Understanding long-term impacts of youth's participation in an informal physics program: A qualitative pilot study

Brean Prefontaine (she/her)
Department of Computer Science, Duke University, Durham, NC, USA

Turhan Caroll (he/him)
Department of Workforce Education and Instructional Technology, University of Georgia, Athens, Georgia, USA

Noah Finkelstein (he/him)
Department of Physics, University of Colorado Boulder, 2000 Colorado Ave, Boulder, CO, USA

Jessica Hoehn (she/her)
JILA, National Institute of Standards and Technology and University of Colorado Boulder, Boulder, CO

Despite numerous studies examining the impact of youth participation in informal physics programs, existing research primarily focuses on short-term outcomes, neglecting the long-term effects. To address this gap, we aim to develop a mixed-methods longitudinal study to understand the long-term impact of youth participation in an informal physics program. This paper focuses on a qualitative pilot study with three prior program participants and serves two purposes: (1) to gauge which elements of the informal physics program may be important to investigate further within the longitudinal study and (2) to further understand the complexities and challenges of utilizing interviews with program participants and alumni as the qualitative approach to the longitudinal study. Findings revealed diverse motivations for program participation, varying levels of program recollection, and a spectrum of impacts on participants. Building upon these findings, our planned longitudinal study will employ both quantitative and qualitative methods to gain a nuanced understanding of the long-term effects of youth engagement in informal physics programs.

2024 PERC Proceedings edited by Ryan, Pawl, and Zwolak; Peer-reviewed, doi.org/10.1119/perc.2024.pr.Prefontaine

I. INTRODUCTION

Informal physics programs take many forms in terms of focus, format, and facilitators, but broadly all aim to provide positive physics experiences for the participants. Informal programs typically grant participants the freedom to choose what they want to learn, without the pressure of grades, and are presented in diverse formats like after-school programs, science festivals, summer camps, and citizen science projects [1]. Prior work has shown that informal physics programs can have a variety of positive impacts on both the youth participants and facilitators [2–6]. However, many of these studies are often focused on the immediate outcomes and typically do not examine long-term impacts.

We seek to understand the long-term impacts of participation in an informal physics program through a mixed-methods longitudinal study. Our other pilot study examined survey data with current youth participants [7]. This paper focuses on a qualitative pilot study with three prior program participants and answers two research questions: (1) Which elements of the informal physics program may be important to investigate further within the longitudinal study? and (2) What are the complexities and challenges of utilizing interviews with program participants and alumni within the longitudinal study? We recognized that three interviewees limits generalizability. Still, this pilot study can illuminate potential next steps in the longitudinal study and the spectrum of impacts that informal program participation can have.

II. BACKGROUND

As we seek to design a longitudinal study informed by this pilot study, it is important to define what a longitudinal study is and what methods are being used. White and Arzi [8] define longitudinal studies as those where "two or more observations of comparable forms are made of the same individuals or entities over a period of at least a year." They advocate for the relevance of such studies in science education, emphasizing that individuals' learning and comprehension of science evolve over a lifetime. However, longitudinal research studies in science education are "relatively rare" [9].

This scarcity of longitudinal studies extends beyond formal education settings into informal science education. Fadigan and Hammerich [10] used a longitudinal, descriptive case study approach with a sample of 152 women who participated in an informal, science education enrichment program during high school to study the impact on educational and career trajectories. Similarly, Bischoff, et al. [11] used pre-, post-, and alumni survey data to understand how participation in a summer camp experience influences academic choices. Joy, et al. [12] also used surveys (administered at the beginning of participants' involvement in an informal program and after one and two years) to investigate interest, mindset, and engagement with science.

While qualitative methods are well-established in the humanities and social sciences [13, 14], their utilization in informal science education longitudinal studies appears less common. One example is a qualitative, longitudinal case study approach to understand the experiences of four students participating in an informal science and math program [15]. Recognizing the potential of mixed methods, Vogl [16] highlights that combining quantitative and qualitative approaches allows for more nuanced and valid insights within longitudinal studies. Chapman, et al. [17] used mixed methods, longitudinal approach to study Hispanic, female participants in a summer camp by examining pre- and post- assessment scores and interviews conducted on the last day of camp. The inclusion of the qualitative data, allowed the researchers to learn more about campers' STEM attitudes and interests.

Our study aims to build upon these prior studies to contribute to the field of informal science education by adopting a mixed methods longitudinal approach. By integrating quantitative and qualitative data collection methods, we seek to capture the multifaceted nature of participants' experiences and provide a more comprehensive understanding of their educational journeys. However, there are significant challenges unique to longitudinal studies that we must reckon with, including time required to conduct and complete the study, effort and resources needed, data management, and attrition [8]. Utilizing interviews in a longitudinal study further complicates the process due to a need for training interviewers (if there will be more than one), coordinating the interview with youth, and ensuring researchers are analyzing data in a consistent manner (i.e., through interrater reliability) [**?**].

III. CONTEXT

This study is part of a larger longitudinal study aimed at documenting the long-term impacts on youth participants in a community partnership-based, informal physics program known as Partnerships for Informal Science Education in the Community (PISEC). It is a weekly after-school program that brings together university volunteers (undergraduate and graduate students, postdoctoral researchers) and youth (grades 3-8) to engage in open-ended hands-on physics activities. Each after-school club meets for one hour per week for 10 weeks each semester. PISEC runs several sites, enrolling approximately 80 youth per semester. Youth participants work in groups with a university mentor and each week they choose which experiments to do and how to do them, often designing their own experiments. Throughout the semester, youth document their activities in their own science notebook and through video recordings. At the culmination of the program, youth go on a field trip to the University of Colorado Boulder. PISEC's primary goals are to cultivate an interest in STEM, help youth develop STEM identities, and allow youth participants to explore pathways to physics and other STEM careers. PISEC youth participants on average are 50% female, 70% underrepresented racial/ethnic minority (primarily Hispanic/Latinx), and 70% low-income. Many youth participants are English Language Learners (na-

tive Spanish speakers) and will be first-generation college students if/when they attend college.

Nearly 16 years of research documents the impacts of PISEC on both youth participants and university volunteers [18–22]; however, each of these studies focused on short timescale impacts (i.e., over the course of one or two semesters in the program). The present longitudinal study builds upon this prior work to understand the long-term impacts of the PISEC program. A mixed method approach is being used to understand a range of impacts including the extent to which participation in PISEC impacts youths' STEM interest, STEM identity, and decisions to pursue STEM.

IV. METHODS

This paper focuses on the qualitative portion of the mixed methods longitudinal study and presents findings from a small-scale, preliminary interview study with three former PISEC participants. Through a partnership with a high school teacher, 60 prior PISEC participants currently in high school were emailed and asked to participate in this study, 5 responded positively, and 3 completed an interview. The interviewees had participated in PISEC 5-8 years prior to this study. We were unable to collect gender and racial demographics of participants due to school district policies and privacy concerns. Gender-neutral pseudonyms have been assigned to each interviewee.

Each semi-structured interview was conducted virtually. The interview aimed to explore participants' perspectives on their PISEC experience and their current engagement with STEM. The semi-structured format allowed for more discussion between the interviewer and interviewees [23]. The protocol included questions about participants' recollections of PISEC, its influence on their STEM interests, other informal experiences, career and educational plans, and their perceptions about being a "STEM person." Follow-up questions were employed as needed to delve deeper into participants' experiences and views on STEM.

The interview transcripts were inductively coded by one researcher using NVivo and the resulting themes were discussed among the research team. It is important to note that having one researcher complete all the coding presents limitations. Efforts were made to mitigate bias and ensure comprehensive analysis within this pilot through regular discussions among the research team about the coding and identified themes. The qualitative analysis carried out in the full longitudinal study will include coding by multiple members of the research team and intercoder reliability.

Positionality Statement: We are a diverse team of two white women, one Black man, and one white man who have varied professional roles (postdoctoral researcher, director of PISEC, and faculty members), geographical locations (all within the U.S.), ages, disciplines (computer science, physics, and STEM education research), and disability statuses. We recognize that our social positions, identities, and privileged statuses as academics shape this work. The interviews were conducted by the director of PISEC, a white woman. The transcripts were analyzed by the postdoctoral researcher, also a white woman. Collectively, our identities and personal experiences with informal physics education, and PISEC specifically in some cases, strengthen our understanding of PISEC and what it means to work with youth in an informal setting.

V. FINDINGS

Interviews with the three teenagers, Lux, Cosmo, and Orion highlighted a spectrum of motivations for participating in PISEC, the activities they remember, and how PISEC impacted them. The interviewees also shared how they and others perceive them as STEM people and their future plans.

Motivation for participating: At the time of the interview, Lux was in 10^{th} grade and recalled participating in PISEC for two years (5^{th} and 6^{th} grades). They shared that despite having a "pretty bad memory," they do remember most of the program and the name of the university volunteer that they worked closely with. Lux shared that they first signed up for PISEC because they, along with a friend, were trying to find something to do after school. Their science teacher told them about the program which convinced them to join. They continued in PISEC because they "thought it was super fun and cool" and "very entertaining."

Cosmo was nearing the end of 11^{th} grade at the time of the interview and participated in PISEC during 3^{rd}, 4^{th}, and 5^{th} grades. Cosmo had been involved with robotics during fourth grade and wanted to continue doing something similar "for fun." They asked their mom to sign them up for the PISEC after-school program and remained actively involved in it for three years. Shortly before the interview, Cosmo went back to a PISEC site and helped run the activities as part of a project they were completing for one of their high school classes. During the interview, Cosmo remembered some of the PISEC activities but needed some prompting to remember more details throughout the interview.

When interviewed, Orion was in 11^{th} grade and recalled participating in PISEC during 4^{th} and 5^{th} grade. They vividly remember three different activities and working with the university volunteers. Orion signed up for the program because their science teacher encouraged them and their cousin was also involved in PISEC. They came back again the second year because it gave them "something to do after school" and they "really enjoyed it the first time."

PISEC activities and processes: Despite having different motivations for joining PISEC, Lux, Cosmo, and Orion all had positive memories of their participation. They each recalled the program with different levels of specificity, but prompting from the interviewer helped each interviewee remember many key program components. In terms of activities, Cosmo remembers having the freedom to choose what to work on, specifically the projects that involved building bridges, cars, and circuits. Cosmo shared:

> The freedom to pick a kit that we wanted to do

> that week.... It was just the freedom of being able to do a different thing. I remember, if you didn't want to do something that week and you wanted to do something else you could always ask, and they always try to get a different kit and then you can do different things.

Lux did not remember as many specific activities, but rather they remembered the processes. Lux talked about writing down what they learned and what was interesting and using cameras to record experiments. Orion remembered a mix of specific activities (like completing a Coke and Mentos experiment and a laser chess activity) and processes such as writing in notebooks. All three interviewees also mentioned the field trips to the University of Colorado Boulder.

Cosmo and Lux also spoke about some skills they learned from participating in PISEC. For example, Cosmo shared that working with their group and mentor on PISEC experiments helped them develop teamwork skills even though they were not "really a team type of person." They went on to say:

> I didn't really like teamwork, I kind of wanted to do my one-man show so it's just nice to like know I was able to work with different people... mentors, different peers, and all that.

Both Cosmo and Lux mentioned that writing in PISEC notebooks taught them the significance of documentation. Cosmo shared that their increase in understanding of how to document the experiments helped with activities outside of PISEC. They reflected on their robotics team's past competition challenges but noted a turning point when in "7th grade we went to nationals because we had a better notebook and we actually were able to learn that we could document better."

Community with mentors and peers: All three interviewees also spoke about ways that PISEC participation was impactful. While each interviewee mentioned working with the mentors, Lux specifically called out that working with the mentors was very impactful for them. They remembered the name of the mentor they worked with and shared that their mentor had been a topic of conversation with a fellow PISEC participant after their participation. Lux shared:

> I think definitely the people, like the mentors that would go, and they were... just all really nice.... They were very welcoming and stuff. When we would go every week with them... I think they made a really good impact on me, because now I think back on it, and they gave me really good memories. I remember having so much fun with all the mentors and all of the science experiments we did in the program. Me and my friends still talk about it sometimes. We're like, "Oh, my God! Remember when we were with Ethan and stuff and we would joke around."... It was all super fun.

In addition to interacting with the mentors, all three interviewees also mentioned that interacting with other PISEC participants was impactful. Cosmo and Lux pointed out that PISEC was an opportunity for them to form lasting friendships that were sustained beyond their participation in the program. Orion also mentioned that PISEC was a way for them to make new friends. They shared:

> It was just a way for me to make new friends and learn how to communicate better because that's something that I was struggling with at the time.

STEM Interest and Identity: When asked if their participation in PISEC impacted their interest in STEM or if they see themselves as a STEM person, all three interviewees agreed that PISEC participation heightened their enthusiasm for STEM. Orion remembers generally having less interest in "science or engineering" during their childhood but being very excited about the PISEC experiments, specifically the Coke and Mentos experiment. Orion shared that that experiment sparked an interest in culinary science and they started to learn more about the science of cooking an egg and baking cakes. When thinking about whether PISEC impacted their interest in science, Orion shared, "I noticed myself getting a bit more excited about stuff like that." They went on to say that PISEC participation helped broaden their career ideas:

> Before [PISEC] I didn't really think of having ... a science or engineering-based job in the future. But I feel like after the program it opened up, I guess, more thoughts of, "What if I did do this as a job? or What if I did try this out?" I feel like before the program I was completely closed off to it.

On the other hand, Cosmo and Lux both shared that they had been interested in STEM subjects during most of their childhood. They also both shared that participation in PISEC impacted their career ideas. Cosmo shared that PISEC allowed them to explore new topics and that it solidified their desire to pursue an engineering career. Lux shared that they are currently trying to decide what career path they would like to pursue, but that PISEC participation pushed them to think more about science pathways. In their own words:

> It did [impact my excitement about science] at the time, but I had always had that sidetrack of mind where I wanted to do something else. But at that time I was really into the science experiments that we were doing in the program.... I'm interested in science, but I'm like going back and forth. I can't decide whether I should just stay with [an] FBI [career path] or actually try to learn more about science and get into that stuff. But I mean, I think that [the PISEC] program definitely made me think more about doing science.

Each interviewee describes different motivations for becoming involved with PISEC, different amounts of interest in STEM during their childhoods, and different ways that

PISEC participation impacted their interest in STEM. This spectrum of STEM interest and involvement continued to be apparent when the interviewees were asked if they currently see themselves as STEM people. Cosmo, who shares that PISEC helped solidify their interest in an engineering career, says that they see themself as a STEM person. Lux is less certain about their career path and decided to identify as a STEM-interested person. Finally, Orion shares that they are "really into art" and identifies as a STEAM person.

The interviewees were also asked if their friends, family, and teachers see them as STEM people. All three agreed that their friends would see them as STEM people. However, Cosmo was the only one who thought their family sees them as a STEM person. (Lux was not sure; Orion's family sees them as more of an art person). None of the interviewees thought that their teachers saw them as STEM people. Cosmo suggested it might vary based on the teacher and subject taught, Lux was uncertain, and Orion believed none of their teachers considered them a STEM person.

VI. CONCLUSIONS AND FUTURE WORK

These pilot interviews with prior participants proved to be both enlightening and challenging. We learned that Cosmo, Lux, and Orion each had a positive experience within PISEC despite different motivations to join and stay within the program. Furthermore, their STEM interest, career ideas, and skill development were each impacted in different ways. These preliminary findings underscore the importance of how informal physics programs are structured. PISEC is intentionally designed to support teamwork, relationship-building, documentation skills, and youth agency, all of which we see indicated in the interviewees' reflections on their experiences in the program. Working with college mentors from a variety of backgrounds and disciplines also provides participants with an opportunity to learn about different career paths. Additionally, PISEC is designed to be flexible and adaptable to the youths' interests. The co-construction model allows the participants to choose which experiments to complete and how to go about completing them. Thus, PISEC participants can have unique experiences that support their interests, identities, and engagement in STEM in many different ways and we should expect that the long-term impact on participants will vary. These findings highlight the spectrum of impact PISEC can have on participants and support the need for qualitative data in our longitudinal study.

Due to this work serving as a pilot study, potential interviewees were only asked to participate once as no remainder emails or calls were used. Nevertheless, recruiting prior PISEC participants for this pilot study posed challenges. With only three participants, our sample size restricts our capacity to generalize the findings. However, there is some consistency across the three interviews that point to themes that should be explored within the longitudinal study. For example, Cosmo, Lux, and Orion all spoke about how their friends likely view them as a STEM person while their families (with the exception of Cosmo's family) and teachers were likely not to view them as a STEM person. This suggests that prior participation in an informal program could influence how peers perceive each other's interest in STEM, contrasting with the perceptions of family members or teachers. Thus, we aim for the longitudinal study to include youth participants with varying lengths of involvement in PISEC.

Another limitation arises from the fact that three interviewees had participated in multiple semesters of PISEC, indicating a potential selection bias, where individuals with more positive experiences may have been more inclined to participate in the interviews. However, it is worth noting that many PISEC participants enroll in multiple semesters due to parental need for after-school care, so repeated participation does not necessarily signify a more positive experience. Selection bias may have also influenced the level of detail that interviewees remembered. Interviewees responding to a cold email many years after participating in PISEC may have been more likely to have a positive experience and thus more likely to remember more about the program.

Future work on our mixed methods longitudinal study will include instrument development, recruitment of more participants, and annual survey and interview collection. Findings from the pilot study indicate motivation for joining, community formation (with mentors and peers), STEM experiences leading to learned STEM skills, and varying levels of STEM interest and identity among participants are all important aspects of the PISEC to further understand. These will be the starting points for developing both quantitative and qualitative instruments to understand long-term impacts of the PISEC program. Current parents of PISEC participants are informed of the longitudinal study and given the opportunity to opt-in and provide contact information. Efforts are underway to create a database of all participants who opted into the study so that annual research efforts can be easily distributed. Starting this year (2024), all participants who opt-in to the study will be asked to complete an annual survey and interview. Additionally, program leaders plan to ensure that PISEC makes and maintains lasting connections with participants so that the mindset is "once a PISEC kid, always a PISEC kid." Then, regular research activities can help maintain the relationship to some extent as the researchers remain invested in the students and their lives. We anticipate that annual surveys and interviews will provide a unique opportunity to help keep program memories fresh in participants' minds.

ACKNOWLEDGMENTS

We thank the PISEC school and community partners, youth participants, and university volunteers who helped make this research possible. This work was supported by NSF awards 2221912 and PHY-2317149. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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