personal and work [36].

This framework was originally designed to assess the development of early career academics [36–38], which aligns with our study as our participants were primarily tenure-track faculty members in their early careers, either pre-tenure or recently tenured. Further, the identity-trajectory framework is gaining traction in STEM and engineering education research. For example, it has been used to understand undergraduate engineering students' identities [39,40], to explore optics and photonics graduate students' academic development [41], and investigate the academic identity of emerging engineering education researchers [42–44].

We focus on the workplace element of the framework to examine our participants' academic identity trajectory. The workplace element consists of three interrelated strands to explain career development: intellectual, institutional, and networking [36]. These three career strands are underpinned by the other elements of identity trajectory, including how the work experiences are embedded within an individual's broader life goals and how an individual's agency and actions drive momentum toward the future [36]. The strands also vary across and within individuals by length, size, and impact [45].

The intellectual strand "represents past and continuing contributions to one's disciplinary specialism or field. The intellectual strand leaves a trail of artefacts, e.g., publications, citations, papers, course/curriculum design" [45] (p. 179). We operationalized this in our study using the participants' research and teaching activities along with the formal and informal dissemination of their work. This could be done through lessons or learning activities developed, journal articles, conference presentations, or research or teaching presentations in other venues.

The institutional strand is the relationships, resources, and responsibilities related to the individual's institution [45,46]. Responsibilities include teaching, supervising, committee membership, and administrative roles [45]. Resources include "office space, libraries, labs, classroom facilities; material, e.g., conference funding, start-up funds; and intellectual, e.g., seminars, workshops and access to supervisors and more senior academics" [37] (p. 964). We operationalized this in our study as the cohort themes and training provided to each of the cohorts, as well as the venues in which the participants presented during the study.

The networking strand is defined as "the range of local, national, and international networks one has been and is connected with, and aside from personal networks includes: (a) research and publication collaborations with others; (b) cross-institutional course/curriculum design; (c) work with professionals if in professional schools; and (d) membership in disciplinary organizations and on journal boards" [45] (p. 179). We considered this in our study to be the interdisciplinary collaboration within each of the cohorts.

2. Methods

We utilized multiple qualitative, semi-structured interviews with each faculty member to collect information regarding the participants' preparation for and experiences with each event. We conducted a longitudinal analysis across these interviews to discern how the participants' identities changed over time. To ensure quality in our methods, we referenced the Q3 framework [47,48] throughout our data collection and analysis processes. Specifically, we ensured that each cohort represented diverse disciplines, that our interview protocols and data analysis aligned with the conceptual framework, that two team members were present at each interview (one to conduct the interview and the other to take notes), and that two team members coded each transcript for consistency with codebook development and use. All research methods presented below were first reviewed and approved by the University's Institutional Review Board.

2.1. Recruitment and Participants

Participants were recruited through a university-wide survey in which those interested in participating provided their demographic information and answered Likert-style questions about their engagement with research and the community and open-ended questions to elaborate on their area of research and research challenges, as well as their views and attitudes toward their research, and they provided a ranking of their interest in cohort themes.

The participants were grouped into four cohorts, named by a theme: Energy, Space, Movement, and Elements. Each cohort was assigned a theme for the participants to converge around and to provide a focus for their research presentations to the public. The characteristics of each cohort, including pseudonyms, the number of events the cohorts participated in, and the timeframe in which the events took place, are provided in Table 2.

We gave participants the option to select their own pseudonyms. If they did not select one, the research team assigned one for them. To protect the anonymity of the participants, we do not map the participants' disciplines to the cohort. However, each cohort was comprised of 3–5 strategically and intentionally selected STEAM researchers to ensure each cohort consisted of varied disciplines. Participants' disciplines included a range across STEAM, such as civil engineering, chemical engineering, clinical psychology, geography, ecology, theater, music, and STEM education.

Table 2. Cohort Characteristics.

Cohort Theme	# Members	Pseudonyms	Timeframe	# Events (Type)
Energy	3	Alena Jack Kacey	January 2019–October 2019	5 (All in-person)
Space	5	Andrew Jerry Maria Mark Mitchell	September 2019–April 2021 (Interrupted by COVID)	4 (2 in-person; 2 virtual)
Movement	4	Amy David James Todd	December 2019–February 2021 (Interrupted by COVID)	4 (2 in-person; 2 virtual)
Elements	4	Doug Jakob Lesley Sean	February 2021–June 2021	3 (All virtual)

2.2. Communication Training

Each cohort participated in a communication training program at the Science Museum before developing their learning interventions. Each individual experienced two half-days of training at times that suited their schedule; the overall roster of training experiences was split across three days. A Master Educator at the Science Museum facilitated the training experiences, introducing the cohort to different ways of thinking about science in the context of informal learning environments. The master educator used a variety of activities with the goal of helping the researchers (1) get to know one another, and particularly other members of their own topical cohort; (2) think about their research from different perspectives; and (3) communicate their research in informal learning environments.

2.3. Data Collection

Interview data were collected at multiple points throughout the research project. A summary of the data collection timeline is available in Figure 1. It is important to note that all interviews were conducted with participants individually; however, Figure 1 indicates which events were individual presentations (single-person icon) and which were group presentations (multiple-person icon). It is also important to note that all individual events were completed prior to any of the group events. For example, the Energy cohort completed both of their two individual presentations for the science museum exhibit and community art walk prior to completing the two group presentations at the same venues, before ending with the high school hackathon event.

Participants first participated in an intake interview that lasted between 45 and 60 min. These onboarding interviews were used to establish a baseline of how faculty participants viewed their identity and how they currently approached presenting their research in formal and informal venues. This interview included personalized questions related to information collected using the recruitment survey. In addition to the intake interviews, before and after each activity, faculty participants were interviewed for 5–10 min. These interviews provided a snapshot of how participants felt before and after presentations,

how they prepared for and created their presentations, and how they felt the presentation was received by the audience. Lastly, within a month of completing their last activity, we interviewed faculty participants in a 45–60 min exit interview. This interview was similar to the intake interview, including questions about how faculty participants viewed their identity and how they plan to approach presenting their research in formal and informal venues in the future. This interview also included personalized questions about their experience in the program and how their views and identities may have changed since the beginning of the experience.

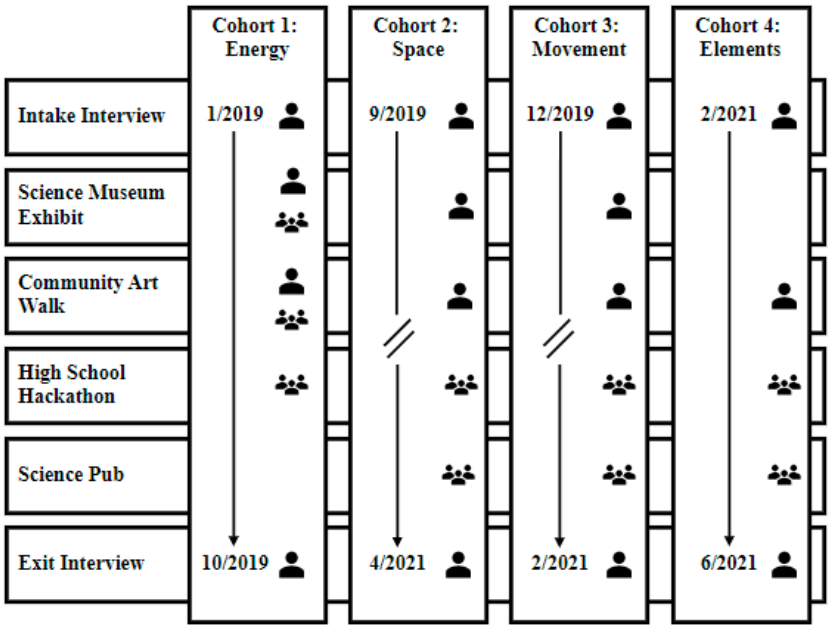

Figure 1. Data collection timeline by cohort. All rows not labeled as interviews (Intake and Exit) consisted of pre- and post-event 5–10 min interviews with each cohort member.

2.4. Data Analysis

Our analysis occurred in two phases: (1) initial coding of interview transcripts and (2) longitudinal coding for each participant [49]. First, after interview data were collected, the interviews were transcribed and coded inductively—this means we explored the data for emergent and salient ideas and thoughts from the participants throughout their interviews. Our codebook was created and refined by applying initial coding [50] to the first cohort, Energy. Primary code categories and sub-codes were established along with a definition for each code [49]. This codebook was subsequently used for the Space, Movement, and Elements cohorts. Initial coding was performed such that every interview for every participant was coded using the developed codebook.

Once initial coding was complete, we applied longitudinal coding to track how participants talked about different codes and how codes changed over time [50]. To analyze the data, a matrix was created for each participant with a column for each interview (in chronological order) and a row for each coding category. We extracted the quotes coded during the initial coding and placed them in the appropriate cells in the matrix. We then summarized each category for each event. Once summaries for each event were generated, we looked over the trajectory longitudinally and then developed an overarching statement to recapitulate the trajectory of the code category. This allowed us to evaluate how the code category changed for each participant and identify emerging themes across the dataset aligned with the workplace strands of the identity-trajectory framework.

2.5. Limitations

Two major limitations of this project were self-selection bias and the unanticipated impacts of the COVID-19 pandemic. Related to self-selection bias [51], when the recruitment survey was sent out to identify those interested in this project, it was likely that those who were predisposed to enjoy public engagement and communication would apply. To overcome this potential limitation, we used the open-ended responses in the survey to identify a variety of potential participants with a range of comfort and experience engaging with the public around their research. While many participants had previous experiences, some were very new to this kind of dissemination, so while self-selection bias could be at play, we believe the cohorts represent a range of dispositions to this type of work.

The second major limitation was the COVID-19 pandemic. Each cohort was impacted differently by the restrictions due to the COVID-19 pandemic. These impacts occurred both in the interaction with the public and regarding the interactions between the cohort members. As shown in Table 2, of the four cohorts, only the first cohort, Energy, which concluded their participation in Fall 2019, completed the study as originally designed, where interactions were in-person. The Space and Movement cohorts began the study in person; however, due to the pandemic, the public presentations stopped abruptly for both cohorts and later moved to virtual platforms once our community partners developed virtual alternatives for their events. While the Movement cohort chose to continue to meet approximately weekly during most of the pandemic lockdowns, the Space cohort went on hiatus for a few months while decisions were being made on how to move the project forward. Finally, the Elements cohort completed all interactions virtually. The differences between the length and modes of interactions amongst members of the various cohorts may have impacted their experiences and thus their trajectories discussed here. We have attempted to address this limitation by fully describing the mode of engagement for each cohort so context can be considered when reviewing the results.

3. Results

Our longitudinal analysis of faculty members' identity changes during their experience and participation in the project found that their identities evolved across all three strands of the workplace element of McAlpine and Amundsen's identity-trajectory framework [36]. In the Results section, we will discuss our findings in relation to each of the three workplace strands of identity trajectory. We will first describe a broader finding regarding participants' identities and then present our further findings using the three strands of the workplace portion of the identity-trajectory framework.

3.1. Intellectual Strand: Expanding Means of Intellectual Communication and Dominant Identities

This finding was related to the trajectory of how participants grew in their understanding of how to present and communicate their research to different audiences in various settings. The development and growth of participants' presentation and communication skills were not only immediately apparent at outreach events but were also reflected when talking with participants in various interviews throughout the longitudinal study.

> *"We didn't overdo it with a PowerPoint, but we still need some visual other than just your face in most of these cases. . . But I think that the way that we set it up as almost like a live interview session where we interviewed each other instead of just talking at the crowd, I thought that was a nice twist and a different way of thinking about how to present who we are, what we do."* —Amy (Movement Cohort)

Most participants, including Amy, started off using PowerPoint for their presentations (sometimes reusing an old PowerPoint presentation that they previously presented) that often included the jargon and terminology from their respective fields. However, throughout the project, members of each cohort started engaging audiences through visuals, appropriate terminology, "hooks," and hands-on activities, as well as using narratives and storytelling techniques to connect with the audience on a personal level.

> *"I realized that it [adjusting your content] is also for those [community] audiences, tailoring the type and topic of content that you are putting out there. And then I felt like a lot of attracting those audiences was as much looking at the fairly broad umbrella and applications of the work I do and asking, 'which part of this is possibly going to be interesting to my audience?' And then creating some things around that."* —Kacey (Energy Cohort)

Just like Kacey describes above, many participants gained a finer appreciation for the importance of context and audience when thinking about how to communicate research and its significance. Participants often discussed in their interviews how they planned to use what they learned and the skills they developed related to presenting and communicating their work in their future research, teaching, and outreach presentations. This emergent finding relates to the intellectual strand of the identity-trajectory framework given the importance of presenting and communicating knowledge for the successful dissemination of research and successful teaching of courses and advising of students.

This intellectual communication growth happened over time in the program and at different rates for the different participants as they learned and adapted through attending training sessions provided by the research team, engaged with one another in their cohorts, and participated in a variety of public engagement activities. How, specifically, each person experienced this intellectual communication growth was ultimately related to each participant's dominant role identity.

The identification and mapping of faculty members' dominant role identities throughout their time participating in this project was an important finding from our data analysis. As data analysis occurred, we observed that all participants most often and strongly described themselves and the work they have done or continue to do in primarily one of two different ways. The two dominant role identities we identified in our participants were teacher and researcher, which makes sense given the two primary roles of faculty members in higher education. These dominant role identities heavily informed their experiences and their identity trajectories throughout the program, as each participant's dominant role identity played a significant role in their experiences and growth, specifically within the intellectual strand. Let us look at an example of each, starting with the teacher identity:

> *"I see the same behavior in college classes where students are far more engaged when they can relate their learnings to their day-to-day experiences. I realized that this is also a way of making them more interactive in class. I keep enhancing my slides with pictures of real-world examples."* —Alena (Energy Cohort)

Alena's teacher identity was present throughout her entire experience. She expressed in her interviews that she sees herself as an educator first and a researcher second. As an educator, Alena's teacher identity was dominant when delivering presentations or leading activities in outreach events. In the quote provided, Alena describes how her teacher identity was further strengthened and how her education materials were enhanced as she learned new ways to engage her audience throughout the program.

Generally, for participants with a dominant teacher role identity, this identity helped participants connect with audience members. Their experiences in formal teaching settings as educators helped them creatively format cohort presentations, engage with the audiences, or share and communicate information to other STEAM cohort members. In this research, we also recognized "teaching" as the mentoring of students.

> *"I like the research part where the teaching was involved in outreach. I mean, I like to be a mentor. So, I also take mentorship courses. I have a postdoc. I have graduate students. Over the summer I have five undergrads on an undergrad research project because that's in the end what's important to me."* —Jakob (Elements Cohort)

Jakob discussed in his intake interview how his priority is mentoring his students, and that he considers himself successful as a professional when his students are successful. The quote above is from Jakob's exit interview, in which he stated he most enjoyed the outreach events when they aligned with his teacher role identity.

Alena, Jakob, and the other participants with dominant teacher role identities reflected on and planned throughout the program how they would improve their presentations to students in their classrooms and drew comparisons between that and presenting to the public audiences as part of this project. These participants often noted in their final interviews how they could, will, or had already incorporated lessons they learned during this project into their classroom teaching and student mentoring.

As participants explored new ways to explain their research to public audiences or interdisciplinary cohort members, other participants leveraged and strengthened their dominant researcher role identities. The more that participants had to explain their research in different ways, the more they discovered new and broader ways to understand and communicate their own research, thus emerging with a stronger researcher identity.

> *"I remember after that [Science Museum Exhibit] presentation, talking to my mom and I was like, 'Mom, I've got some new ways to help you think about my research. And what it is that I do and to explain it'. . . So yeah, I think that it has definitely taught me how to better communicate and just get in a completely different way, maybe not even using some of the words that I would usually use. It made me very much think creatively out-of-the-box at the [Science Museum Exhibit]. So, I think that is very useful in my communication, especially with people like my family that just are interested, but only because it's me, not because they're interested in my work."* —Maria (Space)

In Maria's intake interview, she tells a story of how her mom does not really understand who she is as a researcher. In Maria's exit interview, she shared with our research team that this experience gave her a new way to communicate her research and her researcher identity with her mother.

To showcase how important each faculty member's dominant role identity was to the intellectual strand of their identity trajectories, we offer a quote from Lesley:

> *"I think that it was mostly about how to communicate with others which I guess is relevant to me also as a researcher. I think the perspective that I gained is about how to make sure that people understand the connections, not just jumping into maybe the result, but explaining how it came to be."* —Lesley (Elements Cohort)

Lesley's quote above is from her exit interview; she spoke about her big takeaway from the project: the importance of connecting research results to relevant context and people's prior knowledge in order to improve individuals' understanding and appreciation for research outcomes and their significance. Lesley has a dominant researcher role and says this lesson is most relevant to her as a researcher. Conversely, in Alena's quote earlier in this section, she communicated a similar takeaway: the importance of audiences being able to draw connections between what they are learning and what they are already familiar with. Alena, however, has a dominant teacher role identity and explains this finding as being impactful to her as a teacher in how she delivers course content to students.

3.2. Institutional Strand: Engagement with Institutional Resources

Formal training and informal mentorship during cohort co-working times provided by members of the research team specializing in informal learning and education were the resources often cited by participants as inspiring their professional growth and development throughout this experience. Participants' acceptance of these resources provided to them is most eloquently captured in Mark's quote, below.

> *"Learning how to communicate better, and I definitely feel like that was one of the major valuable aspects of this program for me, both in a very specific sense thinking back to [Science Museum Trainer] trainings at [Science Museum] and these kinds of formal trainings that we received. And there's elements of those trainings that I continue to use in both my teaching and just interacting with people, little tricks and things like that."* —Mark (Space Cohort)

The training and guidance offered by professionals in the field of informal STEAM teaching and learning strongly impacted the communication, collaboration, and presentation strategies of the participants, teaching them how to engage with colleagues and public audiences less familiar with their disciplines through activities and communication methods that they had never previously utilized. This emergent theme is related most directly to the institutional strand of the identity-trajectory framework. The participants of this research fully engaged with the informal learning institutions and experts within those institutions to further their skills and development as professional researchers and teachers.

Our qualitative, longitudinal findings indicated that without the institutional resources (in training and general advising and mentorship) and the participants' willingness to meaningfully engage with these resources, it is likely that the participants would not have seen the amount of growth in their own communication and collaboration practices; nor would they have understood their researcher and teacher identities, which are described and reported on in the Results section.

3.3. Networking Strand: Expanding Opportunities and Possibilities

Our final finding was that the interdisciplinary nature of this project and tasking the STEAM cohorts with collaborative engagement in informal teaching and learning and with public audiences led to a clear growth in the networking strand of faculty members' identity trajectories as they grew and expanded their definitions and understandings of what their professional networks could look like. The growth and expansion were described by researchers as being both internal to their own work and disciplinary interests as well as external when considering others' work. This duality is illustrated in Kacey and Jerry's quotes, below.

> *"I do think that one thing I've learned is that in order to reach for collaborations far outside my discipline, I have to be willing to be more flexible with what I consider my "research interests." While the project strayed rather far from my specific interests at the midpoint, it helped build connections that we ultimately harnessed in the final presentation, which I was able to bring back much closer to my own research areas and interests while still incorporating our common theme."* —Kacey (Energy Cohort)

> *"This is one of the very rare opportunities for me to reach out to other people who are doing entirely different things in their daily research and to attack the problem that has a common interest among all participants. That is very new and very refreshing and very rewarding."* —Jerry (Space Cohort)

Kacey and Jerry both highlight aspects of this project that allowed them to combat common institutional challenges and limitations of interdisciplinary collaborations: flexibility and time. Certainly, we observed from participants that communicating and converging with faculty members from vastly different disciplines posed challenges, but participants often attributed their successes and growth to the expansion of their network to include disparate disciplines and perspectives, citing the meaningful connections and working relationships they created with other cohort members. These are demonstrated in Maria and Doug's quotes, below.

> *"I think that this project set us up for success to collaborate because there was so much interaction and there was so much push for learning about each other, learn about each other and watch each other teach other things and get engaged this way. It's taught me some things that I wish that I could do and so I'm thinking in the future about how I'm going to go about establishing collaborations for work."* —Maria (Space Cohort)

> *"I think, not only is it interesting, but it's just extremely sort of strategic and mutually beneficial for us to be looking for these ways in which creative disciplines and scientific ones can combine. Because I just feel like art can be the megaphone for research. And these kinds of cross disciplinary projects allow, yes, they allow us as artists to get a wider audience. I feel like they allow scientists to reach a wider audience and to be louder and more interesting in their messaging, perhaps."* —Doug (Elements Cohort)

Maria, like Kacey and Jerry, acknowledges that the STEAM collaboration was successful due to the structure of the program that allowed for significant time to be taken and spent learning about and from one another. Maria's quote also demonstrates how she articulates her growth in the networking strand of her identity trajectory, speaking to plans and strategies for collaborations, which was echoed by at least one other faculty member in each cohort.

Doug's quote most eloquently captures a widespread sentiment across participants of an appreciation for the inclusion of arts in what is traditionally science, technology, engineering, and mathematics (STEAM rather than STEM). This expansion was new to many participants and presented a challenge, but it also enriched many of the collaborations in ways that would have not been possible without the inclusion of the "A" in these STEAM cohorts.

4. Discussion and Implications

This research demonstrates the importance and utility of integrated STEAM collaborations to the identity trajectories of STEAM faculty members. Our longitudinal analysis of participants' identities revealed that all participants experienced growth with regard to their identity trajectories, in some cases across both their researcher and teacher identities. In all cases, clear growth was documented related to each faculty member's dominant identity. Through this research project, we were able to create an intentional space for collaboration across disciplines, and collaborations and integrations of participants' disciplines through communication with public audiences in informal spaces heavily influenced faculty members' development through these identity trajectories. The fact that faculty members' experiences in the workplace impact their identity development has been demonstrated in research that has also leveraged the identity-trajectory conceptual framework to explore the development of faculty members' identities [36]. In our study, the participants described their growth in their identity trajectories as impactful to their professional development with regards to (1) presentation and communication skills when teaching science topics to students or others less familiar with their research, (2) their utilization appreciation for institutional collaborations and resources, and (3) the value of broad and divergent networks. This finding aligned with another study that found the integration of arts into teaching professional development related to physics lessons useful for teacher development, specifically with regard to improving pedagogical content knowledge and the ability to use representations when teaching complex concepts [52].

Our findings illustrate that participation in these activities, in which faculty members integrated knowledge and experiences across their disparate STEAM disciplines, helped them strengthen and further develop their academic identities across all three strands of the workplace portion of the identity-trajectory framework [36], but the most apparent growth was typically in the intellectual strand and directly related their dominant role identity as either a teacher or a researcher. The literature related to engineering faculty members' participation in outreach with industry contained similar findings: faculty members reported their participation in industry outreach as positively impacting both the teaching and research aspects of their own roles and the broader university mission [53].

Development was demonstrated by faculty teacher and researcher identities evolving as they worked to communicate and collaborate in new ways with colleagues across a wide range of disciplines, as well as with new audiences in informal learning settings. By finding and leveraging techniques to connect their own research first to that of the other members of their cohorts and then to a larger audience and the public community, faculty members were able to view their research and its contribution through the lenses of others outside of their discipline. This collaboration with researchers in seemingly unrelated disciplines who had never collaborated before, coupled with the challenge of presenting their work to the public in an accessible and impactful way, allowed them to improve how they engaged with others who have less familiarity with their discipline or research area on a regular basis, as part of their role as a professional educator. This growth and development in communicating

science knowledge to the general population has the potential to help mitigate the "expert blind spot" that many faculty members experience when teaching in the classroom. The "expert blind spot" is a phenomenon in which someone's expertise in a field or area leads to assumptions about a learner's prior knowledge or performance that are sometimes inaccurate [54]. Not only did communication with others who do not share expertise in their discipline improve through this project but faculty members also noted that the training and public engagement opportunities inspired them to change classroom teaching practices and approaches and rethink mentorship strategies to encourage interdisciplinary collaboration and communication among their students.

Beyond the ability to better understand the perspectives of others when talking about science and STEM research, our results revealed the importance of the training provided to help researchers communicate their work to a wide-ranging audience. Our findings highlighting the importance of training for significant growth in communication effectiveness align with other research and resources related to training faculty members to improve public communication and research dissemination through inquiry-based methods (e.g., [55,56]). As noted by the participants in this research, these strategies for engaging public audiences in informal learning spaces are transferable to formal education and higher-education classrooms. Engaging students in learning through interactive and inquiry-based methods that promote student engagement and learning has been widely recognized as good pedagogical practice [57] and noted as beneficial by students [58]. By participating in these integrated STEAM faculty development experiences, faculty members were able to acquire these skills and recognize the transferability to their own teaching, mentoring, and course design/classroom practices to strengthen their teacher identities and pedagogical practices in formal education settings.

Alongside the development of more effective teaching practices and the strengthening of teacher identities was the development of research dissemination and collaboration strategies and the strengthening of researcher identities. Faculty members reported feeling more confident in their ability to communicate their research and its relevance as a result of these integrated STEAM experiences. Additionally, they reported feeling inspired to pursue more interdisciplinary STEAM research opportunities in the future, given the success of these collaborations. The faculty members also planned to look for additional opportunities for integrating arts into science, technology, engineering, and mathematics spaces. The faculty members in this study are not the first to find significant value in this integration, as many calls for more intentional creativity and innovation to be included in the STEM fields and STEM education lead to a variety of ways in which the arts have been introduced into STEM teaching and learning spaces [59]. While research and practice still seem to be grappling with what STEAM means and how education research can measure and articulate its impact on students' learning, innovation, and creativity [60], the faculty members in this research were quick to identify the value. In this study, the creative arts faculty members within this cohort were described as what made the STEAM integrations possible. Their ability to make connections between disciplines by hearing the story each cohort member had to tell and then weaving those stories together into an overarching narrative for the group to coalesce around was a common theme across all cohorts. Just as faculty members participating in this research identified the value added by the integration of art into their interdisciplinary cohorts, the integration of art standards into STEM education settings has also been shown to improve students' joy and engagement with learning and improve the learning of STEM content and concepts [61–63]. Our research found that the integration of art in these cohorts was what facilitated the weaving together of interdisciplinary ideas, forming transdisciplinary collaborations, with transdisciplinary defined by Liao: "space that cannot be defined in reference to any traditional sense of discrete disciplines" [64] (p. 48).

5. Conclusions and Future Work

Addressing the most pressing problems we face in the 21st century requires that we leverage the diversity of experience, field expertise, and talent available to us, which means integrating expertise across a variety of fields and disciplines to create innovative solutions. Despite institutional goals to increase interdisciplinary research, collaboration with continuous and active exchange across diverse disciplines is relatively rare and challenging for most universities. We organized cohorts of interdisciplinary faculty members to collaboratively engage the public with their research areas of expertise in a variety of informal learning settings: a science museum, a hackathon, a community art crawl, and a science pub. We sought to understand faculty members' identity development as professionals over the course of the project using the identity-trajectory theoretical framework to answer the research question: In what ways do STEAM faculty members' identities as professionals develop from collaborative informal science communication experiences? We found that interdisciplinary collaborations strengthened faculty members' abilities to communicate their research with those outside of their field, whether that be the general public, their students, or faculty members in other disciplines. Faculty members also demonstrated positive trajectories in the development of their professional identities. Faculty members' dominant identity (as either a teacher or a researcher) was the most directly impacted and experienced the most noticeable growth and development with regard to broadening and improving their communication strategies and approaches when they communicate with others related to science and research. Quite a few faculty members demonstrated growth in multiple aspects of their identities by the end of the project. Additionally, our analysis mapped longitudinal identity development across all three strands of the workplace portion of the identity-trajectory framework: intellectual, institutional, and networking.

By engaging with interdisciplinary STEAM collaborations in learning settings that challenge faculty members to communicate in new ways to new audiences, faculty members across STEAM disciplines could have the opportunity to gain new communication skills, as well as confidence in those skills, which will also benefit their traditional communication means and induce an overall growth in their identity as an academic professional. When faculty members become better communicators, not only are their research and teaching contributions to academia strengthened, but the public's understanding of research also expands. Our results highlight the impact that interdisciplinary educational experiences have on the professional development of faculty members and how these developmental experiences impact their teaching and research practices. Spyropouilou and Kameas [65] have recently published a conceptual framework for STEAM educators for effective teaching and learning, and our research following the identity trajectories of faculty members who participated in interdisciplinary STEAM collaborations in public communication and informal learning spaces provides evidence of development across many of these competencies over the course of their participation. This alignment is exciting, as it indicates that when faculty members participate in integrated STEAM activities, whether it be teaching or research, it is likely that the experience improves the development of the competencies necessary to continue to teach and research through an integrated STEAM lens.

Future work exploring interdisciplinary STEAM collaborations across faculty members can more intentionally explore impacts in the two primary roles faculty members play in higher education: that of a teacher and that of a researcher. Our research revealed nuances in how faculty members perceived the impact of their participation on their trajectories, but exploring the nuances and differences was not our primary purpose, and as such, our insights are limited. Future work could further explore the ways in which interdisciplinary STEAM collaborations influence the teaching and research components of faculty members' jobs to design well-rounded developmental experiences for faculty members working in collaborative STEAM spaces.

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