

Promoting Children's Agency And Communication Skills in an Informal Science Program

Rosemary Wulf¹, Kathleen Hinko^{1,2} and Noah Finkelstein¹

*Department of Physics¹ and JILA NSF Physics Frontier Center for Atomic, Molecular and Optical Physics²,
University of Colorado Boulder, CO 80309, USA*

Abstract. The Partnerships for Informal Science Education in the Community (PISEC) program at the University of Colorado Boulder brings together university and community institutions to create an environment where K-12 students join with university educators to engage in inquiry-based scientific practices after school. In our original framing, these afterschool activities were developed to reinforce the traditional learning goals of the classroom, including mastering scientific content, skills and processes. Recently, the primary focus of the PISEC curriculum has been shifted towards the development of students' scientific identity, an explicit objective of informal learning environments. The new curriculum offers students more activity choices, affords opportunities for scientific drawings and descriptions, and provides incentive for students to design their own experiments. We have analyzed student science notebooks from both old and new curricula and find that with the redesigned curriculum, students exhibit increased agency and more instances of scientific communication while still demonstrating substantial content learning gains.

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INTRODUCTION

The National Research Council report, *Learning Science in Informal Environments: People, Places, and Pursuits* [1], describes the overlapping learning goals of formal, or classroom, and informal environments. Both environments seek to provide opportunities for students to learn science concepts, processes, and skills as well as understand the nature of science and reflect on that understanding. Informal learning, however, provides explicit opportunities for promoting enthusiasm for science and encouraging participants to think of themselves as scientists.

To these ends, the Department of Physics and the JILA NSF Physics Frontier Center at the University of Colorado Boulder have created Partnerships for Informal Science Education in the Community (PISEC) [2]. The PISEC afterschool program is based on the successful afterschool programming model, the 5th Dimension [3]. In PISEC, university undergraduate and graduate students work on a weekly basis with small groups of K-12 children on activities designed to advance their scientific literacy and science identity. Teachers and community organizers recruit children from underrepresented groups (including low-income, minority and female students) to the program. Children from underrepresented groups have fewer role models in science and potentially less access to science programming outside of school; for these children, it is especially relevant to focus on the

informal learning goals of encouraging scientific interest and identity.

One way to influence positive science identity development is by “getting students to take on active expert roles” [4]. In the current study we examine two key elements in promoting students to be actively engaged as experts in our program: agency – the extent to which a child executes control over their activities; and communication – the forms of representation that a child has an opportunity to externalize. Each of these elements is common in discussions of developing identity [4, 5]. In the PISEC afterschool program, examining student agency is a means of probing the identity of students as science learners [6]. In this paper we will discuss the curricular choices made to shift emphasis from a content-centered perspective to one that includes content but emphasizes identity and engagement in PISEC. We then present data from student notebooks that show students exhibited a stronger sense of agency and increased scientific communication skills with the new curricular format.

PROGRAM DESCRIPTION

The structure of the PISEC program follows the 5th Dimension model: scientific activities are organized into a game [3]. To play the game, students enter a “room”, complete activities at their own pace and document their work in a notebook. As students move

through the rooms, they accomplish progressively more complex and sophisticated experiments.

When the original PISEC curriculum was developed its chief goals were focused on promoting mastery of physics concepts and developing an understanding of the nature of science. To facilitate these content-oriented objectives, portions of the research-based Physics in Everyday Thinking (PET) curriculum were adapted to fit the format of the 5th Dimension game [7]. During the Fall 2011 semester, the content focus was circuits. Activities included predicting which pictures of configurations of wire and batteries would light a bulb, testing each configuration, and then writing rules by which the bulb would light. The format of the activities was to complete worksheets that included multiple choice, filling in boxes with short, written responses, and a few open-ended questions. Prompts for each activity were printed on one half to one whole sheet of paper and taped into student notebooks. While there were some hands-on experiments, these were not emphasized. By the end of the semester students were able to correctly build, identify and explain circuit configurations that would cause single bulbs to light, an outcome which had been shown in prior semesters [8].

While content learning was evident, feedback from the participants indicated that attitudes toward science and the program itself were less positive. On more than one occasion children reported being “bored” and expressed exasperation at using nearly the same equipment each week. The children also expressed a desire to conduct more experiments. Discussions with teachers and university students confirmed the children’s reaction. We determined curriculum could address these challenges while maintaining, and potentially enhancing, PISEC goals. The curriculum was modified in order to boost enthusiasm for science and foster science identity, while continuing to increase content knowledge. Thus, a transformed curriculum was developed for Spring 2012, focusing on light and optics.

New activities were developed to ensure a predominance of hands-on experimentation with optical phenomena, using a mixture of science toys, PhET computer simulations [9] and college laboratory equipment. For instance, concepts about reflections were explored using a fiber optic lamp and laser chess game, along with a more typical setup where students measured angles of incident and reflected light using a laser and mirrors. The style of the activities was also altered; instead of long, worksheet-like prompts, the new activities consisted of 3-5 prompts that fit on a quarter of a page of paper and were a mixture of mostly open-ended questions and suggestions of specific items that the student could draw or define.

Another change made to the revised curriculum was the addition of the “Big Idea” activity. When students were working on the original curriculum, they would make observations or design circuit configurations that were not explicitly part of the activity - for example, using two batteries in series to make one bulb brighter or noticing that in some configurations the wire becomes warm to the touch. Students were resistant to writing down these findings, however, partly because the activity format did not provide space for non-prescribed responses. To address this issue, the reformed curriculum included Big Idea activity sheets that encouraged students to come up with their own experiments and document their outcomes. For every two Big Ideas, the student received an article of scientific clothing to wear during the program (clean room shoe covers, safety glasses, rubber gloves, lab coat).

STUDY METHODS

We are interested in the children’s response to the original and revised PISEC curriculum, especially with regard to capacity for these curricula to foster scientific identity and interest for the children. We investigate measurable parameters such as the level of student-directed behavior and communication practices that have implications as to student scientific identity.

Although the new curriculum received verbal praise from children, teachers and university students, the data we focus on exclusively in this paper is drawn from the student science notebook. Science notebooks have been demonstrated to be a useful source of information on student behavior and communication practices and are authentic tools in both educational and scientific settings [10].

We compare the nature of student responses in the Fall 2011 (more traditional, content-focused) and Spring 2012 (transformed) semesters. The original circuits curriculum was used at two middle school sites during Fall 2011; the revised optics curriculum was used at the same schools during Spring 2012. The program ran for 8 weeks in Fall 2011 and 10 weeks in Spring 2012; to account for this difference, subsequent data are presented as a percentage of activities, not sessions, completed. Sessions were held after school in a classroom for one hour each week. At each school up to fifteen students in grades 6-8 attended each session. The middle school students and university adults worked in small groups with an average ratio of 2:1. Between the two schools, a total of twelve students participated in both fall and spring semesters. Student data are aggregated across sites since both schools are in the same district and had demographics and

outcomes that did not vary significantly. Thus, twelve student notebooks from both the Fall 2011 and Spring 2012 semesters were analyzed along two major themes, agency and communication, in order to gain insight into opportunities for students to develop positive scientific identity.

AGENCY

In order to probe opportunities for students to develop a sense of agency in PISEC, student trajectories through the space of possible PISEC activities were charted from dated activity worksheets taped into student notebooks. A selection of student paths mapped onto the corresponding semester game board is shown in Figure 1.

In the original curriculum, the conceptual complexity of circuit activities built in succession from one activity to the next (from room to room), and so all students started with activities in Room 1, Level 1. After completing this level, which took between 2-3 sessions, students would make a choice between moving to Room 1, Level 2, or skipping to Room 2, Level 1. Over 80% of students chose the path that did not skip the second level of a room and was thus necessarily identical to the paths of the other students.

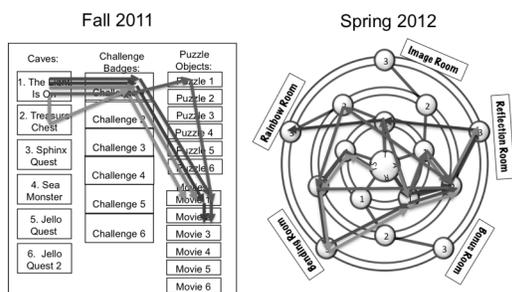


FIGURE 1. Student paths (only 5 paths are shown for clarity) through the activities are indicated with lines on the game board that corresponds to the Fall 2011 and Spring 2012 curricula.

In the transformed Spring 2012 curriculum, the activities were organized into five topic areas, or rooms (Reflection, Bending, Rainy, Image and Bonus Rooms) with three levels each. Students started at Level 1 in the room of their choice; upon completion of the associated activities, students could continue to Level 2 in the same room (a vertical move), or switch to a different room (a horizontal move). Around half the students chose to make only vertical moves, that is completing all the levels in a room before moving to the next room – similar to the strategy most students used in the circuits curriculum. A quarter of students chose to complete all of Level 1

for the game, moving room to room, while the other quarter of students chose a combination of vertical and horizontal moves so that their path around the game board was more random. Thus, when provided with more choices, students exhibited a wider variety of strategies for playing the game and exploring the conceptual space of light and optics.

To determine levels of student agency within the activities themselves, student responses to the activity prompts were examined for student-directed behavior in three categories. For the first category, instances were counted when a child answered all or most (all except one) of the prompts for an activity. In the second category, instances were counted when students added scientific information that the prompts did not ask for directly. Depending on the activity, this non-prompted information could include drawings, further observations, notes about procedure, and descriptions of how the outcome would change if the experiment changed. “Big Ideas” were not included in this category. It is to be noted that a child could receive no points for the first category and still receive a point for the second – that is engaging in non-directed scientific exploration. The third category was the number of times children designed their own experiment – in Fall 2011 this coding was for original ideas written between activities, while in Spring 2012 it also included Big Ideas. In each category the counts were normalized for the number of prescribed activities.

Figure 2 shows the outcomes of the coding analysis on student self-direction for the scientific activities. During the Spring 2012 semester, students were more willing to ignore the prescribed prompts and respond with information they deemed to be necessary. Furthermore, the rate of students’ designing their own experiments was six times higher with the reformed curriculum – likely a result of the incentives linked to the “Big Ideas”.

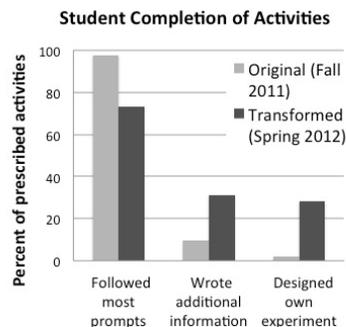


FIGURE 2. Notebook responses to the prescribed activities show an increase in student self-directed behavior. There is a significant difference in population based on contingency table analysis, $p < .001$ [11].

COMMUNICATION

Communicating scientific ideas and investigations by keeping records and writing journal articles is a necessary undertaking that professional scientists must perform as part of a scientific community of practice. Students, however, are often resistant to writing down their scientific activities because they may have difficulties reading and writing, they might rather be engaged in physically examining scientific equipment, or they may not see the value in documenting their observations and conclusions. We interpret notebook communication as evidence that students are practicing an identity as scientists who communicate their efforts.

Most scientific representations in student notebooks could be classified as either “writing” or “drawing”. Other representations were rarely found; for example, no instances of equations were recorded, and there was only one instance of a student using a table. To establish how much scientific writing the students engaged in, the words related to activities were counted. Likewise, when coding for scientific drawings, only drawings related to activities were coded. Due to the varied nature of students’ pictorial representations (drawings had different sizes, labels and colors; some had multiple parts, like a wide view and zoomed-in view of the same apparatus), only one count was given per activity for any illustrations included by the student. Both scientific word and drawing counts were averaged over the total number of activities completed during the semester, including activities where children designed their own experiments.

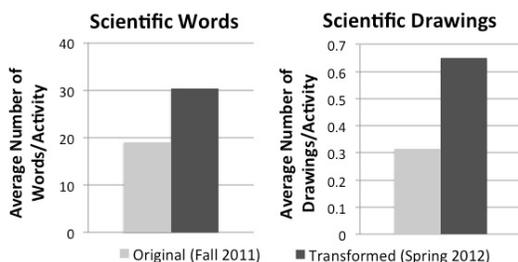


FIGURE 3. Scientific words and drawings were counted in student notebooks for the original curriculum (Fall 2011) and reformed curriculum (Spring 2012).

Figure 3 shows the average number of scientific words and drawings per activity for each semester. Students generated nearly 1.6 times more words and over twice as many drawings in Spring 2012 than in Fall 2011. Thus, students practiced their communication skills significantly more with the transformed curriculum. While this result does not describe the quality of writing and drawings, other

studies have shown that experience with decontextualized language is linked with school success [12, 13]. We suggest that the affordances of the new curricular format and the engaging nature of the experiments empowered students to communicate at higher rates than the original curriculum.

DISCUSSION

With this new curriculum we have seen students execute more choices about what activities they work on as well as an increase in student directed behavior within each activity. These findings indicate an increase in students taking active control of what they are doing in our program. We also see an increase in the amount of writing and drawing. Students are practicing more communication in their notebooks and are thus practicing more expert science behavior. While additional studies must be done to investigate quality of student work and content knowledge gains, this study presents evidence of our students taking on more active expert roles that could lead to positive science identity.

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