Characterizing the Development of University Students who Participate in Informal STEM Programming
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SUMMARY
We seek to investigate the impact on university students who participate in informal STEM programs. While university informal STEM programs geared toward K-12 children or community members often report outcomes in terms of these groups, our work will focus on the university educators (UEs) who participate in these informal programs, providing insight into this less-studied group. These findings will inform university support for and design of informal STEM programming, as well as have broad implications for all types of informal STEM environments. For this project, we will primarily study university physics students who participate in the University of Colorado Boulder (CU Boulder) Partnerships for Informal Science Education in the Community (PISEC) programs [1]. PISEC is supported by the CU Boulder Department of Physics and the JILA Physics Frontier Center [2] and whose main programming component consists of weekly, afterschool physics clubs for underrepresented populations in grades K-8. This program relies on physics undergraduate and graduate UEs to interact with children, teachers and community members as both scientists and educators. For this project, we will design assessments and implement pilot studies of the UEs by building on initial findings from our program that indicate the potential for improvement in the communication and pedagogical skills of UEs, as well as positive shifts in their affect and self-efficacy as scientific communicators and teachers [3, 4].

BACKGROUND
Informal STEM programs are prevalent among university departments in the United States, including those at CU Boulder. The types of programs range from one-time events (CU Wizards [5], CU Astronomy Day [6]) to intensive summer camps (CU Science Discovery [7]), and they can span the age range from grades K-12 to adult. The motivation for university scientists to facilitate these programs includes: serving the local community, fulfilling grant requirements, and providing university students with opportunities to gain teaching experience. Broadly, university informal STEM programs seek to increase the number of students from underrepresented groups majoring in STEM fields and to improve the scientific literacy of the general population [8]. For instance, in the state of Colorado, African Americans and Hispanics account for about 25% of the population and 30% of high school graduates but only 16% of CU bachelor degrees and 7% of CU bachelor degrees in STEM [9]. The CU Flagship 2030 Initiatives [10] indicate that CU should play a leadership role in supporting diversity and in serving local communities with educational programming. At the same time, the Boulder region, state of Colorado, and nation at large are desperately short of highly qualified math and science teachers [11, 12], and CU has targeted science teaching as part of valued outcomes for undergraduates, graduate students and postdocs. To these ends, PISEC seeks to engage local K-12 children from underrepresented populations in the sciences and simultaneously to promote a University identity that includes informal science education with an emphasis on diversity as part of the culture for scientists and science teachers in training.

The importance of including university students in facilitating informal STEM programs and communicating to the public has been described by Leshner [13]. He has made the case to include training in STEM “outreach” as part of the graduate student experience. Additional calls to train university STEM students in communicating science to the public have been ongoing in recent years [14]. The rationale for community engagement has emphasized the importance for scientists to be concerned with the scientific literacy of non-scientists, especially with regard to public referenda on funding of scientific projects. The impact of training and participation in informal STEM programming on the university students themselves, however, is likely just as important. In a recent study, Feldon, et al. demonstrated that graduate students who were teaching assistants had
better research proposals than students who had not been teaching assistants [15]. The NSF GK-12 program has been successful at training STEM graduate students for classroom teaching [16]. Additionally, here at CU, Kotys-Swartz has shown that service-learning efforts incorporated into college courses can have a positive impact on university student motivation and retention [17].

**PISEC Program:** Since 2005, the PISEC afterschool program has taken physics undergraduate, graduate students and post-doctoral researchers from CU Boulder into schools and community centers to work on physics activities with children from underrepresented groups, primarily in grades K-8. UEs are recruited to the program via email, flyers, connections through affiliated organizations such as the Learning Assistant (LA) [18] and CU Teach programs [19], encouragement by professors, and most frequently, by word-of-mouth among students. When asked about their motivations for volunteering, students give a range of reasons, from wanting to gain teaching experience and improve resumes to having fun, promoting science and giving back to the community. The model for the PISEC program is the Fifth Dimension, an afterschool model developed by Cole [20]. In PISEC, we focus on scientific literacy, with the overarching goal of engaging children in authentic scientific practices to engender the identity of someone who is both capable of and enjoys doing science. We work with community partner organizations (described later) to establish PISEC sites and integrate afterschool physics into the identity of each site. Prior to participating at the sites, the UEs attend 5 hours of workshops in pedagogy, diversity, communication and activity-related content. UEs then partner with groups of 2-3 children to conduct hands-on physics inquiries during weekly afterschool sessions for 8-10 weeks during a semester at community sites. In the current PISEC model, each semester, a total of 20-25 UEs volunteer at 4-6 afterschool sites with a total of 70-90 children per term. The structure [20] and content of the inquiry-based afterschool curriculum promotes agency and communication skills of children [21] and encourages university students to take on a mentoring role. At the end of each semester, the children in the afterschool program visit the Dept. of Physics and JILA on the CU Boulder campus. UEs assist in the facilitation of these field trips by providing grade level appropriate research presentations, tours of physics laboratories and interactive demonstrations. Children are able to see and interact with UEs in their work environment and ask them questions related to their interests and ambitions doing science.

**STUDY DESIGN AND METHODOLOGY**

Drawing from the work of Feldon and Cole, along with the calls to incorporate “outreach” and communication training into STEM undergraduate and graduate school curricula, we seek to characterize university student professional development through participation in the informal physics PISEC program. We will study the development of university students across three main themes: communication, teaching and emergent aspects, such as attitudes.

**Communication:** Scientific communication is a theme that is increasingly relevant to scientists: significant implications for funding, establishing public trust and policy-making stimulate the call for training for scientists in communication. Many large funding agencies, such as the National Science Foundation, require grant recipients to communicate their research to the general public in some way [22]. Scientific communication includes both models and practices of communication. Trench offers an analytical framework of science communication models that stem from basic communication models [23]. He defines three dominant models for the public communication of science and technology: deficit, dialogue and participation, with the deficit model being the most commonly held by scientists [24, 25]. In this project, we aim to measure the communication skills of the UEs, their communication practices in the context of the informal setting, and their attitudes and beliefs towards scientific communication. From these measures, we will then extrapolate the UEs’ models of communication and determine shifts between deficit, dialogue and participation.
In order to measure overall changes in UEs’ verbal ability to communicate in everyday language, we will further develop and validate the Communication in Everyday Language Assessment (CELA). The CELA is an instrument that consists of an explanation by an UE of an introductory textbook paragraph on motion and velocity, where the UE presents the material as if speaking to a middle school audience. A second section of the CELA asks the UE to describe his or her physics research or a physics topic they are interested in to the same imagined audience. The CELA is given as a pre/post assessment (in the case of the afterschool program, before training and after one semester of participation), video-recorded. We have pilot-tested the CELA on UEs in PISEC, and UE improvement has been measured when coding for specific indicators of language use, gestures and style of presentation [3]. As part of this project, we will update the CELA instrument protocol, validate UE responses through interviews, and refine the evaluation rubric for the video-recordings in consideration of the literature on gesture analysis and language usage [26, 27] along with extensive experience in developing and validating observational data [28] and instrument development [29, 30]. While we have collected CELA videos of UEs describing their research, these videos have yet to be analyzed. Findings from these videos may be the most relevant to addressing the calls from scientists and academic institutions to improve training for scientific communication to the public.

We will also track the development of UE communication skills over the course of their participation in the afterschool program and demonstration show by collecting observational and video data in situ. While the CELA will capture snapshots of a UE’s communication skills, tracking the UEs’ communications during PISEC events will give insight into the development of these skills. UEs will be observed multiple times over a semester either interacting in small groups with children or presenting a demonstration to a large audience. For the afterschool program, video cameras on tripods will be set up on a weekly basis, such to record the interactions of individual UEs with their respective groups of children over the course of the semester. We anticipate collecting data from 5-10 total UEs across all sites, recording each weekly afterschool session. Initially, we intend to analyze sessions from the first week, a middle week, and one of the last weeks that each UE works with the children. An observational coding rubric based on and expanding the CELA will be developed for both real-time observational data and video data. From these data, we will focus on characterizing communication skills in the same vein as the CELA, with regard to language, gestures and style, but with attention paid to subtle differences that may emerge from the dialogue, rather than CELA monologue, that is inherent to group interactions. By observing in situ, we will also be able to analyze the feedback from the audience along with the communication behavior of the UEs; this analysis may provide insight into the nature of the UE changes in communication over time. For instance, we expect to be able to track the use of scientific vocabulary used by UEs over time as well as over the course of a semester. The unique environment of the informal setting may afford an increased rate of improvement in communication abilities due to the immediate and uncensored nature of the feedback from children, an occurrence that is promoted by the PISEC curriculum.

Along with these direct measures of communication skills, we will assess student attitudes with regard to the importance of scientists’ communicating to the public and what constitutes “good” scientific communication, as well as UE beliefs in their own communication abilities. UEs are asked to respond to open-ended pre/post survey prompts about scientific communication as well as to write weekly field notes on their experiences at the PISEC site. These writings provide a window in the thinking of the UE shortly after their weekly experience and thus provide insight that may not be captured by the post survey alone [31]. Data from previous semesters of the afterschool program indicate that UEs may undergo significant shifts in their beliefs about their own ability to communicate and about the nature of scientific communication for general audiences. In order to gauge changes in UE communication awareness, we will further develop and administer pre/post participation surveys as well as require weekly field notes for afterschool UEs. These UE self-
reports may be analyzed as to their communication practices with children, strategies for adjusting communication, confidence levels in communicating scientific information or processes, and perceptions of the importance of communication skills to professional scientists. An interview protocol will be developed and interviews performed to validate the surveys and probe more deeply into UE beliefs about communication. We anticipate that these surveys/interviews will show an improvement in UEs’ self-efficacy about their scientific communication, as well as shifts from a deficit model of communication towards a participation model.

Teaching: Another aspect of development that we will investigate is the effect of informal physics participation on the teaching skills and pedagogical beliefs of the UEs. Building on national moves to develop the interest and capacity of undergraduate (Learning Assistant Program [18], CUTeach [19], Noyce Scholars [32]) and graduate students (CIRTL [33]) in teaching, we seek to characterize such impacts of PISEC involvement on the university participants. Teaching requires at least three forms of overlapping types of knowledge: pedagogical knowledge (which includes general teaching strategies and approaches), content knowledge (such as physics or optics), and pedagogical content knowledge (knowledge of how to teach specific content, including student difficulties and effective approaches) [34, 35]. We will monitor UE development of pedagogical and pedagogical content knowledge over the course of participation in the afterschool program and demonstration show by monitoring them in situ (see observational and video data collection referred to in previous section). A coding rubric specific to the teaching aspects of UE and child interactions will be developed based on schemes validated and used in classroom settings for teachers [36] and faculty [37], and our own extensive work on observing and characterizing teaching practices [28] and beliefs [38], with an eye to emergent pedagogical behavior that may be unique to the informal setting.

The beliefs of UEs with regard to what constitutes “good” teaching, the nature of knowing and learning, and their own teaching ability will be assessed through pre/post surveys, field notes and interviews, building on existing assessments. Preliminary data suggest that over the course of the training and semester-long program, the university students demonstrate substantial progress in the sophistication of their pedagogical skills and perspectives on teaching and learning as evidenced from their field notes and surveys. We expect that from the surveys, field notes, and teaching statements, we will be able to measure changes in attitudes and beliefs for first-time UEs as well as increasingly sophisticated pedagogical understanding for UEs who have participated multiple semesters.

Emergent Themes and Framework: From the UEs’ documentation of their programmatic experiences and our analysis of their in situ conduct, we expect to discover new themes with regard to UE attitudes, behaviors, and learning. We will look at student motivation for participation in informal programs through open-ended pre/post surveys, as well as reassess UEs who participate over multiple semesters in order to discern long-term changes in views about the nature of science, its role in reaching the public, the nature of community, the capabilities of children, and the UEs’ motivation for participation. In consideration of emergent themes, communication, and teaching, we will develop a framework describing the interrelated aspects of impact with regard to UE modes of participation. While we do not anticipate this framework to be a complete taxonomy of the impacts of informal STEM experience on university students, it will begin to capture some of the dominant areas of impacts and provide guidance as we establish metrics for evaluating those impacts. We expect this framework will be applicable to facilitators of informal STEM programs across disciplines and for programs outside of university settings.

IMPACT OF PROJECT

This proposal would provide key personnel resources necessary to forwarding the research agenda described. In order to achieve a deeper understanding of the development of university students in informal STEM programs, we need undergraduate research assistants (URAs) to assist

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the PI in data collection and analysis. The outcomes of this project are research tools, pilot studies/results, and a framework derived from these studies that will shape future research about UEs and communication, teaching, and the emergent themes. We expect that from our research findings we will be able to make evidence-based, concrete recommendations as to the best practices for university student participation in informal STEM programming. Specifically, the results of this project will directly influence the ongoing development of our UE training modules, the format of our afterschool programs, and means of informal STEM culture building in the CU Physics Department and at CU at-large. We also expect that the findings of this project will be applicable to museums, community STEM organizations, and other groups that utilize personnel to assist in the facilitation of STEM programming. On an institutional level, demonstrating the impact of participation on all participants (university and community alike) can provide leverage for funding, help grow the pool of volunteers/educators, and incentivize structural change to support informal programs within both the CU Boulder Department of Physics, JILA and the University. The audience for this work includes university administrators who make decisions about support for informal programs, departmental administrators and STEM professors who may or may not choose to encourage their students to participate in informal programs, and informal STEM professionals who are working on hiring, development and implementation within their organization.

Additionally, PISEC adopts a model of university-community partnership designed to serve the self-interests of participating institutions and individuals [39]. We have established close, working partnerships with organizations whose purpose is to serve children from underrepresented populations and who work with us to recruit children into the PISEC afterschool program. These organizations are Colorado Mathematics, Engineering, Science Achievement (MESA) [40], Family Resource Schools of Boulder County (FRS) [41], the Latin American Center for Science, Arts and Education (CLACE) [42], and Casa de la Esperanza Community Center [43]. This project will allow us to support these partner institutions with research-based learning resources.

PROJECT TIMELINE

Fall Semester 2013: Two URAs will conduct the weekly operations of data collection and analysis. During the first semester, URAs will collect weekly video data at site from 3-5 UEs. We will test observational and video-recording methods and develop a protocol for coding these data. The URAs will also work with the PI to analyze pre/post CELA videos, pre/post surveys, and field notes. Interview protocols will be developed and implemented for validation of the CELA and surveys. It is possible that the URAs will work together on all parts of the project, or we may have one URA collect and analyze CELA and pre/post survey data, and the other URA collect and analyze in situ video data. Weekly project meetings between the PI and the URAs will ensure continuity and provide feedback on project protocols, formative evaluation, and ensure timely completion of project goals.

Spring/Summer Semester 2014: During the second semester, the URAs will collect video data from an additional 3-5 UEs, as well as CELA, pre/post survey and field note data. Throughout this semester and in the summer, the rest of the year’s data will be coded and analyzed, and revisions will be made to the protocols and instruments. Based on our findings, we will begin to develop a framework for UE impact. Findings will be presented at several seminars and will be also published in the Proceedings of the Physics Education Research Conference in Summer 2014.

BUDGET

We ask for two undergraduate research assistants, each at 10 hrs/week for two, 15-week semesters (Fall13/Spr14) and for one 8-week semester (Sum14):

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$10/\text{hr} \times 10 \text{ hrs/week} \times 15 \text{ weeks} \times 2 \text{ semesters (Fall13/Spr14)} & \times 2 \text{ undergraduates} = $6000 \\
$10/\text{hr} \times 10 \text{ hrs/week} \times 8 \text{ weeks} \times 1 \text{ semester (Sum14)} & \times 2 \text{ undergraduates} = $1600 \\
\text{Total:} & \quad $7600
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REFERENCES

2. JILA NSF Physics Frontier Center for Atomic, Molecular, and Optical Physics, http://jila.colorado.edu/.
7. CU Science Discovery, http://sciencediscovery.colorado.edu/.
22. NSF solicitation nsf07567, for example.

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