Examining community of practice formation within a new informal art and physics program

Brean Prefontaine, Raymond Smith, Dena Izadi, and Kathleen Hinko
Department of Physics and Astronomy, Michigan State University, 220 Trowbridge Rd, East Lansing, MI, 48824

The need for physicists to work with others outside of the discipline of physics has become more prominent due to the growing necessity of interdisciplinary subjects and careers. While this need exists, there are few opportunities for physics students to gain collaborative experiences and skills. This study looks at how a community of practice formed within an informal physics program that was designed specifically to bring undergraduate physics and graphic design students together to create an aesthetic physics teaching tool. Throughout this 10 week summer project, we collected qualitative data in the form of interviews and written responses from a team of four undergraduate students, observed meetings, and interviewed the project co-developers. These data record the students' and co-developers' experiences as they work together to develop a public engagement project aimed at combining physics with art and design. Using an operationalized Communities of Practice framework to analyze these data, we are able to explore the formation of a Community of Practice and better understand how developing informal physics programs can foster a community of practice environment.

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I. INTRODUCTION

Each physicist is a complex individual with many different interests both inside and outside of the field. The field that has historically faced underrepresentation among women and people of color and struggled to recognize the interests and identities of many of its members. Prior work has shown that physics identity development can lead to persistence within the field and other successes [1, 2]. One place where a physics identity can develop are informal learning spaces that allow for participants to become agents of their own learning [3]. Prior work has shown that some informal physics programs can support physics identities of its members by serving as communities of practice [4–9]. However, this prior work is focused on established informal physics programs, i.e. programs that are at least five years old, have robust volunteer support, and have clear organizational structures. As the physics community seeks to expand its informal education activities, insight is needed into how new programs are formed. This work is the beginning of looking at how new informal physics spaces can form a community of practice because ultimately the community of practice might be able to supports the multiple identities of its members.

In this paper we examine the development of a new, specific informal physics learning project that was conceptualized and designed to be a community of practice. The project was first conceptualized by a physics postdoctoral researcher working with a physics education research group at an R1 university. She responded to a call for community contribution to a science and art exhibit at a local museum that aims to combine art, science, design, and technology. The secured funding led to four undergraduate students (two majoring in physics and two majoring in graphic design) being hired for ten weeks during summer 2020. Select demographics of the students can be found in Table 1. The students mainly worked with the postdoc researcher, graphic design faculty member, and a physics graduate student to create a website, called Bohring Art. The project was deliberately designed to bring together physics and art and provides a unique opportunity to examine the formation of a community of practice and the impacts it has on identity development within a project that consciously combines physics with other areas of interest.

TABLE I. Select Student Demographics

Pseudonyms	**Demographics**
Muhammad	Senior physics major, male, Asian
Aaron	Sophomore physics major, male, Black
David	Senior graphic design major, male, white
Richard	Senior graphic design major, male, white

Here we consider the following research questions: To what extent did a community of practice form throughout the duration of the Bohring Art project? How did the more central members (the undergraduate students) perceive the formation of the community of practice? To answer these questions, we followed the project from design through implementation, looking for markers of community of practice. Our approach was qualitative and utilized multiple data sources, including observations, participant reflections, interviews with participants, and collection of project artifacts.

II. COMMUNITIES OF PRACTICE FRAMEWORK

The Communities of Practice (CoP) framework was originally developed in 1991 by Lave and Wenger as a way to understand the functioning of groups of people caring about the same goal [10]. Lave and Wenger describe that for a group to be viewed as a CoP, it must consist of members striving to achieve a shared goal (domain), working to support each other (community), and sharing a set of information or norms (practice). Past work has utilized an operationalized version of the CoP framework to examine informal physics spaces [4, 5, 8, 9]. This operationalized CoP framework includes 'community dimension' constructs that describe how members of the group are involved. Below we outline three community dimensions that we then can use to determine member's perceived formation of the CoP.

Accountability to the Enterprise establishes the necessity of a shared goal or interest (domain) within a CoP. This construct refers to the members' understanding of the overall goal of the CoP and their commitment to achieving it. In the context of this study, this construct captures how the students conceptualized and redefined the project's focus both as a response to the pandemic and because they had the agency to make the project their own.

Mutuality of Engagement captures how the group must have an exchange of ideas among members who support each other in achieving the goal. This construct refers to the ways that members interact with each other and build relationships within the CoP. In this study, this captures the interactions between members, as well as the sense of community that formed and the changing ways in which the students viewed their roles within the Bohring Art team.

Negotiation of the Repertoire captures the practices that members of a CoP employ in order to work toward the goal. The construct focuses on how a member's participation in the CoP can shape their personal experience and memories as they relate to the practices regularly performed within the community. In this study, we identify the development of individual members' skills and behaviors as they related to Bohring Art and how the CoP's practices changed over time.

III. METHODOLOGY

This paper examines an informal physics project from the conception and planning phase to the implementation of having students work together to create a public engagement tool. Data about the planning phase of this project came from inter-

views conducted after the conclusion of the project with the co-developers (the physics postdoc and graphic design faculty member) and from observations of planning and project meetings. The interviews asked co-developers about their motivations and intentions for the project.

In order to examine how a CoP emerged within the project, we looked at 8 interviews (four students with two interviews each), a set of 36 written reflections (four students with nine reflections each), the 2 interviews conducted with the co-developers, and frequent observations of project meetings. Each student was interviewed once at the beginning and once at the near end of the 10 week project for about 30 minutes. The first interview focused on prior experience and expectations for the project while the second interview captured the experiences of each student within the summer project. Starting the second week of the project, the co-developers asked each student to write and submit a short reflection each Friday in response to unique prompts, such as "Can you describe in your own words what it means to do 'physics research' and to 'design' for some project" and "What was the hardest thing for you personally about working in this group?"

The three community dimension constructs from the operationalized Community of Practice framework were used to code the data (Accountability to the Enterprise, Mutuality of Engagement, and Negotiation of the Repertoire) [8, 9]. We also created an emergent category for ideas that were not fully captured with the community constructs. These ideas typically related to the unique combination of physics and graphic design. Two researchers coded all data sources and resolved all differences. Analysis was also discussed with two additional researchers.

IV. DESIGN OF THE COMMUNITY OF PRACTICE (PLANNING PHASE)

In this section, we describe the planning of the project and the co-developers' design choices related to domain, community and practices. When the physics postdoc researcher had her proposal accepted by the museum partner, she was auditing a graphic design class and asked the graphic design faculty member if she wanted to become involved. Together, the physics postdoc and the graphic design faculty member worked with the museum partner to lay out the project and identify undergraduate students who would work on the project (indicated on the top of Figure 1). While the project leaders hired the students and had a general idea of the goals of the group, they wanted to ensure that the students were able to guide the work. When ask about about the motivation for this project, the physics postdoc described her intention for the domain by saying:

> So I always felt like there is this great opportunity in graphic design... because it all talks about how you could communicate something with someone in a new, different way.... So I think that was the starting point for bringing in people from both groups. But then after we got the money from [the museum partner], we figured, 'That is a great opportunity now to bring in students together from both disciplines so that they can work together.'

The Bohring Art project team included four paid undergraduate students (the graphic design students were invited to participate and the physics students who were chosen out of a pool of applicants). The physics postdoc and graphic design faculty were the main advisors for the students and a physics graduate student also attended project meetings, gave feedback to the students, and carried out all of the data collection activities for this research. Two other physics faculty were tangentially involved and gave support to the two faculty/staff during the project formation process and to the students by giving feedback on a semi-regular basis. This group of people were the community of the Bohring Art CoP.

In May 2020, the undergraduate students were tasked with creating a portion of a museum exhibit that would convey physics concepts to a 'general audience' of non-physicists, with a focus on young adults. Their portion of the exhibit was originally supposed to be a physical object located within the exhibit; however the COVID-19 pandemic required the students to shift to a virtual contribution. Due to strict social distancing protocols, the entire team collaborated remotely. Throughout the summer, the four students negotiated practices for the group, through meeting daily via Zoom throughout the work week to discuss physics concepts and planning out activity designs. The final product became the aesthetically appealing Bohring Art website consisting of several interactive activities on introductory physics topics.

V. DEVELOPMENT OF THE COMMUNITY OF PRACTICE

Applying the three community codes from the Community of Practice framework to our data, we were able to track how the participants experienced and perceived the Bohring Art project as it developed. Figure 1 shows three snapshots of the Bohring Art team at different moments during the project and where each member is positioned with respect to each other.

After the physics postdoc, graphic design faculty member, and museum partner conceptualized the project during the planning phase (spring), the Bohring Art team started to grow and embark on the bulk of the work. At the beginning of the project (early summer), new members of the project team joined and the community of practice started to form. The co-developers and students began to discuss and plan the major output of the project. Also after the planning phase, the museum partner institute provided only minimal feedback - they were excited about the ideas for bohringart.com and left it up to the team to complete the work.

By the end of the project (late summer), the undergraduate students had become the central members of the community of practice, having done all of the website development

work with frequent input from the co-developers. The museum partner did not provide any input and so dropped out of the community of practice. Throughout the following sections, we examine the students' interviews in depth because we were interested in how the central members viewed the CoP formation.

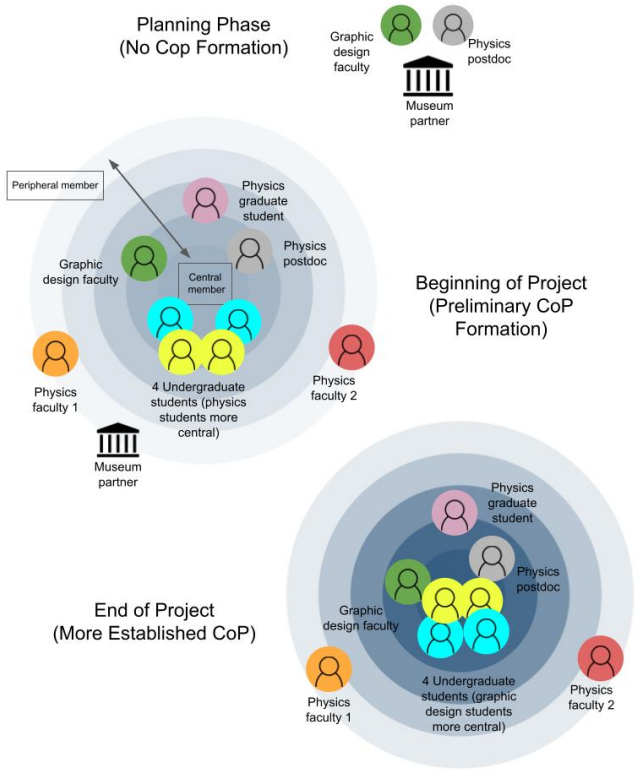

FIG. 1. Visualization of three phases of the project (from top to bottom): 1) Planning Phase - the graphic design faculty member and the physics postdoc met with the museum partner but there is no CoP formation. 2) Beginning of Project - individual's initial roles and degrees of membership are indicated; this early CoP development is signified by the lighter color membership circles. 3) End of Project - the CoP is more established.

Establishing the Domain (Accountability to the Enterprise code): To understand if a CoP was forming, we tracked how the members saw the enterprise and viewed their accountability to it. Throughout the timeline of this project, we saw each of the students grapple with the goals of the project and the eventual product of the Bohring Art website. Looking at the Accountability to the Enterprise codes, we find that students were initially interested in working on the project for personal reasons. For instance David and Richard both mentioned gaining job experience through working on an interdisciplinary project. Both Muhammad and Aaron talked about looking specifically for paid physics experiences to add to their resumes. Because of the different backgrounds of the participants and their reasons for embarking on the project, initially the group found it challenging to establish what the project goals and outcomes would be. Richard explained:

> It was tough at the beginning to figure out where to start off on the project because we were kind of the ones that were laying down the foundation.

The initial design of the project was intended to give the students agency about the product that they created, but there was an intentional focus on combining physics and graphic design. During the first seven weeks, we saw the students continually talking among themselves about what the goals for the individual activities on the website should be and why. They also had to deal with the completely virtual nature of the project as a result of COVID restrictions. They decided to create a series of online physics activities that would interest and excite users about circuits, the star cycle, lasers and lenses, and kinematics. All the students felt strongly about creating a visually appealing physics website that would teach others about the chosen topics. Muhammad described this motivation by saying:

> I think the [website visitors] will really like the website.... I kind of just want to put this science interest in them that'll make them go and want to learn more about it and see that, "Oh, this is really interesting." ... So I hope that ... it'll break the stereotypes off of a lot of science stuff where it's like there's no way that ... you can make learning about this interesting.

One of the graphic design students also described his feelings toward the final product:

> Obviously, you want students to notice the website has a cool design appeal to it, or the components are designed a little better or more in-depth than another website that might have some of the similar activities. But really we wanted it to reach all students of our age and like something that they wanted to take on, something they wanted to actually just experience if they weren't into science.

This arrival at a set of goals for the website became the domain of the Bohring Art community.

Developing the Community (Mutuality of Engagement code): Simultaneously while figuring out the goals of the project, the students were also building relationships with each other. David and Richard already knew each other from a class that they had both taken during the spring semester. However, Muhammad and Aaron did not know each other nor did they know the design students. During the first week of the project students decided that project communication should occur through daily Zoom meetings as well as discussion over Slack. While the students only worked on this project for 10 weeks, their decision to meet virtually with each other for four hours every Monday through Friday created an opportunity for them to work closer together than other structures would have allowed.

Through the Mutuality of Engagement codes, we found that all the students described the process of forming rela-

tionships with the other members in a positive way. All mentioned needing time to get to know the other community members, including working with the physics postdoc and the graphic design faculty member. The earlier project meetings were more business-like with the students only focusing on the task at hand. However, later project meetings would include time for off topic conversation about everyone's personal lives. In the words of David:

> I think we have a strong relationship. At first, there's definitely a lot of hesitation and you don't really know each other ... but obviously, during the course of a 10 week period, you start to form a little bit of a friendship because you're really meeting every day and ... you're learning more about each other as you go on. Where they're from, what they're doing outside of this project. So, it's really cool.

Richard mentioned how working with people outside of the field of design was very important to him which in turn created a sense of importance around the project. Aaron pointed out that the relationship between everyone was important because it provided a space to be able to both critique and provide ideas:

> And by relationship, I guess, I mean the comfort level, where you're not afraid to say, "No, I actually think that's wrong." Or you're not afraid to like, "What if we did blah, blah, blah?" and give your opinion.

Another theme that came out of the Mutuality of Engagement coding was related to the difficulties of having to work on the Bohring Art project remotely. Some students noted that it took longer to establish relationships with members of the team, particularly with the co-developers who were less central to the group, because they had never met them in person and only saw them virtually a few times a week. One of the physics students also noted that teaching physics using online platforms was a challenge. These interactions among the members of the group formed a sense of community.

Engaging in Practices (Negotiation of the Repertoire code): To create the final product, the team of students had to use their physics and design skills. The team met daily to work on different aspects of the project, including learning about the physics topics they wanted to cover and developing a wireframe for the website. Through the Negotiation of the Repertoire code, we see that while the design students started the summer with minimal physics knowledge, by the end of the project they felt as though they had learned the concepts and were able to make the physics ideas more interactive. As Richard put it:

> I think some of the highlights of the summer were kind of learning about the topics that [Muhammad and Aaron] were teaching us and how we can incorporate them in a fun aspect.

In contrast, Muhammad and Aaron both mention having minimal to no knowledge about design but only learning a small amount throughout the summer. They mainly saw their role as teaching David and Richard so that they could then build the website. As Muhammad put it at the end of the summer:

> Because I know that I'm a physics student, so I'm supposed to be helping [David and Richard] with certain things that they're trying to design, and I'm supposed to be working with [Aaron] to come up with a curriculum for the website. But at times, it just seems like there was no work for me to do, or nothing to contribute sometimes because a lot of it would just be designed.

The design students also mentioned wanting to be able to share more about design with the physics students. In the words of David:

> I wish there was some time designated to teach [Muhammad and Aaron] some basic design skills.

However, Aaron did share a newfound appreciation for design near the end of the project. He shared:

> One interesting discovery I made was that physics and art are more interconnected than I previously imagined. I realize that while the methodologies and requirements... are very different, the tasks are really the same. Both physics and art try to capture the essence of the universe in some sort of way, whether it be via equations or drawings of objects.

VI. DISCUSSION

In contrast to prior work that looked at CoPs within well established informal physics programs, this paper is a first step at looking at how a CoP might form within a newer or developing informal physics space. We found that the project team did eventually form a CoP throughout the summer implementation phase. The meeting observations and the interview data pointed to a well formed domain, community, and practice for the Bohring Art group during the summer implementation phase. We used the operationalized CoP framework to understand how the students perceived the formation of the CoP. The students, being the most central members of the CoP, determined the domain of creating an interesting and educational website, the practices of working together online and sharing physics and graphic design concepts, and the community of drawing on each others' strengths. Additionally, we saw the physics students doing more teaching and less learning than the graphic design students, resulting in them being more central during the content development and less central during the final stages of graphic design. Overall, this exploration of a CoP formation in an informal physics program is important as the first step to understanding if and how physics identity is being formed within the experience.

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