

New Media and Models for Engaging Under-Represented Students in Science

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Abstract. We describe the University of Colorado Partnerships for Informal Science Education in the Community (PISEC) program in which university students participate in classroom and after school science activities with local precollege children. Across several different formal and informal educational environments, we use new technological tools, such as stop action motion (SAM) movies [1] to engage children so that they may develop an understanding of science through play and “show and tell”. This approach provides a complementary avenue for reaching children who are otherwise underrepresented in science and under-supported in more formal educational settings. We present the model of university community partnership and demonstrate its utility in a case study involving an African American third grade student learning about velocity and acceleration.

Keywords: Physics education research, informal science education, technology, pre-service training, computers.

PACS: 01.40.Fk, 01.40.-d, 01.40.jc, 01.50.H-

INTRODUCTION

According to the recent National Research Council report, “Rising above the Gathering Storm” [2] the future economic infrastructure of the United States relies on a population better educated in science, technology, engineering and mathematics (STEM). One of this report’s primary suggestions focuses on enlarging the pipeline of students entering science majors. The report states, “Particular attention should be paid to increasing the participation of those students in groups that are underrepresented in science, technology, and mathematics education, training, and employment.” [2, p.129] Increasing effort is being spent on K12 STEM education and on reaching under-served populations. To this end, the NSF has included an education / outreach component in all Center grants, and required “broader impacts” of all grant proposals.

As part of the JILA NSF Physics Frontier Center (PFC) for Atomic, Molecular, and Optical Physics and in collaboration with the Physics Education Research group at the University of Colorado (CU), we have developed the Partnerships for Informal Science Education in the Community (PISEC) program. Unlike many educational outreach programs, this community partnership model seeks to simultaneously serve the interests of both

university and community agencies. In this program, we recruit university students to participate in science activities with underrepresented populations of precollege children. Within these programs, children develop an understanding, interest and identity in science. The participating university students have an opportunity to develop an interest and understanding of teaching, to enhance their communication skills, and to be exposed to working in the community – benefits that they will take with them as they become teachers or researchers at other institutions. The success of such a program hinges on creating social contexts in which activities can effectively utilize research-based technological and pedagogical tools, and employ a reasonable assessment strategy. This model of university-community partnership builds on theories of learning, which posits that individual development and learning is coupled with social, cultural and environmental contexts as well as the use of key educational tools. [3,4]

The PISEC program takes advantage of infrastructure, organizations, support, and collaborations wherever possible. For example, we recruit university students from the Learning Assistant and CU Teach programs, which prepare future K12 STEM teachers. [5] Another synergistic collaboration includes the University of California at San Diego Laboratory of Comparative Human

Cognition (LCHC). LCHC researchers developed this model of university community partnership [3] and run an analogous program in inner city San Diego. In the San Diego collaboration, science majors at CU are able to communicate (via video) with LCHC social science majors engaged in activities with children at a local housing project. In this way, the CU students can remotely provide science expertise to children already participating in an after school environment.

Some barriers to creating an effective learning environment in this context include the voluntary nature of the after school program, administrative organization such as getting an appropriate number of trained university students to the site, and language and cultural barriers. This program has added technological and social barriers introduced because of the remote program. One might argue that providing effective science learning environments is hard enough in the college setting without these barriers. Indeed, Trowbridge and McDermott document the ways that college students struggle with motion in one dimension. [6,7] However, diSessa *et al.* [8] document the potential for children to understand these sometimes abstract ideas in the case of a classroom of sixth graders “inventing” the notion of one-dimensional motion graphs to explain observed phenomena.

Along these lines, we describe the case study of Karl, an African-American third grader living in subsidized housing at the San Diego site, who participated in the remotely supported after school program. We focus on Karl because he was present at multiple sessions and because he was able to show clear progress. Karl was able to demonstrate his understanding of constant motion consistently and acceleration with some help. Months later (with no other physics sessions) he was able to demonstrate that he still understood the concepts. We examine the social context and the technological tools that facilitate his learning. Not only was Karl able to learn these concepts in a series of two sessions

CONTEXT: TECHNOLOGY AND SOCIAL ENVIRONMENT

Two technological tools provide avenues for engaging children in play to learn science. Stop action motion (SAM) [1] movie software offers a nontraditional medium for students to demonstrate what they know. Using a simple and intuitive interface, children use cameras built-in or attached to a computer to take a sequence of snapshots stitched together to produce a continuous movie. This software provides a non-verbal form of expression.

For students who did not learn English as a first language or for students who have difficulties in reading and writing, SAM presents opportunities for engaging in science. In the activities we describe in this paper, Karl is asked to make a movie depicting acceleration and constant speed. A training session with the SAM software provided Karl with the skills he needed to make movies. The use of this new tool enabled him to demonstrate his understanding of speed and acceleration concepts. Notably, other educational tools, particularly simulations from the Physics Education Technology (PhET) [10] project are instrumental in these educational environments. Presently, however, we focus on the role of SAM.

The social context itself is essential for enabling science learning in these informal environments. At the San Diego site, two supportive social science majors from LCHC worked with Karl in a (non science) after school program over many weeks. Then, once per week, CU PISEC students and staff began to communicate via video with the children to participate in science activities. The LCHC students are in a position to support technical and administrative challenges, to capture these sessions on video for research, to attend to social issues that arise locally, and to facilitate when the children have trouble understanding what they are asked to do. In this case, because Karl is young and was not exposed to the ideas and vocabulary necessary to understand this exercise, some care was given to make sure our activities were clear to him. Notably the social science students at the San Diego site expressed some discomfort teaching this subject, exhibited an incomplete mastery of the topics of constant speed and constant acceleration themselves, but learned the material along with Karl.

PERFORMANCE DEMONSTRATIONS

From the outset, we sought to develop Karl’s level of understanding by tracking his performance according to Table 1. Our goal was to determine what Karl could achieve before the intervention and to have him move to the highest level of performance after the intervention. We wanted him to be able to perform at that heightened level of achievement at another time in a slightly different environment or context.

At the beginning of the video taped physics session, Karl did not know what the word “constant” meant. When we described “constant speed” as the case where a car does not slow down or speed up, he was only able to repeat back these words. Further questioning revealed that he did not understand the idea of constant speed.

| Level | Successfully makes a stop action movie depicting: |
|-------|---|
| 0 | Unsuccessful |
| 1 | Object moving |
| 2 | Object moving with constant speed |
| 3 | Object moving with increasing/decreasing speed |
| 4 | Object moving with constant acceleration |

At first, Karl had no idea how to make a movie in which an object moved. We tried to give him a few cues, but he was unable to do it. Even after he understood how to make a SAM movie, he could not figure out how to make something move on the screen. When we asked him to make a movie of motion, he did not know how to begin. For this reason, we judged Karl's initial level to be Level 0. After he was shown how the words, "This is constant speed," could be made to move across the screen, Karl was able to make a movie of a car moving (Level 1). Figure 1 (a-c) shows three consecutive frames of his movie from left to right.

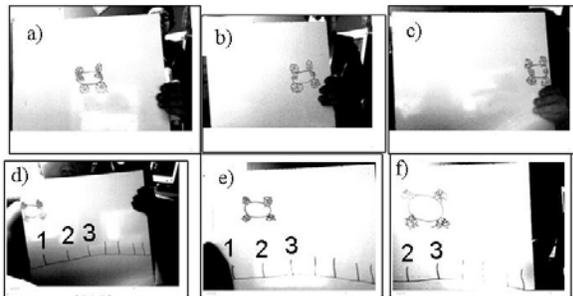


Figure 1. Consecutive frames of Karl's movie (l to r) shows a car moving across screen (a-c) and slowing down (d-f).

At this point in the session, we had not yet introduced Karl to the concept of a scale tool to show fixed and equal spacing between cars. We asked him several questions to be sure he intended that the spacing between cars was equal, which he answered to our satisfaction (Level 2).

Next, we asked Karl to make a movie of the car slowing down, which was more problematic. We tried introducing a scale tool in the form of a number line with no numbers. We talked about dotted centerlines painted on the road. We introduced the concept of "equal distance in equal time" but we have no reason to believe that he understood that "equal time" mapped to taking pictures at even time increments. We described that if the car were slowing down that it would not get as far in each picture. He indicated that he understood, so we asked him to draw the spacing of cars that are slowing down. He drew three uniformly spaced objects. When asked what that represented, he replied, "Constant speed." When asked again to draw objects

slowing down, he erased the third object and drew it closer to the second. However, the next two objects he drew were again evenly spaced. We questioned him about whether the object was still slowing down in the last two frames. His response was to erase the last two and draw them closer and closer together in a demonstration of screen shots of an object slowing down (Level 3). We asked him to make his movie of the car slowing down.

Figure 1 (d-f) show three consecutive frames from left to right of Karl's movie depicting the car slowing down. We have added numbers to the scale, corresponding to Karl's first, second, and third tick marks. In the first frame, the car is roughly centered on the first mark. In the second frame, the car is roughly centered on the second mark, but in the third frame, the car does not get as far as the center of the third mark (Level 3). All of this work was conducted in a single session. From this evidence, we argue that Karl was able to progress in one session from Level 0 to Level 3.

In the next week's session, we asked Karl if he remembered what constant speed meant. He repeated the phrase he had previously used replying, "Constant speed means it doesn't stop." In preparation for this week, we had prepared a cutout of a man, which he could use to move across the whiteboard. Unprompted, he drew the scale and made his movie, but the man's movement was not a constant speed (Level 1). We pointed out that the man did not move equal distances in equal time. He seemed to understand this and made the movie. Consecutive frames of the movie are shown left to right in Figure 2 (a-d). Notice that the man moves one unit with each frame (Level 2).

When we asked Karl to make a movie of the man speeding up, he initially made a movie of the man moving at constant speed. Although we had worked at length with him in the previous session on how to make a movie of slowing down, he did not seem to understand the idea. We tried to explain that if someone took pictures once a second and the man was moving at constant speed, the man would appear to move one unit each time. However, if the man were speeding up, he would travel more than one unit by the time the picture was taken. His responses to this were hesitant and unsure compared to his responses about constant speed. Although he was able to make the appropriate movie of increasing speed (Level 2), he was hesitant enough about it to make us doubt he understood it enough to reproduce it next time. Consecutive frames of his movie from left to right are shown in Figure 2 (e-h).

During this session, Karl was interviewed as a movie director. The interviewer said, "Tell me about

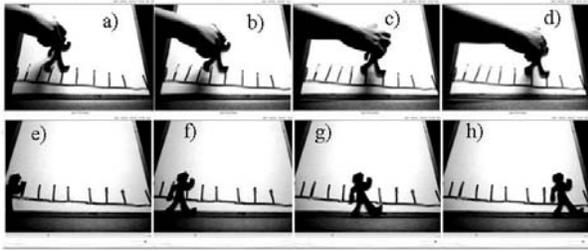


Figure 2. Consecutive frames (left to right) of Karl's movie depicting constant speed (a-d) and increasing speed (e-h).

your movie.” Karl replied, “It’s mostly about constant speed...That is when anything stays the speed, doesn’t speed up and doesn’t go slower. It stays the same speed.” Karl’s explanation does not repeat his previously memorized answer, the first *verbal* evidence that he understood constant speed. He did not discuss increasing speed, further evidence that he had not fully digested the idea.

Six months after the initial session during a site visit to San Diego, the CU researchers met Karl in person for the first time. He was asked to make a SAM demonstration of constant speed, using cardboard cutouts from the PhET *Energy Skate Park* simulation. [10] Without cueing, Karl, made a movie of the skater moving across the screen in a fixed distance for every picture. Karl was careful to move the skater in equal increments using a shadow of the previous picture in SAM showing what has changed in the frame (the “skin frame” feature of SAM). A video similar to that of Figure 2 (a-d) demonstrated his understanding of constant speed (Level 2).

DISCUSSION AND CONCLUSIONS

Karl was able to move from performance Level 0 to Level 3, in which he was able to make movies of constant, decreasing and increasing speed. Karl demonstrated the ability to make a movie of constant speed (Level 2) six months after his initial sessions with the SAM software. We feel that this was impressive for a third grader in such a short time. We believe Karl’s success, in part, to be due to the use of innovative tools and social interactions. Although the one-on-one attention appeared to be an important factor, the concept of variable speed appeared easier for Karl to understand with a visual representation (SAM), a hands-on medium for exploring the concept, and a feedback mechanism to observe what happened. Verbal interaction was not enough; he was not able to articulate the idea of constant speed in his own words until he had made several movies.

In the final session, Karl used a feature of the software to make sure that a fixed distance was traversed before taking a second snapshot. The social

context allowed Karl to play with ideas, to create an object for public display [9] and to draw on the resources (adult supervision / support locally, and science support remotely via video). While intensive in terms of resources, this proof-of-concept demonstrates that with appropriate tools and social interactions, children can learn complex ideas in these informal settings, and that it is possible to distribute the resources (in this case geographically) to support such learning. Scaling these efforts to reach more children simultaneously is the subject of current research.

ACKNOWLEDGMENTS

The authors wish to thank the AAPT / AIP / APS PhysTEC program; the JILA PFC; Noyce Fellow Shaun Piazza; Michael Cole, Robert Lecusay, Ivan Rosero, and David Coughlan of LCHC; and William Church, Brian Gravel, and Chris Rogers of Tufts University Center for Engineering Education Outreach. This material is based upon work supported by the National Science Foundation under Grant No. REC 0448176. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF.

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