A Design-Based Informal Physics Program from a Youth Perspective

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A core principle of design-based educational programming is its focus on iterative improvement through the incorporation of viewpoints from multiple stakeholders. The youth who participate in informal physics programs are heavily invested and spend their time and energy interacting with the program; however, their feedback is not often considered in the iterative design process. The Partnerships for Informal Science Education in the Community (PISEC) is an informal physics program adapted from the design-based Fifth Dimension afterschool model. Here, we consider the child participants as stakeholders in the program and ask what it is that children value in an informal physics program. Semi-formal interviews with the children are coded within the context of the Fifth Dimension framework to understand the youth perspective on a program built with physics practice as a core principle. We see a variety of themes in the children's responses that align with Fifth Dimension principles and additionally aligns with several practices outlined in the Next Generation Science Standards.

I. INTRODUCTION

Informal physics programs are important endeavors to scientifically engage children, build physics identity, and improve access to physics-related careers [1–3]. Examples of informal physics programs for youth that are often facilitated by university physics departments include popular lectures, summer camps, and afterschool programs. While these programs are dependent on children's participation, the children themselves are often not included in the design of these programs. Since informal learning is voluntary by nature, it is critical that design of such programs prioritizes children's engagement.

We seek to understand how informal physics programs are perceived by youth, in order to design physics learning environments for engagement. To accomplish this goal, we turn to Design Based Implementation Research (DBIR) [4]. DBIR seeks to provide tools and methodology to guide continuous improvement of programs through a number of shared principles. Among those is the creation of a team with a vested interest in the improvement of a program and continued incorporation of each of these stakeholder's views throughout the design process. In informal physics programs, teams of adults come together to create programming for children. However, the youth who participate in the educational programming are also stakeholders in the process. Children have a unique perspective and may be more likely to participate if we align with their goals, given their time committed to these activities.

In this study we examine youth perceptions of the design and implementation of an informal physics program. We examined one particular informal physics program for youth, the Partnerships for Informal Science Education in the Community (PISEC) program, which the authors co-facilitate. This program was created as an instantiation of physics content and practices in a more general afterschool program model called the Fifth Dimension (5D). As instructors and organizers, we have goals for this program we want to achieve. Part of the rationale of this study is to de-center the instructor perspective and consider the perceived program outcomes from the viewpoint of the youth participants. We believe this approach is important - communication to youth audiences is often framed by physicists as "outreach", implying that there is an expert perspective that must be conveyed to novices. With this work, we seek to interrogate not only the implementation of our program, but also the design principles on which it was built. To do this, we interviewed children and analyzed their responses with respect to both the 5D design principles and physics practices.

II. PROGRAM DESCRIPTION

PISEC is a joint collaboration of JILA NSF Physics Frontier Center and the PER group in the physics department at the University of Colorado Boulder [5]. In PISEC, university educators (typically undergraduate/graduate students and researchers in physics) travel to local K-12 schools with larger proportions of students historically underrepresented in physics. They engage in open-ended physics activities with small groups of children for one hour a week for 8-10 weeks.

PISEC was founded on the core principles of the 5D afterschool programming model, but focuses on building physics interest and identity for all participants. 5D uses a sociocultural model intended to improve general literacy through the use of technology, social interaction and play in an imaginative setting [1]. The PISEC program applies the core principles of the 5D framework and weaves in a physics curriculum throughout its structure. Physics activities are presented within a game-like environment that offers children with choices of how to progress through sets of experiments, with opportunities to create their own experiments. An entity known to the students as "Mission Control" provides tools and equipment necessary to complete the activities. Students may interact with Mission Control by reporting their experimental findings through science notebooks and by making videos. Mentors are encouraged to co-explore the materials with the children. Early on, PISEC focused on a highly directed curriculum of a variety of physics topics ranging from electricity and magnetism to optics and light with a focus on content acquisition. Subsequent iterations saw a shift toward greater emphasis on physics practices through an inquiry-based curriculum design that was driven by hands-on activities. Research on this curriculum shift through analysis of student notebooks was found to increase student agency and scientific communication within PISEC [2].

Interestingly, despite the 15 year history of the program, youth participants were never actively included in a research study about the impact of PISEC. Previous work analyzed artifacts or observational data to determine impact on youth; verbal or written feedback from youth was only used for cursory evaluative purposes, and not to answer larger research questions. A large part of this choice was due to the challenge of obtaining substantive feedback from young children without compromising the 'integrity' of the learning environment (i.e. removing them from their chosen activities to answer questions). Looking back this is curious (and unfortunate) because we view children as major stakeholders in the program. We suggest, however, that this situation is not unique to our informal physics "outreach" program. Thus, we seek to answer the questions: What do the children value in their experiences in a program designed from the core principles of the 5D framework? Given their experiences in PISEC, what do children value as physics practices, as outlined by NGSS, in a program that seeks to emphasize practice over content?

III. STUDY DESIGN

Methods: We conducted 3-5 min video interviews with individual students from all PISEC sites during the Fall semester 2016 through Fall 2017. The interviews are done with the premise that Mission Control is looking for feedback from the students on the program. The interviewer was a program facilitator who is embedded in the daily operations of the program, but is explicitly not a part of Mission Control. The data set comes from 81 children over: 2 semesters of a PISEC site 1 (grades 6-8), 1 semester of PISEC site 2 (grades 5-8), and 3 semesters from a PK-8 school group (grades 4-6). The questions posed to the children were:

Q1) *Why did you choose to join [the program]?*
Q2) *What do you like about [the program]?*
Q3) *What do you like the least about [the program]?*
Q4) *What would you change about [the program]?*

The questions themselves do not aim to lead children to a particular response from the design frameworks, but rather allow children to present the ideas they value most. The interviews were transcribed and coded using the 5D model from which we identify themes in the perceptions of child PISEC participants. Two researchers independently coded 10% of the data. Disagreements were mostly on MLA and VPC codes but inconsistencies between coders were discussed and resolved until reaching at least 80 % agreement per code at which point the rest of the data was coded.

Fifth Dimension framework: The Fifth Dimension has seven core principles that are listed on Table I. Codes were developed *a priori* according to the explicit definitions of each principle found in the 5D framework [1]. The purpose of coding based on these principles was to check for alignment with the children's responses in the interviews. The codes are closely connected theoretically and in practice - thus, a single youth response have multiple codes.

Scientific practices: In PISEC, physics practices are built into the program's structures. Each child is given a science notebook to write about their experiments. They are prompted to plan their experiment and consider materials they may need given what they think may happen, and report their observations through words, pictures and diagrams. Additionally, children work in small teams of 2-5 peers and a mentor to collaborate on their experiments. As a proxy for physics practices, we decided to use the the Next Generation Science Standards (NGSS) practices. The NGSS practices "describe behaviors that scientists engage in as they investigate and build models and theories about the natural world" [3] and are essentially a codification of what physicists do in their pursuit of research and what we seek to do in PISEC. The eight NGSS practices are:

1. *Asking Questions and Defining Problems*
2. *Developing and Using Models*
3. *Planning and Carrying Out Investigations*
4. *Analyzing and Interpreting Data*
5. *Using Mathematics and Computational Thinking*
6. *Constructing Explanations and Designing Solutions*
7. *Engaging in Argument from Evidence*
8. *Obtaining, Evaluating and Communicating Information*

To examine alignment with the NGSS practices, a subset of 57 children's interviews were selected that contained responses related to the scientific activity of experimenting, rather than programmatic-specific responses (e.g. time of the day the program takes place). This categorization includes children reflecting on experimenting, what experiments they did, how they experimented and how they reported their experimental findings. The practices were not assigned as codes due to the large overlap within the NGSS practice definitions. For example, we expect obstacles in distinguishing between devising of a scientific question and planning an experiment present in NGSS practices #1 and #3 from the children's responses. Also, we do not expect children to use NGSS language to describe their scientific activities. Instead, we noted when children's words reflected one or more practices as defined and how they coincided with the 5D framework [3].

Some of the 5D principles are closely connected theoretically and in practice in PISEC. In looking at the 5D principles and scientific practices, we identified emergent themes that span the constructs of those frameworks. We identified major themes related to *choice/agency, socializing/collaboration, fun and experimentation*, and *writing/communication*. Presentation of the findings is organized by the emergent themes and how those connect to the 5D codes and NGSS practices.

TABLE I. Fifth Dimension principle codes, brief definitions used to analyze the interview transcripts, and examples

5D Code	Code Definition	Example	Counts
Mixing Leading Activities (MLA)	Tying together multiple forms of the leading activities (attachment to others - play - learning - peer interaction - work).	"I guess it's really just like a community thing and everybody gets along and you have fun even though you're learning new things."	83
Role of Intergenerational Participation (RIPG)	Interaction between participants and adults (mentors, teachers, facilitators or parents).	"The best thing is the people that come to help us. It's pretty awesome."	26
Centrality of Mediational Means (CMM)	The wide variety of activities the students do in the program or want to do in the program or related to the tools they use in the program.	"I like doing the fun experiments you guys have and I like the bottle rocket and measuring how far it went."	124
Centrality of Communicative Practices (CCP)	That the students choose to communicate and how they choose to communicate their experiences to any outlet.	"I never like writing, but it's a good thing to learn. So, probably least is the writing part."	22
Importance of Goal Formation (IGF)	Student-formed goals of participation during the program and the choices they make on a day-to-day basis.	"Instead of in a regular class, you don't have to... Oh, you have to make this. You can make whatever."	91
Voluntary Participation of Children (VPC)	The variety of reason students join the program, inclusive of reasons the students choose to return to the program.	"Because my friends were telling me it was fun doing science and I wanted to see how it was and it was pretty fun."	119
Privileging Diversity (PD)	Program adaptation to site-specific and cultural norms in the community.	n/a	0

IV. YOUTH RESPONSES TO PISEC DESIGN

Fifth Dimension Principles: The right column in Table I is the total counts of student responses in each of the 5D categories. Looking closely at the content of the student responses coded for each 5D principle allowed us to identify connections between the code categories. For example, kids report enjoying being able to choose (IGF) from a variety of activities (CMM) in the program. Here we report the overarching themes, while indicating the presence of the individual 5D categories, to present a nuanced understanding of students' perception of PISEC.

Choice Children speak to the value they place on being able to choose to do what they do during the program. They have a sense of freedom in deciding which experiments to do or not do and being able to exercise agency in how they do the experiments. Built into this concept of agency is an idea that the space they are in is distinct and less limiting than their formal classroom setting. They contrast their formal environment by its rigid structure and their inability to choose how they interact with the subject matter. They value the creativity they can show in their experimentation. These themes were coded for the IGF principle which promotes children's ability to form their own objectives in the program. Responses akin to the quote for IGF in Table I were a common response to Q1 pertaining to what they like about the program. The theme of choice indicates that the children's values and expectations for the program align with PISEC design goal of IGF.

Socializing and teamwork Children value their ability to participate in the program with their friends both through means of socializing and collaborating on experiments. The children are not forced into specific groups —observationally, they often form groups with their friends. Even when they are not in the same group as their friends, they are free to interact across groups during their experiments. This sentiment aligns with MLA and the VPC principles. In MLA, socializing and collaborating are examples of the build-up that occurs as one progresses through the leading activities of 'attachment to others', 'play', 'learning', and 'peer interaction'. In VPC, we see the participation of friends and family (overlapping with RIGP) as a major motivating factor for joining and returning to the program. As these responses are to Q1 and Q2, this theme indicates the children implicitly place value in these aspects of the MLA and VPC design principles.

Fun Children value the act of experimenting/'doing science' and having fun - this word appears 96 times in the interviews and is found in the same response describing experiments 85 times. As described by children, this defining theme is a manifestation of the CMM, VPC and MLA design principles. For example, shown in Table I one student enjoys "doing fun experiments" like measuring (MLA) how far a bottle rocket (CMM) goes. Having fun in the role of a scientist has been associated with engagement in informal science learning [6], and may be a major motivating factor for youth participation in informal physics education leading toward sustained physics interest and continued participation in physics programs. An interesting aspect of this theme is having fun despite doing physics. This is evident in the quote for MLA in Table I. We see this idea that physics is perceived by some youth to not be inherently fun; however, the experiments done in PISEC (which are physics) are fun. This tension is a subject of further research to determine how informal physics programs like PISEC associate physics and fun.

Writing This theme is reflected in CCP and largely found in responses to Q3 and Q4. Children who specify communicating their results through writing overwhelmingly consider it to be a negative experience of the PISEC program. While this sentiment is only communicated by 15% of the children interviewed, it does constitute the second most prevalent theme in the responses to Q3. This presents a clash in the values of those children who spoke of writing as a medium of communication with the CCP principle as implemented in PISEC.

Also, none of the responses were identified as aligning with the PD design principle. While diversity in some forms is recognized and valued in PISEC, the curriculum does not explicitly discuss or incorporate cultural diversity in its practices, so this finding is not necessarily surprising. For example, children from Spanish speaking backgrounds are seeing and doing physics in English in PISEC, so they may not know that other possibilities exist and how those would make them feel.

Scientific Practices: Looking at the 5D codes, we found two major scientific activities: experimentation and communication. We identify salient NGSS practices from the language youth use to describe these activities.

Experimentation Children reflect on the various ways they experiment within PISEC. The children place value in the freedom to choose their experiments, choose how they experiment, and to choose what they learn from an experiment, which coincide with the IGF, MLA, and CMM principles. Consider an example from a response to Q2: *"Well, there's a lot of experiments I get to do and I always like that I get to make a goal and stuff. Sometimes, I wish I could just do all of the experiments."* In this response, we see evidence of several practices, such as planning, conducting, designing solutions, and completing experiments in alignment with the NGSS practices #1, #3 and #6. Another student wrote: *"Probably like all...we've done a lot of electric stuff and I like to relate it to real life."* Here, we see interest in the experimentation activities, but further emphasis on NGSS practice #2 in the form of analogies and #6 in describing their experiences in the natural world.

In examining the responses related to experimentation, we noted few examples of alignment with the NGSS practice #5. Observationally, we note that students do appear to engage in the use of mathematics within the program, but they do not talk about it within the interviews. We recognize that understanding the children's perception of scientific practices is important, but are likely underrepresented in the children's responses. This examination of their perception provides part of the story and encourages us to investigate youth-enacted practices in conjunction with their perception in future work.

Communication As mentioned, the children who discussed writing during the interviews regarded them as a negative experience. The communication of scientific ideas through written observations is a key aspect of partaking in the scientific community of practice, which are reflected across the NGSS practices, including but not limited to #4 and #8. An example of a response to Q3 is: *"Not writing afterwards. Just say what you learned instead of writing."* It may be tempting to make the claim that, from the youth perspective, writing is not a worthwhile scientific practice; but this has several confounding factors. The children may not be able to distinguish the writing they do in PISEC from the writing required of them during their formal education. Many children served by PISEC are still learning how to write formally, and scientific writing may pose additional challenges. Furthermore, many of the children who participate in the PISEC program are not native English speakers. Responding to these results and following the PD principle, we have begun making it explicit to the children that they may choose to communicate with Mission Control in the language most comfortable to them. We also find children wishing to report their findings in other media, such as video or social media, which presents possibility for future PISEC programs.

V. CONCLUSIONS

In this work we took a DBIR approach to stakeholder input. We were able to collect data on what youth value in the PISEC informal physics program. We see how children value the activities in PISEC and the agency they have in navigating the program present in the 5D model. Similarly, we see value aligned with the practices involved in experimentation. Areas of mismatched values are made apparent in how some children communicate their findings and the act of scientific writing. Future work will look at the intersection of both youth perception and youth-enacted practices to help us understand their perspective on the physics practices that are inherent to the design of the PISEC program. Continuing, we seek to support youth voice in the field of physics education research and in the design of future informal physics programs. We thank the youth who participate in PISEC, JILA NSF Physics Frontier Center, the CU Boulder PER group, the IPER team across the globe, and acknowledge NSF Grant #1423496.

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