Impact of Informal Science Education on Children's Attitudes About Science

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Abstract. The JILA Physics Frontier Center Partnerships for Informal Science Education in the Community (PISEC) provides informal afterschool inquiry-based science teaching opportunities for university participants with children typically underrepresented in science. We focus on the potential for this program to help increase children's interest in science, mathematics, and engineering and their understanding of the nature of science by validating the Children's Attitude Survey, which is based on the Colorado Learning Attitudes about Science Survey [1] and designed to measure shifts in children's attitudes about science and the nature of science. We present pre- and post-semester results for several semesters of the PISEC program, and demonstrate that, unlike most introductory physics courses in college, our after-school informal science programs support and promote positive attitudes about science.

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INTRODUCTION

The University of Colorado Partnerships for Informal Science Education in the Community (PISEC) [2] offers an afterschool program as part of the JILA NSF Atomic, Molecular, and Optical Physics Frontier Center in collaboration with the Physics Education Research group at the University of Colorado (CU). PISEC has been running afterschool informal science programs since fall 2007, in which volunteer university participants guide children through inquiry-based science activities. Each program runs about an hour every week for 6 to 10 weeks each semester or summer.

From the fall 2007 through the spring 2010, PISEC was involved with students aged 9 to 15 at five different afterschool sites in Longmont, Colorado, including two elementary schools, one middle school, and an all-Latino residential housing development. Students were recruited through the Mathematics, Engineering, Science Achievement (MESA) program [3], an organization that facilitates afterschool science and mathematics instruction for ethnic minority and at-risk children.

While informal science education programs are becoming increasingly popular and recognized as a mechanism for reaching students otherwise not engaged in our educational system, it is important to track the impact of these programs on children, especially in ways that are authentic, aligned with goals, and embedded as part of the program activities. One aspect that we have focused on includes children's attitudes about science.

In a review of literature, Osborne *et al*. [4] describe how declining interest in pursuing science careers threatens national economic prosperity, that in general students show no improvement in attitudes towards science after age 9, and that the attitudes appear to decline rapidly after age 14. Some factors that influence attitude include gender, support, teacher effectiveness, curricula, and the perceived difficulty of science. The correlation between attitude and achievement appears to be moderate. Academic motivation and self efficacy may be stronger predictors of success in school science than positive attitudes alone. Engagement can also be raised by students taking a greater role in their learning.

These recommendations are part of what guide the PISEC program [5]: supporting the children with a small student to instructor ratio (3:1), providing quality teaching training, providing research-based curricula, and providing opportunities for the children to take control of their own learning. The PISEC Children's Attitude Survey (CAS) was designed to measure shifts in children's attitudes after participation in the program.

The CAS was modified from a subset of questions on the Colorado Learning about Attitudes in Science Survey (CLASS) [1], designed to measure shifts in college students' attitudes in introductory physics classes. Most questions on the CLASS were not appropriate for children in both context and language such as, "A significant problem in learning physics is being able to memorize all the information I need to know." More appropriate questions such as, "I think about the physics I experience in everyday life," were modified for language.

The CAS validation procedure (following the CLASS) determined validity of each question through analysis of children's interviews and responses to short answer questions. This qualitative procedure provided deeper understanding about the children's attitudes about science, a source of commonly used wording, and a degree of validity, justifying that the instrument measured what we intended. In this paper we present the different CAS versions, how questions were changed based on the analysis, and the results of the survey.

DESCRIPTION

Each version consisted of 4 to 6 questions (limited by the amount of testing that is possible in voluntary afterschool programs.) Each question on each of the five versions of the survey was followed by five multiple choice answers such as, "strongly agree," "agree," "neutral," "disagree," and "strongly disagree," and a short answer response asking the child to explain their reasoning. The five versions of the CAS had version numbers 1.0, 1.1, 2.0, 2.1, and 2.2. For versions 1.0, 1.1, and 2.0, modifications were made from the written response analysis only.

Starting with version 2.0, interviews were conducted during the semester. A list of interview questions was composed for each version, including follow-up questions such as "why do you think that?" For example, after the child had completed the survey, the interviewer would ask the first question in a new way and then ask why they answered that way. The interviews were held at each site during the PISEC sessions by the same interviewer. There were 124 matched pre- and post-surveys administered. Statements on CAS 1.0 and 1.1 were reviewed using 104 written responses, while statements on CAS 2.1 were evaluated through 55 interviews.

Validity of each CAS version was tested by counting the number of times the children's multiple choice answer matched their short answers or interview answers for each statement. If short answers to the prompts were positive, highly detailed and contained examples, we determined the response was "strongly agree" (or the corresponding strongly favorable option). If answers were not detailed but expressed a positive feeling, we determined the response was "agree." If there was some confusion or an in-between response, we determined the response was "neutral." If an answer was not detailed but expressed a negative feeling we determined the response was "disagree." If an answer was negative, highly detailed, and contained examples we determined the response was "strongly disagree."

The first question, "I like doing science activities," (CAS 1.0) became "How do I feel about doing science activities?" (CAS 1.1), then "I like science," (CAS 2.0) based on the short responses. The phrase "science activities" led the children to believe we meant the PISEC science activities. After interviews on CAS 2.0 we determined that children understood what we meant by the question and answered it based on how they felt, thus the question remained unchanged on subsequent versions.

The second question, "There is science in everyday life," (CAS 1.0) became "Do I think there is science in everyday life?" (CAS 1.1). The phrase "everyday life" was confusing, yielding answers like, "yes, in my science class," so the statement was changed to "There is science in my life outside of school," (CAS 2.0). In interviews, this question was still confusing, so it was changed to "There is science within the reach of my fingertips right now," (CAS 2.1). The word "fingertips" was confusing, so the resulting statement based on children's actual language became, "I can touch something to do with science right now," (CAS 2.2).

The third question, "I would prefer to find out why something happens by doing an experiment than by being told about it," (CAS 1.0) was intended to explore whether children appreciated the nature of science, but the children found this confusing and almost always answered in the positive. The next version was more direct, "Would I like to do an experiment or be told about it?" (CAS 1.1), but the confusion persisted. After observing that doing the experiment was related to the children's confidence about science, we changed the next version to, "I can figure things out for myself," (CAS 2.0, 2.1) and asked the children to give an example. Finally, after interviews the wording was changed to, "I can figure things out *by* myself," to reflect children's syntax.

The final question, "I would consider doing science or math as my job," (CAS 1.0) was particularly interesting to MESA which hoped to show that their program would increase the likelihood of underrepresented youth going on to study science in college. Despite the different manifestations of the question, "How would I feel about doing science as my job?" (CAS 1.1), "I would like to have a job connected to science," (CAS 2.0),

"I would consider a job in science," (CAS 2.1), and "What do you want to be when you grow up?" we found that most children wanted to be a celebrity or sports hero, and did not recognize careers related to science such as nurse, doctor, or engineer. We concluded that although this question deserves further study, the results were indeterminate.

Table 1. CAS version, site, number of surveys, semester (spring, summer, fall), and year for Statement 1 ("I like science,"), Statement 2 ("There is science in everyday life,"), and Statement 3 ("I can figure things out by myself,") and variations. The pre- and post-scores were multiplied by 100 (and standard error.) Scores represent percentage of children that agreed with the expert-like answers of "strongly agree" or "agree."

					Statement 1		Statement 2		Statement 3	
CAS	Site	N	Semester	Year	Pre	Post	Pre	Post	Pre	Post
1.0	A	4	Spring	2008	75 (25)	75 (25)	50 (29)	50 (29)	75 (25)	100 (0)
1.0	A	8	Summer	2008	88 (13)	88 (13)	63 (18)	63 (13)	100 (0)	63 (18)
1.1	A	11	Fall	2008	82 (12)	64 (15)	73 (14)	92 (9.1)	82 (12)	91 (9.1)
1.1	B	11	Fall	2008	100 (0)	100 (0)	82 (12)	91 (9.1)	100 (0)	82 (12)
1.1	A	8	Spring	2009	63 (18)	88 (13)	88 (13)	63 (18)	100 (0)	100 (0)
1.1	B	6	Spring	2009	100 (0)	100 (0)	83 (17)	83 (17)	100 (0)	67 (21)
2.0	A	9	Summer	2009	78 (14)		89 (11)		44 (23)	
2.0	B	12	Summer	2009	100 (0)		50 (15)		42 (15)	
2.1	A	6	Fall	2009	100 (0)	83 (17)	67 (21)	50 (22)	100 (0)	67 (21)
2.1	B1	12	Fall	2009	100 (0)	92 (8.2)	50 (15)	42 (15)	83 (11)	58 (15)
2.1	B2	10	Fall	2009	100 (0)	100 (0)	70 (15)	60 (16)	90 (10)	80 (13)
2.1	C	12	Fall	2009	92 (8.3)	75 (13)	8.3 (8.3)	25 (13)	33 (14)	67 (14)
2.2	A	9	Spring	2010	89 (11)	89 (11)	67 (17)	67 (17)	56 (18)	67 (17)
2.2	C1	10	Spring	2010	100 (0)	100 (0)	10 (10)	20 (13)	70 (15)	60 (16)
2.2	C2	7	Spring	2010	86 (14)	86 (14)	14 (14)	57 (20)	57 (20)	43 (20)
2.2	D	10	Spring	2010	70 (15)	90 (10)	50 (17)	80 (13)	80 (13)	80 (13)

RESULTS & DISCUSSION

The CAS was given to elementary and middle school students participating in PISEC at the beginning and end of each semester. Site A was a Latino housing project with students from 5th to 8th grade. Sites B and C consisted of primarily Latino 4th and 5th graders at an elementary school, while Site D consisted of primarily Latino 6th graders at a middle school. Most of the participating children qualified for free or reduced lunch and had been identified as at-risk by parents and teachers.

Scores (percentage of answers agreeing with the expert-like answers "strongly agree" and "agree") for question 1 averaged over matched pre- and post-semester surveys at each site are shown in Table 1, with standard error shown in parentheses. Similar results for statements 2 and 3 are shown in the table. Results were consistent with the literature, in that almost all scores (both pre and post) were positive; using the T-test ($p>0.05$), no survey score shifts were statistically significant; and matched surveys at each site were evaluated across semesters with no statistically significant shifts in any case.

For these 3 statements, the "strongly agree" and "agree" categories were indistinguishable; students who chose "agree" often gave evidence of "strongly agree" during interviews or written responses, and vice versa. For this reason we have combined these results. For example, if the child chose "agree" and the evidence suggested "strongly agree," we counted this as a match. The percentage of times children's multiple choice answers were supported by written or oral responses is shown in Table 2.

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Table 2. Percentage of children's multiple choice responses supported by written or oral responses. SA, A, N, D, SD stand for "strongly agree," "agree," "neutral," "disagree," and "strongly disagree". A dash indicates that no child chose that response.

		Multiple Choice Answers			
Statements		SA, A	N	D	SD
CAS 1.0	#1	93	78	-	-
	#2	68	89	33	-
	#3	97	67	20	100
CAS 1.1	#1	100	67	-	-
	#2	98	88	80	0
	#3	90	100	100	-
CAS 2.1	#1	98	100	100	-
	#2	80	57	33	-
	#3	87	41	0	0

From this table, most of the time when a child indicated the "strongly agree" or "agree" answers, the evidence suggested that they meant it. Because these two answers were not distinguishable, we were justified in combining them in calculating the score (percentage of times the student agreed with the expert-like, favorable answer.) .

From Table 1 we observe that almost all scores for statements 1 through 3 were positive on average, with no statistically significant changes during or across semesters. Results from the CLASS survey with college students [1] tended to show attitude shifts decreasing in traditionally taught courses. Only in reformed courses where the instructor specifically addressed issues related to the CLASS did the scores remain unchanged, and few courses experienced positive shifts in attitudes [6,7].

On the last version, CAS 2.2, statement 1 ("I like science,") appears to be validated in that from interviews and written responses, the children understand what they are being asked and are answering the question we attempted to ask. The expert-like answers ("strongly agree" and "agree") were combined and appear to represent the children's attitudes on this question.

Statement 2 ("I can touch something to do with science right now," and variations) provided interesting and verifiable results, but appeared to have a saturation effect in that once the children had the idea of science in everyday life, they did not lose the idea. This was based on observation, although longitudinal studies with (a low number of) matched surveys across semesters showed no statistically significant shifts. It would be interesting to keep this question on the survey to observe additional results. .

Statement 3 ("I can figure things out by myself," along with the follow up question "give an example,") appears to be measuring the children's confidence.

Statement 4 ("I would consider a job in science," and variations), not shown in Table 1, was determined to be a poor measure of whether children would actually consider a job in science. Not only did they have trouble identifying jobs in science, but most children wanted to be something more dramatic such as sports hero. This question will be removed from subsequent versions of the survey, but may be interesting for future study.

In future versions of the survey, we will try out a few new questions modified from the CLASS. We have found that the most number of questions children in elementary and middle school in this demographic are willing to answer truthfully without becoming tired or bored is four to five. Similar short answers and interview procedures will be conducted to further validate the survey.

It is important to track the impact of the PISEC program on children as part of the goal of improving children's attitudes and beliefs about science and their understanding of the nature of science. We have shown that the PISEC program does not result in a degradation of these parameters and may be an important supplemental educational experience for children in this demographic.

CONCLUSION

We have developed the Children's Attitude Survey (CAS) modified from a well-studied instrument (CLASS) [1]. The CAS was developed and modified using written responses and interviews over 8 semesters in the PISEC program at 5 different sites. Following results from the literature and the CLASS, significant changes in attitudes were not observed during the course of any one semester. The final version, CAS 2.2 included the questions: 1) I like science, 2) I can touch something to do with science right now, and 3) I can figure things out by myself.

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