What Representations Teach Us About Student Reasoning

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Abstract: The importance of informal science education to the field of Physics Education Research includes extending to a broader range of ages and environments than formal science and focusing on broader goals such as inspiring interest in science in participants and the development of participants' identities as scientists. This paper describes 3 aspects of informal science education: programming, research, and curriculum development. A summer camp was run through JILA's PISEC (Partnerships for Informal Science in the Community) program. Participants' use of representations, in particular drawings, in response to different types of prompting was analyzed in both lab notebooks and stop-motion videos made by the participants. In light of the results of this study, a new curriculum was developed for use in the Fall 2012 semester of the PISEC program.

I. INTRODUCTION

Only in the past few decades has the field of Physics Education Research become recognized as an important aspect of a physics department. Physics Education Research (PER) uses the scientific method to investigate the learning process in both qualitative and quantitative ways. In his introduction to Physics Education Research, Robert Beichner defines PER as "focused inquiry into what happens as students struggle to grasp and use the concepts of Physics."[1] Within PER, there research is done in both the basic theoretical aspects of how people learn as well as applied research focused on the evaluation and modification of an educational approach and the improvement of instructional techniques.

While the more familiar context in which PER is carried out is the formal environment, particularly classrooms and university courses, PER also extends to informal science environments. Informal science environments include one-time experiences such as visiting a museum, repeated experiences such as after-school programs, and independent learning. These environments are of special interest because they extend to a much broader range of spaces and are lifelong experiences.[2]

The University of Colorado Boulder's PER group looks at three groups as subjects of investigation in informal science. The first group is composed of the learners: the person visiting the museum, the students in an after-school program or camp, or the independent learner. The second group includes the presenters of the material, for example the docents at a museum or the mentors in an after-school program. The third group is composed of the institutions or structures involved, such as the museum itself, the school hosting an after-school science program, or the community in which informal science takes place. The content learning, attitudes towards science, and communication of each of these groups are areas of informal science research.

II. PISEC

Overview of the Program

The first aspect of my project this summer was running a summer camp through the JILA Physics Frontier Center's Partnerships for Informal Science in the Community (PISEC) program.[3] PISEC is a collaboration between the University of Colorado at Boulder and the larger community, training university students to present an after-school science program to K-12 students, who often come from backgrounds underrepresented in science. In the program, the university students, along with teachers from the schools it is presented at, mentor children as they work through science experiments and activities. Typically, the after-school programs are presented at middle schools once a week for an hour and a half during the school semester. The PISEC program includes research on informal science in conjunction with the University of Colorado Physics Education Research Group (PER@C).

Curriculum Used

The curriculum used in PISEC is based on the 5th Dimension afterschool program model developed by Cole.[4] It is presented as a game in which participants progress from being "students" to "principal investigator" by doing science experiments. The game has several "rooms" featuring different topics in physics. Within each room there are three levels that are successively more sophisticated in equipment or concepts, each with multiple activities that students can choose from. The goal of giving students options of what they do in the program is to allow participants agency in their learning and to inspire excitement and motivation. The curriculum used in the PISEC program in Spring and Summer 2012 was focused

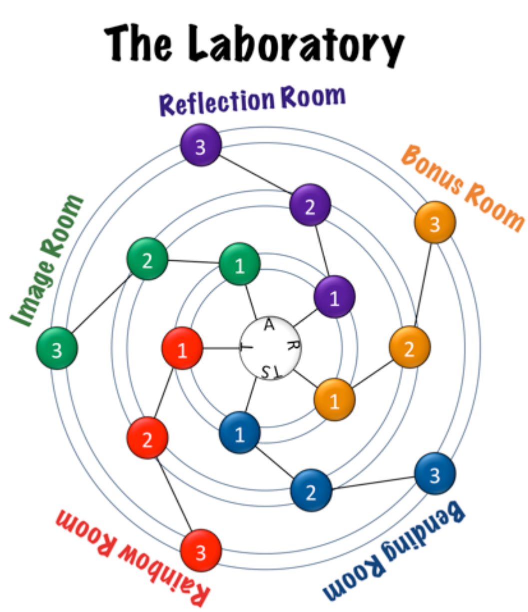

Figure 1: Game board used in PISEC program. Once level 1 is completed in any room, students can move to level 2 of same room or level 1 of a new room

on optics, including activities on reflection, refraction, and magnification.

During the program each student is given a lab notebook to document what he or she does in the program through writing or drawing. For each activity the students do, they are given a card with instructions and questions for the activity to tape into their notebook. These prompts serve two purposes: the first is to give the students direction while allowing for free-form answers; the second is to document what activities the students have done for future reference. At the end of each session, the students place their notebook in a bin for "The Wizard" (a mythical character that students never see, but is implied to the architect of the game) to review and comment in for the next session. When the students pick up their notebooks at the beginning of the class, they review the notes the Wizard (in actuality a member of the PISEC staff) has written them in their notebooks.

Casa de la Esperanza Summer Camp

We used this curriculum to present a summer camp at the Casa de la Esperanza Community Center in Longmont, Co. The camp was an hour and a half each day, 3 days a week, for two weeks. There were 4-5 adults from the University of Colorado at Boulder each day to act as "science advisors" for the program. While the number of students varied from day to day, there were usually from 20-25 students participating. The age range was much greater than in the typical after school setting .The students ranged in age from 6 to 14, since many of the middle school aged children who had been encouraged to come had younger siblings who came to the program as well. Each day during the camp, the kids were split up into groups of 3-6 students. While smaller groups of 2 or 3 students might have been preferred, when other children showed up late they joined groups with their friends so the groups were often larger than planned. The groups were very segregated by gender, with one group of six girls and several groups of 3-6 boys. On some of the days, there were one or two girls who worked by themselves or with boys, but for the most part all of the girls formed one group. There seemed to be a range of ages in every group, especially because we asked the older students, some of who had done the program before, to be youth leaders and help the younger children. Since all of the students lived in the same housing community they knew each other and many were friends, so mixing the ages of the groups happened naturally.

The first week of the camp and the first day of the second week the students did the activities from the optics curriculum. We videotaped various groups as they worked through the experiments in effort to capture their learning process so it could be analyzed later. While the videos did show what the students were learning, the room was very loud and their conversations were not distinguishable on the videos. On Tuesday of the second week, we had the students make their own stop-action-motion (SAM)[5] movies about one or two of their favorite experiments. On the last day of the camp, Wednesday, we watched the movies the students had made and made liquid nitrogen ice cream. Later in the summer, the participants came to the University of Colorado on a field trip that included lab tours, science demonstrations, and more liquid nitrogen ice cream.

Observations

Overall, the students seemed to enjoy the camp and were excited to come each day. It was a very high-energy group and it was often challenging to get the students focused, particularly because the room we were in was very loud and because of the age range of the students. The large age range also seemed to affect how the students interacted with each other, did the activities, and wrote or drew in their notebooks, as many of the older participants copied what the younger ones were doing. Because the environment was somewhat chaotic, some things that would have been enforced during a semester program such as going through the rooms in a proper order and finishing one room before moving to the next were not enforced.

I worked mainly with a group of boys: Adam, age 8, David, age 12, and Sam, age 11. This group represented a spectrum of attitudes of students in the PISEC program, displaying various levels of enthusiasm and focus. Sam was the quiet member of the group and did a lot of work individually. He did not appear to be overly enthusiastic about the activities, but he spent a lot of time and was very thorough about writing in his notebook and always answered all of the questions on the prompt. Sam needed very little direction from me in order to do the activity, but was less confident about trying new things that were not included in the prompt. David did not always answer all of the questions on the prompt in his notebook, but he still put effort into recording what he did. David was the most responsive to the questions I asked verbally. David was more assertive and was usually the one to suggest an activity and get the equipment. He followed the directions given, but once he had finished he was more confident about testing out new things. Adam was the most enthusiastic member of the group, but it took more effort to get him focused on the activities. He was very interested in playing with the equipment and less concerned with following the directions given. He only drew pictures to record things in his notebook, and although he did spend time on his drawings, he recorded less than the other members of the group.

One of the activities that this group did involved setting up several mirrors in a circle, shining a laser on one of the mirrors, and tracking the path of the laser beam around the circle. We looked through the activities to find some that they had not already done, and the boys all agreed on the mirror experiment. David was the leader of the setup. They used playdoh to hold the mirrors up in a circle, and Adam played with the playdoh while David and Sam started to set up. Sam showed Adam how to use the playdoh to hold up the mirrors and then Adam started helping. I asked questions about where we should shine the laser and where they thought the beam would go, and David was the first to answer both. Adam was the first to draw a picture of their setup tracking the laser beam, and the other two copied him. Sam saw that the prompt instructed to use a post-it note to track the laser beam, so he did this and put the post-it in his lab notebook when they were done. Adam had gotten out a piece of equipment from another activity that involved a curved mirror and was playing with it, and he got the idea to put it on top of the circle of mirrors like a roof. Adam and David both seemed interested in what happened with the concave mirror in their setup and tried shining the laser on it in different places, but

Sam just watched them talked to some of the other students. When I asked questions about what they thought would happen with the concave mirror and how it worked, David was again the first to answer my questions. Adam drew a picture of the setup with the curved mirror, which neither of the other boys did.

This type of interaction seemed typical of most of the groups in the camp. The group I worked with was smaller than many of the groups, which had 5-6 students. It was also one of the more focused and enthusiastic groups. I noticed that especially the groups with older students were less enthusiastic about science and their mentors were challenged to motivate the groups to do the experiments. While it was hard to tell during the camp if the participants were enjoying science, the director of the community center told us later that they were asking when we would be coming back, which seemed to show that the camp had interested them.

III. RESEARCH

Introduction

The focus of my research was on the students' use of representations during this summer camp. The main forms of representation that the students in the Casa de la Esperanza summer camp used were verbal communication, writing, and pictures. They rarely, if ever, used other types of representations common to physics problems such as graphs and equations.[6] Representations, the different ways in which the students communicated what they knew or what happened in their experiments, were of special interest because of the important role they play in the learning process as well as the insight they provide into students' content learning, attitudes toward science, and identity as a scientist.

For most of the students in the summer camp at Casa de la Esperanza, pictures were an important form of representation. I speculate this could be the result of several factors: first, almost half of the students were under 10, and writing may have been more difficult for them than the typical PISEC student. Second, English was the second language of many of the students, posing a barrier to writing in their notebooks for an English-speaking adult. Third, the content of the curriculum, optics, has many visual elements and may have naturally lent itself to pictures.

I first reviewed each student's notebook looking at their use of different forms of representations. Subsequently I analyzed student drawings for several specific activities and for the Stop-Action-Motion movies that the students made. The study I conducted examined the types of pictures students drew in comparison with the prompt given for a specific activity. My research question was: do students follow the prompts they were given about the use of representations, especially pictures, and when do they display content learning with pictures?

Methods

In analyzing the notebooks, I only counted the pictures that were related to the activities the students did in some way. I did count pictures that showed experiments that were part of the curriculum even if a student did not tape in the prompt or if it wasn't clear that the student had finished the activity. If the student did not label a drawing but it did appear to describe one of the experiments in the curriculum, I counted the picture toward the activity that I thought they best described. Doodles about unrelated things (ninjas, bows and arrows, cats) did not count as pictures. I counted separate pictures as drawings that described something on their own. Two separate drawings drawings did not depend on each other to make sense, and usually showed two separate thoughts, experiments, or parts of the experiment.

Since the SAM videos often included pictures that students added to over several frames to describe one idea, I separated the pictures when students erased the white board that they were filming and started a new drawing. Most of the videos included pictures that were unrelated to any of the activities in the curriculum. Some of these did not involve science at all, and I these did not count as scientific pictures. However some students' drawings described experiments that were not part of the curriculum. These were still "scientific" and demonstrated knowledge of the scientific process, so I defined a scientific (countable) picture as one that shows the equipment, setup, results, or an explanation of an experiment, whether it was in the curriculum or not. Since almost anything could be the equipment for some experiment, it had to be clear what the intended experiment was in the videos that were not about an experiment in the curriculum.

In both the notebooks and videos, I looked at the amount of information in pictures that students drew. I categorized the pictures according to the amount of information provided as follows:

Category 0-no picture
Category 1- a drawing of the equipment used in the experiment
Category 2- a drawing of what the experiment looked like
Category 3- a drawing that included some type of modeling, interpreting, or explanation (something that was not obviously visible)

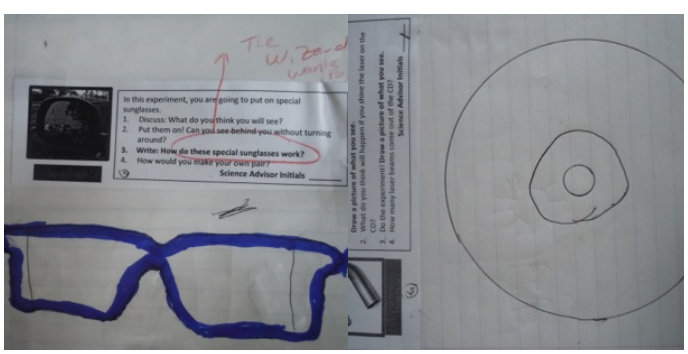

Figure 2: examples of category 1 drawings. Students drew pictures of the equipment used in the activity. Glasses that allow the wearer to see behind him are on the left; a CD used in a reflection experiment is on the right.

Figure 3: exapmles of category 2 pictures. Students drew what their experiments looked like. These showed the use or outcomes of experiments. The rearview glasses are on the left; light through a diffraction grating is shown on the right.

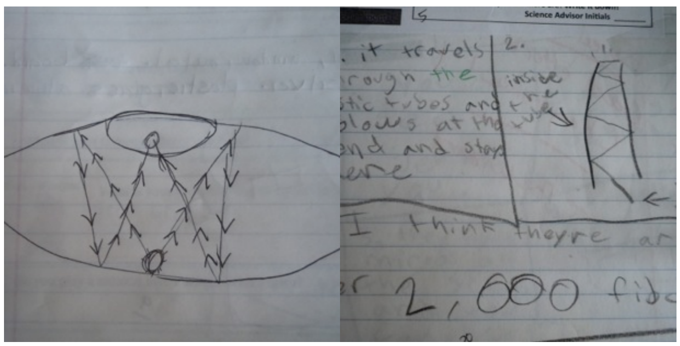

Figure 4: examples of category 3 pictures. Students drew pictures explaining or modeling an experiment. A "3-D Hologram Chamber" involving concave mirrors is on the left; a fiber optic lamp is on the right.

In total, I analyzed ten different activities for each of the 26 participants in the camp (however not all students did every activity). These activities used three different styles of prompts: activities that did not ask students to draw a picture, activities that asked students to draw a picture of what the experiment looked like, and activities that asked students to draw a picture of how they thought something worked or to model a part of the experiment that was not visible (see Appendix B). None of the activities had prompts asking the student to draw a picture of only the equipment. The prompt given for the video did not give any specific instruction on whether to use pictures or what kind of pictures students should use in their videos.

Data

In my initial overview of the notebooks, I noticed some correlation between age and number of words and pictures used. On average, younger children, especially those under 10, tended to draw more pictures and write fewer words than their older counterparts. The older students drew pictures when they were prompted, but younger children were more likely to draw pictures when they were not prompted or to draw more than one picture for an activity.

Out of the 10 activities included in the analysis of the notebooks, four did not ask for a picture, four asked for a drawing of the experiment (category 2), and two asked for an explanatory (category 3) picture. There were a few activities where other factors may have influenced the students' drawings. One activity did not ask for a picture, but did instruct students to look at a diagram of how it worked. The diagram may have had an influence directly on the pictures by the students who looked at it, but also indirectly on the students who did not look at the diagram but saw their peers drawing pictures. For another activity, which used glasses with mirrors on the sides to allow the wearer to see behind him, one of the adults suggested that his group draw the glasses in order to focus the group. This seemed to catch on in the room since quite a few students drew pictures of the glasses. However, the results show that students are fairly consistent in following the prompt in their drawings. For the activities that did not ask for any drawings, 60% of the students who did the activity drew no scientific pictures. The 40% who did draw pictures were spread out over the three categories. For the activities that asked for category 2 drawings, 57% of students drew category 2 pictures, and the remainder either drew no pictures or category 1 pictures. No student drew category 3 pictures for any of these activities. For the activities that asked for category 3 pictures, 86% of students drew category 3 pictures.

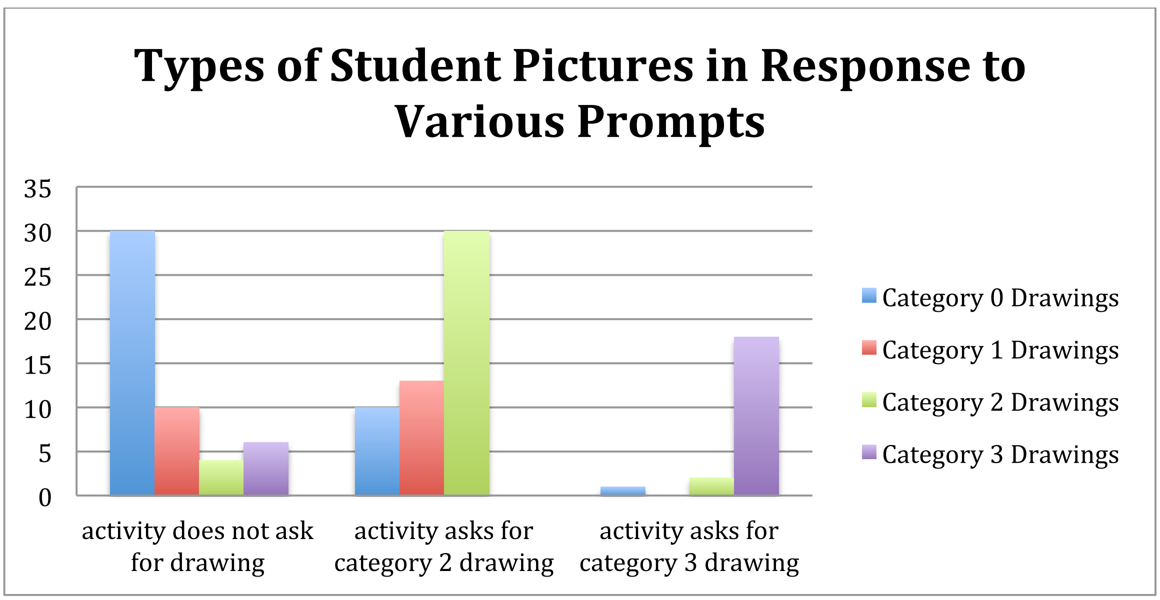

Figure 5: Number of each different type of student drawings for various prompt styles.

In the videos, which did not have instructions about pictures, the largest number of the pictures drawn were category 2 drawings, but 7 out of 9 total scientific videos included at least one category 3 picture. Many of the videos the students made were about one of the experiments that had prompted the students to draw a category 3 picture in their notebooks, which they copied in their movies. These students often included category 1 and 2 pictures to further describe their experiments. The students who chose to make movies about activities that had only asked for a category 2 picture or no picture at all drew category 1 and 2 pictures to describe their experiments, but very rarely drew category 3 pictures in their movies.

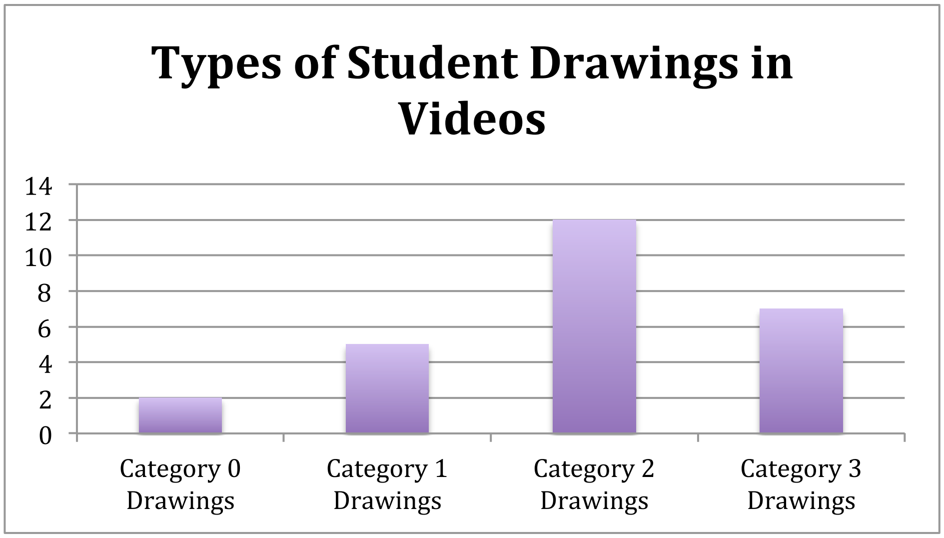

Figure 6: Number of each type of drawing found in student videos.

Discussion

Of the three different styles of prompts, students were most likely to follow those that asked for category 3 drawings. Perhaps the category 3 prompts were easier for students to follow or left less room for their interpretations, so they drew more of the types of pictures they were asked for. It is also possible that students perceived category 3 pictures as more important or interesting and thus were more motivated to draw them. Additionally, the fact that most of the students chose to make movies about activities that they had already drawn explanatory pictures for suggests that the drawing of the picture may be an important part of the student's learning process. One could reasonably infer that students chose to make videos about the experiments they understood better and were able to explain or because they experienced more excitement about activities in which they were able to discover how something worked.

Future questions the results of this study bring up include the purpose drawings serve for students and the degree of student's agency in their drawings. Do students draw pictures because they are using drawing as a means of working out and grasping a concept, to record thoughts for later reference, or simply because they were told or they think they are supposed to draw pictures? Will students draw pictures entirely on their own, or only when they are told to?

Implications for Curriculum Development

The results of this study imply several alterations to future curriculum that is developed. It seems reasonable to ask students to draw what they see in their experiments as drawing the experiment is good practice in keeping a lab notebook for future reference and engages the students, making them reflect on what they have just done. As we have seen, however, in order to get an idea of students' understanding it is better to ask for the student to draw a picture that explains the experiment. Further, simply asking for what the experiment looks like may be overlooking an important step in the learning process that leads to more excitement and better understanding of the material.

IV. CURRICULUM DEVELOPMENT

The third aspect of my project was the development of a new curriculum to be used in the PISEC program in Fall 2012. The curriculum for Fall 2011 had been on circuits and the curriculum for Spring 2012 was on optics, so I chose mechanics as the subject of the new curriculum. I chose to keep the game format used in the Spring 2012 curriculum, with several rooms with three levels.

Improvements Made in Fall 2012 Curriculum

Although the mechanics curriculum follows the basic format of the spring 2012 optics curriculum, there were several improvements made for the fall. Most of them are directed at putting more emphasis on explaining how and why experiments work or at giving students more room for discovery.

The style of prompts was changed to make them more open-ended, giving the students less information to start with. Many are simply "how does ________ work?" The prompts have a space for students to write down something they are going to test, in effort to encourage students' creativity and independent discovery. We added an "Idea Card" to supplement the prompt with questions for groups to discuss or ideas of things they could test in the activity in case students are unsure what to do with an activity. Additionally, we created an extra help card with suggestion for the adult mentor for every activity, whereas in the spring curriculum there had been an extra help card for the entire level.

We decided to integrate videotaping of the classroom and video interviews of the students into the curriculum, in order to have another source of data. We hope that video will allow us to capture the process of learning, especially students' "ah-ha!" moments and to record the outside factors that influence what the student write or draw in their notebooks. We hope that video interviews asking students about an experiment they did will encourage them to explain activities without prompting and so take more agency in their learning.

Another improvement made in the new curriculum is the introduction of a design problem as the main component of the third level in each room. The intent of this is to encourage students to reflect on what they have learned in levels 1 and 2 and apply it to the design of something new. We hope that this will result in students explaining the experiments without being expressly told to, as well as make the learning process more exciting and student-directed.

Some other questions addressed in the development of this curriculum were the role of the game format, the importance of "The Wizard", and whether to group the activities by the scientific concepts or by the topic of the activity. It was decided that the game format of the curriculum serves an important purpose in that it provides motivation to do the activities and it takes the students outside of the normal learning environment, and so barriers to their creativity and investigation are lessened. We decided that the wizard was also an important component of the curriculum because it provides motivation for students to write in their notebooks and a figure of authority to comment on students' notebooks without it seeming like they were being graded. We did decide to change this figure from a wizard to an imaginary professor, because professors are actually involved in science and would be knowledgeable about the students' experiments. We discussed whether to group the activities by concept, such as Newton's laws, or by topic, such as cars, because so many activities involved the same type of equipment. However, we decided to group the activities by concept as had been done in the spring because this imitates how an expert scientist is likely to classify experiments.[7]

Development Process

We created the curriculum with the "strands of science learning" articulated by the National Research Council[8] as goals. These strands describe the learner's experience in informal science: learners experience excitement, interest, and motivation to learn; learners generate, remember, and apply concepts and explanations; learners use the scientific method to discover; learners reflect on science as a way of knowing things and on their own process of learning; learners participate in science and use scientific language and tools; learners develop an identity as a learner and sometimes contributor to science. The curriculum was especially developed with the first and last strands in mind (experiencing excitement and developing identity), as these are the strands specific to informal science education.

We began with brainstorming activities that were both exciting and instructive and categorizing them by topic. I created four "rooms" for the game based on the activities I had come up with: the Friction Room, which focused on frictional forces, the Energy Lab, focusing on conservation of energy, The Revolution Room, focusing or circular and angular motion, and Sir Newton's Study, focusing on Newton's laws. Once I had divided the activities into rooms, I separated them into level 1 and level 2 based on the sophistication of the concepts involved. I created a design problem, in which the students design, build, and test something like a catapult or a marble roller coaster for level 3 to incorporate the concepts from levels 1 and 2.

We wrote a storyline for each room involving the imaginary professor Dr. Whatshisname, the head researcher on a project the students are part of. The storyline introduces the design problem in level 1 to give students goals to think about as they complete the activities in levels 1 and 2. Then we wrote out the prompts, idea cards, and extra help cards for each level in each room.

In its finished form, the curriculum is a game including the four rooms, each with three levels. The first two levels have 3-5 activities for students to choose from, which are experiments, challenges involving scientific concepts, or PhET computer simulations. The third level of each room involves a design project and a video summary in which students explain what they made to Dr. Whatshisname.

V. CONCLUSION

It is our goal that what was learned about student use of representations has improved the curriculum for the Fall 2012 semester. We anticipate that the incorporation of video documentation will allow for more in-depth study of students' learning process. We hope that the revised style of prompt will encourage students to explain more often and more effectively accomplish the twofold goals of content learning and inspiring identity and enthusiasm about science.

ACKNOWLEDGEMENTS

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APPENDIX A- Field Notes

June 25, 2012

Casa de la Esperanza is a low-income housing community in Longmont, CO. We were doing a summer science camp for the kids living there. The kids were all Hispanic, and it seemed like Spanish was their first language. They mostly spoke Spanish to each other when they weren't around the (English-speaking) adults. When the adults were nearby, they sometimes spoke English, and they always spoke English when they were talking to the adults. It also seemed like they used English for the science activities. There wasn't much to absorb the sound in the room, so it was very loud. We arrived early to set up, but most of the kids were 5-10 minutes late. There were 20-25 kids there and they all seemed energetic. They all knew each other and were very talkative.

I worked with Adam (age 6), David, and Sam (both 11 or 12) (all boys). It was hard to get the class started-none of the kids seemed super excited about doing the activities at first. To start the session we asked them what scientists do. Lots of the kids said they do experiments or research, and one student said scientists discover new things almost every day. Nick (6) said that scientists do experiments and make magic potions. We asked the kids if they were scientists and most kids said they were not. We asked them why not, several said it was because they didn't have lab coats, and no one seemed to disagree with this idea. We asked why scientists need lab coats, and some kids said to hold things or to protect them from chemicals. One said they have lab coats because scientists are rich. We moved on to the activities after the discussion. My group chose to work on the same room they had done the last time- the reflection room. They started with the 3 mirror experiment, and we spent about half the time on this activity and half making a movie about spies and the rearview glasses. David was really interested in the mirrors &lasers, Sam seemed uninterested or maybe afraid to try it, and Adam just wanted to play with the equipment. David did most of the setup of the experiments, Sam watched, and Adam was a little distracted by the playdoh. They were able to show me the path of the laser when it bounced off the mirrors & explain that when you shine the laser at more of an angle onto the mirror it also bounces off with more of an angle. We tried shining the laser off of the curved mirror from the hologram chamber as well. It seemed like most of the kids thought the light would reflect off of the curved mirror in many directions like it did with the CD because the curved mirror was round.

One thing I noticed is that the boys would describe what was happening in the experiment without any prompting, but I had to ask them questions to get them to explain why. When we made the movie, they decided it should be about spies using the rearview glasses to defeat "bad guys". We did two "takes" of the video, the first they didn't show any science content. In the second it didn't seem like they were going to show how the glasses worked, so I suggested they could explain how the glasses worked at the end of the movie, and they seemed excited about doing that. Another thing that I noticed was that David wrote and drew pictures in his notebook, Adam only drew pictures, and Sam mostly wrote or drew, but not both. In one case, Sam started writing but then he saw Adam drawing and decided to draw instead. Their preferences for writing or drawing could have to do with age. Since Adam was 6 it makes sense that he wouldn't write as much. David was more involved than Sam was, so maybe he was more willing to take time to draw &explain.

NOTE 8/2/12: this was my first impression of Sam, but after working with him other days and reviewing his notebook, I saw that he did write and draw a lot, and he was more interested and involved that I had originally thought. Maybe he was having an off day this day. He also was more of the studious, timid type and it seems like he did a lot by himself, so I may not have noticed what he was doing.

It was challenging to get the kids started because the room was so loud. The discussion was a good way to start off because it made the kids think and talk to each other about science & be engaged, but it seemed like it might have been better if we had split them into different groups and gone into different rooms or outside to help with the noise.

In my group, it seemed like the kids who were more involved or interested in the experiments were better at explaining them.

I thought it was interesting that one of the boys said that scientists wear lab coats because they are rich since we were in a low income housing community. Maybe there is a barrier I the way of these kids viewing themselves as scientists because of their families' income.

I felt like my group could have been more controlled if the groups were more separated from each other or if I had been able to get the kids to interact more with each other and with me.

It seemed like the second movie we made was more successful because I was able to encourage them to explain the glasses. The fist was less successful because the science content was unclear.

I noticed that my group seemed to be more successful than some of the others because there were only 3 students, while some had 5 or 6 and were much more chaotic.

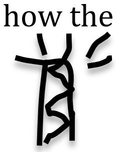
June 26, 2012

When we got to the site about ten minutes early, there was another class for the kids going on. They were making cornstarch and water stuff and it seemed like they were really enjoying it. We set up 6 tables and we had 9 computers for the kids to use so some tables had one computer and some had 2. We set up the tables for SAM movies with a computer, webcam, wire stand, and whiteboard.

The instructions we gave the kids for the day were that there could be no more than two people per computer and that we wanted to see a movie about their two favorite experiments.

I worked with a group of two boys (Sam and Jake). Adam showed up late and joined our group, but he moved to his own computer while they were making the movie because he said there was nothing for him to do. To start, I asked the boys what their favorite experiment was, & Sam said it was the fiber optic lamp (not in those words). Jake agreed that the lamp was cool. I asked them what they were going to make the movie about and neither gave much of an answer, so I asked them how the lamp worked. Jake said that the light teleports up the tubes, and I asked him how that happened and if it was magic. Sam said, "oh! I know! It bounces off the inside of the tubes to the top." She asked what the tubes were called and I told him fibers. I also suggested the boys could go get the lamp to use in their movie.

The movie started with a drawing of "HI", then they spelled out fiber optic lamp. They put in a few slides showing the lamp, and then Sam wrote out on the whiteboard how it worked. Jake was the "photographer". I prompted Sam with a few questions like "where in the lamp is the light?" and "how does it get to the top?" He was able to answer my questions and wrote out the description on the white board. Both kids really enjoyed watching the whole movie after every slide they added, so the process took a while. I suggested to Sam that he draw a picture of how the lamp worked at the end, so he drew something like:



We only had a few minutes left in the class so instead of making another movie I let them play with the camera. They drew some pictures of people and explosions to put at the end of the movie and made credits with their names. They showed the movie (pre-explosions) to a friend (Danny) who came in at the very end of the class he laughed and said he loved it because it was scientific and funny.

Reflection:

I felt like the movie was really successful because the boys seemed to really enjoy making it and it had some science content. It was cool that Danny enjoyed it even though he wasn't involved in making it. I don't know whether he thought it was funny because it was scientific (nerdy?) or for some other reason. I did wonder if I had given them too much prompting/directions and if it would have gone well if I had left them on their own more. From what they did at the end of their movie when I stepped away it seemed like they needed some guidance for the science part, but maybe it was just because they had already explained how the lamp worked. They were able to tell me what was going on in the lamp and draw a picture when I asked about it, so it was clear that they understood it. I thought it was interesting that they chose to write out the description of the lamp in the video, because from what I saw they & most kids drew mainly pictures in their notebooks.

June 27, 2012

Today was the last day of the program so our plan was to led the kids put finishing touches on their movies and play Khet (a game similar to chess involving a laser and mirrors), then watch their movies and make liquid nitrogen ice cream at the end. There were quite a few kids who were not at camp yesterday and most of them chose to make new movies. Only two groups of kids decided to actually play Khet and there were two or three other groups who were just playing with the lasers and mirrors.

I talked to most of the groups today, but I worked the most with Danny and Alicia and Bethany, who were making movies. Danny, who is 11 or 12, really likes science and could list almost the whole periodic table and told the class the temperature of liquid nitrogen when we made ice cream. Danny made a movie about how to grow a square watermelon. My interaction with him was mainly asking how you grow a square watermelon and if he had ever done it before (he explained how to do it and that he learned this from the show Mythbusters and he had never done it himself). I wasn't giving him guidance on how to make the movie. He made a movie that explained with pictures and words how to grow a square watermelon, along with some random non-scientific drawings at the end. He made a credits slide at the end of his movie that said: "Data: Mythbusters By: Danny".
The other group, Alicia and Bethany, made a movie about rainbows and prisms. I gave them a little more guidance than I gave Danny, asking them what the prism does and why (they never really answered my question though). They showed in their movie that the prism makes a rainbow from the light of the flashlight. They weren't able to get the flashlight and prism to show a rainbow, so they drew it on the whiteboard with different colored markers. They couldn't explain why the prism made a rainbow from the white light. At the end of their movie they drew a rainbow in the sky with raindrops. I asked them how the two rainbows were alike and I think one of the girls said because they are both rainbows. I asked them how the sky makes a rainbow and they were unsure, so I asked them what they rain does to make a rainbow. They were still unsure, so I asked if they thought that rainbows might be like prisms and they enthusiastically answered yes.
I also talked to some of the kids playing Khet and asked them where the laser beams were going and they all were able to trace the path of the light. I asked one group why the beam came off the mirror at an angle instead of perpendicular to the face of the mirror and they explained it was because the laser had also hit the mirror at an angle.
Reflection:

Even though Danny's movie did not have anything to do with the activities he had done in the camp, I thought it was cool because he described the process and he used both pictures and words to explain. I also thought it was cool that he attributed his "data" to Mythbusters. He seemed like he understood the scientific process and he was really interested in why things work. Alicia and Bethany (and most of the kids) had a hard time associating similar concepts like rainbows form prisms and rainbows from raindrops. This makes me think that it would be better to organize the mechanics curriculum by science concept than by category. A lot of the kids also didn't seem to be overly interested in why anything happened. Maybe a successful curriculum would get kids excited about why things work.

APPENDIX B- PROPMTS FOR ACTVITIES ANALYZED

Examine the 3D hologram chamber. Be careful not to leave fingerprints on the inside of the chamber!
1. Put at least 2 different objects: try something shiny, clear, or solid. Write down what you see!
2. Discuss: How do you think the chamber works?
3. Look at the Diagram of the chamber. Discuss what it means with your group.
4. Try this! Take the bottom half of the chamber and move it from far away to close to your face. Write: What happens to your reflection?

Examine two mirrors.
1. Use one mirror and hold it so you can see other parts of the room without turning around. Write: How does a mirror work?
2. Hold two mirrors at a right angle to each other in front of your nose. Write: How many images of yourself do you see?

In this experiment, you are going to out on special sunglasses.
1. Discuss: what do you think you will see?
2. Put them on! Can you see behind you without turning around?
3. Write: how do these special sunglasses work?
4. How would you make your own pair?

Examine a lens.
1. What do you see when looking through it?
2. What do you think would happen if you move the lens farther away or closer to your face?
3. Do the experiment! What do you see? Try looking at something written or typed. Write what happens.
4. Write: How do you think glasses work to help people see?

In this experiment you are going to use a "rainbow peephole" to look at the lights in the room.
1. Discuss with your group what you think you will see.
2. Now do it! Draw a color picture of what you see. What is different from your prediction?
3. What will happen if you rotate the peephole? Write down what happens.
4. What do you think the peephole is made out of?

In this experiment you are young to shine a flashlight through a special piece of glass called a prism.
1. Discuss with your group what you think will happen.
2. Now do it! Draw a color picture of your experiment.
3. Write: what is important about the position of the prism and the flashlight?

4. The color of the light from the flashlight is "white" until you shine it through the prism. Write: what is it that the prism is doing to the light?

In this experiment you will shine a laser on the bottom surface of a CD.
1. First look at the CD when you hold it up to the room lights. Draw a picture of what you see.
2. What do you think will happen if you shine the laser on the CD?
3. Do the experiment. Draw a picture of what you see.
4. How many laser beams come out of the CD?

In this experiment use the magnifying glass to look at various objects.
1. Find three different objects. Predict what the objects will look like with the magnifying glass.
2. Do the experiment! Draw two pictures of each object: what it looks like with your eye and what it looks like in the magnifying glass.
3. How does what you see compare with your prediction?
4. How does the magnifying glass work?

Examine the Fiber optic lamp.
1. Write: How does the light get from inside the base to the ends of the fibers? What does this have to do with reflections?
2. Draw a picture of how you think the light gets from the base to the ends of the fibers.
3. Guess how many fibers there are. Write it down!

Set up a series of at least three mirrors and a laser pointer in playdoh.
1. Make the laser beam go in a circle using the mirrors.
2. Draw your set up. Track the beam with a post it note. Label the beam with arrows to show its direction.
3. Write: why does light reflect off of a mirror? What will light not reflect off of? Why?

APPENDIX C—EXAMPLE ACTIVITIES FROM MECHANICS CURRICULUM

AIR PUCK EXPERIMENT

Friction Lab: Level 1

Equipment: Air Puck

How does an air puck work?

What I am going to test:

____

____

____

____

____

Idea Card

- What happens when you add weight to the air puck?
- How far will the air puck go?
- What kinds of surfaces does the air puck work on?
- ____
- ____

Extra Help Card

- Something to think about: the puck stays almost still until they push it, then it goes until a force is exerted to stop it -- Newton's first law
- Some questions to ask if students get stuck:
  - How do you know ______?
  - How do you test _______?
  - How does the air puck float?
  - Why does it go further when it is on than when it is off?

CAR
EXPERIMENT

Friction Lab:
Level 2

Equipment:
incline, small car
with motor

How does friction help a car on a hill?

What I will

test:________________________________

____

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____

____

Idea Card

- Place the car on a ramp so that it is facing up the hill. What is the steepest angle of the ramp that the car will not slide back down? Now, with the incline at that angle, turn the motor on. What happens? Why do you think this happens?

- ____
____

Extra Help Card

The goal of the experiment is that students see that kinetic friction is less than static friction, since the car will slide down the hill once the motor is turned on. They might test out different angles where the car will slide no matter what, and angles where the car will go up the hill when the motor is turned on.

- Some questions to ask if students get stuck:
    - How do you know ______?
    - How do you test _______?
    - What is the best angle? How do you define best?

DESIGN CHALLENGE

Friction Lab: Level 3

Equipment: matchbox cars? track? Sandpaper, gravel, cotton balls, etc for terrain

DATE_______________

Your challenge is to build a racetrack for the city of Whereverdyville. It is up to you to decide what to make the track out of and what to race on it. The only requests of the city managers are that you use three types of terrain to challenge the drivers, that you include at least one curve, and that the car stop in as short of a distance as possible without causing any damage to the driver (crashing into walls is painful).

What I Will Test:_____________________

____

____

____

science advisor initials_______

Idea Card

- Use friction to keep cars from sliding off the track at curves
- Use friction to help cars up hills
- ____
- ____

Extra Help Card

Some questions to ask if students get stuck:

- How do you know ______?
- How do you test _______?
- How do you measure or define the best racetrack?
- How can you use science to build the racetrack?

VIDEO SUMMARY

Friction Lab: Level 3

Convince the mayor why your design is the best for his city. Is it most entertaining for the crowd? Is it fun for the drivers? Fast? How does it use science?

science advisor initials________

DATE_______________

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