

Changes in Science Content Knowledge and Attitudes toward Science Teaching of Educators Attending a Zoo-based Neuroscience Professional Development

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Abstract: Informal learning environments often host teachers for learning opportunities, but little is known about the impact of these experiences on teacher professional development (PD). This article describes a unique collaborative PD experience between zoological park personnel and university faculty, examining the impact on teacher content knowledge, attitudes, and classroom lessons. Our findings suggest that the PD improved science content, but made no impact on already high attitudes toward science. In light of the high level of self-reported satisfaction and high frequency of teacher lesson plan use, we propose that the PD had other positive outcomes such as pedagogical knowledge and authentic learning experiences.

Keywords: professional development, informal learning, museums

Improving Educators' Science Content Knowledge and Attitudes through Professional Development in an Informal Setting

The national fallout in science, technology, engineering, and mathematics (STEM) interest is no mystery despite recent economic demands for STEM careers (Hill, Corbett, and Rose 2010; Matthews 2007; National Research Council 1996; National Science Foundation 1999; Weber 2011). Tytler and Osborne (2012) assert that education's failure to engage students in studying science for a future career propels attitudes toward science to a position of importance as a matter of concern for society and policymakers. In response, informal science education centers, such as zoos and museums, are of growing interest for researchers seeking ways to encourage the pursuit of STEM subjects and

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careers. This is evidenced by the National Science Foundation's (NSF) recent program name change from Informal Science Education (ISE) to Advancing Informal STEM Learning (AISL) (National Science Foundation 2012). In doing so, NSF has emphasized that this title "better emphasizes the priorities of the solicitation and the changes at NSF" (National Science Foundation 2012, 1). While student informal STEM learning is somewhat common, it is challenging to find research on informal education for teachers. Yet, teacher professional development (PD) plays a central role in STEM initiatives (Corcoran 1995; Garet et al. 2001).

The impact of teacher content attitudes and teaching beliefs on student attitudes and learning is also well documented (Kirikkay 2009; Miranda 2012); therefore, it stands to reason that efforts to improve teacher content knowledge, pedagogies, and attitudes will have positive impacts on not only classroom performance but perhaps also student attitudes toward science content. While there is little research into student performance based on teacher attitudes toward their subject matter (Furtado 2010), more than a dozen studies report that teacher PD has positive outcomes on student classroom achievement (Blank, de las Alas, and Society for Research on Educational Effectiveness 2010). Exploring informal learning environments (such as zoos and museums) is vital because these environments may have the capacity to motivate teachers and improve student learning in STEM subjects.

The National Science Foundation defines informal education as anything taking place outside of the classroom (National Science Foundation 2012), which applies to learning opportunities for students, adult learners, and teacher PD. Interpreting informal education research, however, becomes challenging when one looks at the breadth of existing learning experiences. For example, when a school group takes a visit to a zoo or park, a range of very teacher-guided to student-centered activities may occur. Conversely, informal learning programs may mirror formal education practices of classroom-based instruction. For example, an informal learning experience may involve a formal, classroom-based presentation by a guest speaker, but this presenter utilizes during the presentation novel resources such as live animals and virtual field trips. These types of learning experiences blur the lines between formal and informal education.

We argue that informal education is more than the place where learning is fostered and is more appropriately identifiable by the authenticity of the learning experience and the opportunity for self-directed learning. Falk and Storksdieck (2010) succinctly distinguish education in zoos, museums, and the like as being "free-choice learning" in "leisure environments." While these environments make learning science much more effective and motivating for students (Braund and Reiss 2006), little is known about their impact on teachers.

As a result, researchers must be very specific in reporting and interpreting findings so as not to confuse outcomes and potential benefits of these programs with more formal practices that may coincidentally occur in informal settings. In other words, when reporting findings informal research needs to consider the interaction between the educational approach and the location.

In reviewing teacher PD literature, there are clear trends in what educators value. For example, teachers in science PD seem to value authentic, hands-on experiences as well as exposure to real scientists; these types of PD have positive outcomes in teacher learning and self-efficacy (Sinclair, Naizer, and Ledbetter 2011). Ahlfeld (2010) questions how well our modern PD practices allow for teacher-centered learning opportunities, but when given a choice, teachers pursue PDs that are of personal interest (Sinclair, Naizer, and Ledbetter 2011). According to Gudmundsdottir (1990), teachers' values and orientations to subject matter also influence their choice of content. Attitudes, such as anxiety, confidence, and enjoyment, tie into the teacher's day-to-day activities in the classroom, including selection of content and pedagogy. For teachers, research tends to focus on anxiety in teaching a particular subject. This research is often linked to their training (Westerback 2006), which ultimately may indicate their self-perception and/or confidence in pedagogy or content. Therefore, changes in content and teaching attitudes could have serious implications for how teachers will draw on PD to inform their classroom practices. A PD workshop designed to inherently impact both knowledge and attitudes toward science may have a more profound impact on classroom pedagogies.

With a host of peers, mentors, and educators available, informal learning venues provide opportunities to view real scientists in action and can provide *sanctuary* for learning science in a manner that allows both interest and lines of practice to evolve at the learner's discretion (Rahm, Martel-Reny, and Moore 2005). As a result, informal science centers break down barriers to enjoyment and interest in science learning, and perhaps also teaching. Professional development in an informal learning environment offers unique opportunities for participants to partner with working scientists while having authentic, hands-on learning opportunities. Based on the existing PD literature, we contend that such PD not only improves teacher science content knowledge, but also teacher attitudes toward teaching science.

The Unique Partnership Behind the PD

Professional development in informal learning environments, such as a zoo or museum, offers participants unique opportunities. A partnership among the Center for Behavioral Neuroscience (CBN), Georgia State University (GSU), and Zoo Atlanta provided a distinct

PD experience aimed at meeting the missions of each organization through improving neuroscience understanding, teacher education, and animal awareness. The CBN is an interdisciplinary consortium composed of more than 120 neuroscientists working at universities in metro Atlanta. Its goals include improving neuroscience education and science literacy, promoting neuroscience education programs, and providing teachers with innovative approaches to teaching science. Facilitators and presenters of the PD included faculty at GSU and postdoctorate and graduate students from the GSU College of Education and Neuroscience Institute in the College of Arts and Sciences. Finally, Zoo Atlanta is an Association of Zoos and Aquariums accredited park that strives to inspire visitors to value wildlife and safeguard existing species through conservation. Zoo Atlanta physically serves as the learning facility as well as provides a myriad of zoo employees, such as keepers, trainers, curators, researchers, and veterinarians, to support tours, give presentations, and lead other behind-the-scenes experiences. Together these three educational institutions have collaborated to create an informed, authentic, and meaningful PD by providing distinctive resources for use by the teacher participants.

The PD Workshop

According to Garet et al. (2001), three core features of PD have significant positive effects on teachers' self-reported increases in knowledge and skills and changes in classroom practice:

1. Focus on content knowledge
2. Opportunities for active learning
3. Coherence with other learning activities.

These features provide the framework of this PD workshop as later described.

For seven summers, the Animal Behavior and the Brain PD workshop has been instructing between 8 and 18 local inservice educators on site at Zoo Atlanta. Although some of the presenters and workshop sequencing may have varied through the years, the overall design, content, and logistics of the workshop have remained the same. The workshop consists of 35 hours of face-to-face participation from the teachers during the course of one week. Teachers also produce a final lesson plan (LP), which requires work outside of PD hours. The PD wraps up with one final follow-up session that occurs after the fall semester begins.

Three instructional methods are utilized throughout the week to provide coherence for the workshop's learning goals: field trips, direct instruction/discussion, and lesson-plan development involving teacher co-planning. These methods interweave content of animal behavior and the brain throughout the first four days of the program. To provide opportunities for active learning, teachers participate in several fieldtrips within the zoo each day, including tours focusing on conservation,

animal nutrition, the hoofstock barn, birds and small mammals, behind the scenes of a training show, and elephant care. Guest speaker presentations cover topics such as insect behavior, giant panda behavior and reproduction, primate behavior and conservation, and zoo veterinary care. To provide content knowledge, workshop instructors, specifically CBN and university faculty and graduate students, facilitate discussions about brain anatomy and adaptations; hormonal and neuronal controls of behavior; parental, aggressive, and social behavior; and animal ethics. Collaborative opportunities take place for several hours during the week. During these times, participants work with instructors in small groups or individually to co-plan draft science lessons. To help incorporate using the zoo as an education resource in the LPs, a zoo education specialist provides all of the participants with information on scheduling field trips, the zoo-mobile, or zoo classroom guest speakers. On the fifth and final day of the workshop participants present their lessons by providing a lesson overview and by teaching a component of the plan.

Sample Lesson

The unique partnership between the zoo, as an informal education facility, and GSU allows for the implementation of activities that highlight the strengths of both organizations to support the workshop goals. For example, to better understand animal behavior instruction, teachers first explored science concepts by recording observations from a short video clip of seagull behavior without any previous discussion on behavior or what they would be watching. This video was followed by an explanatory lecture/discussion on animal behavior and an introduction to ethograms (catalogs of different behaviors displayed by an animal). Teachers then completed a seagull ethogram while watching the clip again with a greater understanding of behavior and animal interactions. Teachers continued to build on their knowledge by using an ethogram to record gorilla behavior, paired with a discussion on gorilla behavior given by the zoo primate curator. Teachers then applied their understanding by completing an ethogram for an animal of their choice. Interactions of these activities allowed teachers different opportunities to learn about behavior and to expand their knowledge.

Follow-up Session

In the time between the summer workshop and a follow-up session, teachers continue to revise and seek feedback on their LP from the program instructors. The follow-up session lasts about six hours and generally occurs 10–12 weeks into the following fall semester. The first two hours of the follow-up focus on amphibian and reptile behavior content knowledge. Teachers have an in-depth behind-the-scenes tour of the reptile house at the zoo and plenty of time to interact with the reptile keepers. The remaining four hours is spent with

participants presenting and reflecting on experiences with teaching their LP. Teachers also use this time as an opportunity to clarify what they had learned during the summer session. This portion is participant facilitated to provide a sense of accomplishment and camaraderie.

Research Purpose

With this research we hoped to provide both the type of program feedback that would help us improve the reach and the strength of its impact on educators as well as insights into effective PD strategies for the education community at large. The goal of the workshop was to provide teachers with the science content knowledge to feel comfortable teaching animal behavior while maintaining or increasing their positive attitudes toward science. With these needs and interests of all three institutions in mind, we asked the following research questions.

- How does the workshop impact teacher neuroscience and biology content knowledge and attitudes toward science and motivation?
- How do content knowledge and attitudes toward science impact teacher use of the workshop lesson plans in their classroom?

Methods

Participants

During a seven-year period, 103 teachers participated in the PD workshop. Inservice teachers from the greater Atlanta area elected to participate in this program, which was free and came with a typical PD fee paid by the CBN. Teachers were recruited using advertisements sent to district offices and schools in addition to Zoo Atlanta's website. Most participants sought opportunities to fulfill continuing education unit (CEU) requirements, but as our surveys revealed, some actively pursued such opportunities beyond what their job demanded. A basic demographic overview in Table 1 describes this self-selected pool. It is also interesting to note the disparity between male and female participants as well the relatively even distribution of more mature participants by age range. Perhaps the higher number of female participants can be attributed to higher numbers of female teachers in K-12 education (Feistritz and Haar 2005) as well as the propensity for female scientists to lean more toward the biological fields (Miller, Blessing, and Schwartz 2006). Furthermore, although this workshop was open to all educators, a breakdown of the grades taught helps to clarify the size of our secondary educator population. While earlier years of the professional development were evenly mixed (elementary and secondary), the final four years contained exclusively secondary participants.

TABLE 1. Demographic Data of Participants.

	Total
Gender	
Male	15
Female	80
Ethnicity	
Caucasian	64
African American	25
Hispanic	2
Native American	1
Mixed	2
Unknown	1
Age	
22-30	15
31-40	32
41-50	20
51+	27
Unknown	1
Grade(s) Taught	
K-5	34
6-8	29
9-12	31
Substitute	5
Home school	2

Some teachers elected to omit some responses for the demographic survey.

Data Sources

Data collected included a short pretest and posttest, a demographic survey, a preattitude and postattitude survey, LPs, and reflections. After an introductory activity on the first day of the workshop, participants completed a content knowledge pretest, a short demographic survey, and a presurvey of attitudes toward science. All instruments were administered the last day of the one-week workshop with the exception of the demographic information.

Content Test and Attitude Survey

Quantitative data included a 20-question content test developed by the collaborators and a validated 40-item attitude-related statement survey (described later). The content test included multiple choice and true-or-false questions focused on neuroscience and biology topics and terminology. Following are two sample test questions.

Content Knowledge

1. For questions 1-4, answer which animal best describes the following features:
 - a. Chimpanzee
 - b. Rat
 - c. Pigeon
 - d. Frog
 1. Has proportionally large olfactory bulbs _____
 2. Has the most convoluted cortex _____

3. Has the most "primitive" brain _____
 4. Has a proportionally large cerebellum _____

2. For this question answer True or False: All behaviors are either learned or inherited.

The content knowledge test was reviewed independently by three neuroscientists to establish content validity. The resulting Cronbach's alpha value for content knowledge was 0.773, indicating a high, or good, reliability.

The Weinburgh and Steele (2000) attitudinal scale, Attitudes Towards Science Instruction (ATSit) was used because of its multidimensional nature to determine what PD workshop participants believed, perceived, and/or felt about (1) learning science and (2) teaching science. This instrument was selected due to its high reliability, previously established by Gogolin and Swartz (1992) with alpha coefficients ranging from 0.73 to 0.90, yielding a high, or good, reliability. The modified instrument was a five-point Likert-type response 40-item survey requiring teachers to indicate their degree of agreement (strongly agree, agree, neutral, disagree, or strongly disagree). The statements addressed teachers' perceptions of the following attitude constructs: anxiety, value, self-concept, enjoyment, and motivation. The following are sample statements.

- Anxiety: I feel at ease when teaching a science class.
- Value: Science is useful for solving everyday problems of life.
- Self-concept: No matter how hard I try, I cannot understand science.
- Enjoyment: Science is one of my favorite subjects.
- Motivation: I have a real desire to teach science well.

Data for the content test was assessed as either right or wrong with one point earned for each correct response. Data for the attitude survey was quantitatively analyzed by calculating the aggregate of participants' responses to statements reflective of each construct with the values for negative statements (such as the self-concept sample statement) reversed. Descriptive statistics, including aggregate numerical mean, standard deviation, and error, were performed to graphically represent the data. An independent paired *t* test was used to determine if a statistically significant difference existed between precontent and postcontent knowledge or attitude.

Lesson Plans and Follow-up Session Reflections

The LPs drafted by participants during the workshop and completed during the four months between the workshop and follow-up session were useful for measuring proficiency to apply content knowledge to instruction. Data were collected on the number of lessons developed, quality and quantity of lessons developed, and when in the school year, if at all, the lessons were taught. Lesson plans were evaluated using a nine-

component rubric: (1) the standards addressed by the LP, (2) time frame, (3) procedure to follow, (4) materials needed, (5) development and demonstration of hands-on activities, (6) assessment/evaluation, (7) overview of LP, (8) creativity, and (9) teacher presentation of LP objectives. During the initial week of the workshop, teachers and instructors provided written evaluations of each LP. The quality of each LP was determined by examining how carefully and creatively the LP included workshop content and how this aligned with grade-specific standards. Many LPs included field trips to the zoo or school visits by CBN faculty.

The fall follow-up session provided additional insights. The purpose of this meeting was to help the facilitators and researchers better understand how the workshop continued to impact their interests and use of the content. The percentage of teachers who taught their LPs by the time of the follow-up meeting was documented. Teachers were asked also to reflect on the LP they created during the summer and share their experiences with teaching them. Findings from this meeting were recorded and used as a qualitative means of comparison to the previously collected motivational survey results.

Results

Data analysis showed a statistically significant increase in content knowledge as well as insignificant gains in attitude toward teaching science. Additionally, a review of final lesson plans illustrated the use of active learning pedagogy.

Content Knowledge and Attitudes Toward Science

Participants' precontent and postcontent knowledge tests and attitudes toward science survey data are presented in Table 2. Since incomplete data were excluded from analysis, the sample size (*n*) was slightly less than the total number of workshop participants. Teachers responded accurately on less than 50 percent of the content knowledge pretest (9.84 out of 20). This number increased to a 67 percent average (13.42 out of 20) on the posttest—a statistically significant increase ($p < 0.001$). ATSit survey item ratings were interpreted for strength of attitude based on the following scale: less than 2 = negative, 3 = neutral, and above 4 = positive. Participants maintained a positive attitude overall and in four of five constructs (anxiety, value, enjoyment, and motivation). They maintained a high neutral attitude in the fifth construct of self-concept.

Lesson Plan Content

Participants' LPs included objectives tied to the state standards, time frame, procedures, lists of materials needed, descriptions of activities, descriptions and examples of assessment/evaluation, and lists of resources. Lesson plans varied based on the needs of the teachers

TABLE 2. Comparison of Pre and Post Data.

	Pre		Post		<i>n</i>	<i>t</i> test
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Content knowledge	9.84	4.01	13.4	3.52	99	< 0.001*
Overall attitude	4.17	0.74	4.20	0.81	95	0.579
Anxiety	4.23	0.84	4.26	0.91	95	0.654
Value	4.32	0.62	4.38	0.71	95	0.328
Self-concept	3.90	0.89	3.92	0.89	95	0.742
Enjoyment	4.31	0.77	4.32	0.81	95	0.969
Motivation	4.08	0.58	4.11	0.68	95	0.659

* $p < .001$.

Content knowledge ranges from 0 to 20 points (0–100%). Overall attitude, anxiety, value, self-concept, enjoyment, and motivation range from 1 to 5 on the Likert scale.

and grades taught. Example LPs included: “Enriching Primates: A Science-based Unit for Students New to an Elementary Gifted Program”; “How Does My Brain Let Me...? An Inquiry Unit for Middle School 7th Grade Life Science Students”; “Measuring Behavior and Communication: Similarities between Humans and Gorillas,” for an 11th grade high school biology course; and “Neuroanatomy: The Brain as a Universe,” for an advanced placement high school psychology class.

Material Implementation

While the workshop modules developed were referred to as LPs, 91 of the 103 LPs developed were actually multiday units that incorporated multiple LPs. The average unit length was three days for primary grades (K–5) and a range of from three to five days for secondary grades (6–12). Of the workshop participants, 88 percent strongly agreed that the workshop would be of value in their classroom prior to the school year beginning, and 88 percent stated that the workshop increased their content knowledge. Indeed, 89 percent presented their LPs during the following school year, suggesting that teachers’ belief in the value of the workshop products aligned with their actual utility during the school year.

Participant Reflections on the PD

Typically, most of the elementary and middle school teachers taught their lesson by the fall follow-up session, while fewer high school teachers had done so. Overall, 81 percent of participants taught their LP by the follow-up meeting. During the follow-up session, participants wrote anonymous evaluations about the value of the workshop as it related to their professional teaching goals and needs. Teachers stated that they liked “the diverse and knowledgeable speakers from the zoo,” “the opportunity to study behavior first hand,” and provided

suggestions on “how to use the information with my students.” Several zoo speakers were specifically highlighted by teachers as providing excellent and student-friendly information, including the curator for giant pandas, who incorporated giant panda physiology, behavior, and conservation information in her talk. Many teachers responded that the mix of lecture, demonstrations, zoo tours, and hands-on activities was the best way for them to learn. Teachers also stated that “hearing from other teachers about implementing the workshop ideas” was helpful. Overall, teachers expressed a high degree of satisfaction for what they learned and experienced during the workshop, and the resources provided were considered to be of great value. Of particular note was the workshop organization, which highlights the need for both careful organization and visible plans during PD workshops.

In their evaluations, teachers also shared their complications, mostly logistical, with the program. Several commented on their frustration with the length of their commute to the zoo, while others raised concern over the amount of walking and outdoor exposure involved in the program. While we regularly alerted participants that walking around the zoo in warm weather was inherent to the workshop, perhaps clearer descriptions of workshop activities in the program advertisements would be beneficial to future participants.

Discussion

Analysis of data suggested that teachers’ content knowledge significantly improved as measured by the precontent and postcontent knowledge test and participants’ self-assessment of content knowledge. However, workshop facilitators expected to see more understanding of the content emerge than the 13 of 20, or 65 percent, accuracy participants achieved on average. Perhaps this suggests that the difficulty of the material was beyond what was reasonable to expect of teachers within

this one-week timeframe, or maybe the material was more appropriate for honors biology and chemistry educators than general science teachers. Nevertheless, test results demonstrated a significant increase in teachers' science content knowledge between the start and end of the summer session. This finding might counter critics who feel that informal education PD is not beneficial to teachers' learning.

We also saw two potential ways that content knowledge outcomes may impact teacher attitudes. First, attitude scores started around 4.2 out of 5 in favor of the attitude measures and remained so at the end. Because teacher attitudes toward science were so positive at the beginning of the workshop, it stands to reason that there might have been a bit of a ceiling effect for observing any improvement as a result of the workshop. Second, the previously mentioned rigor of the workshop content and timing of the test may have counteracted any positive attitudinal gains teachers had as a result of working with subject-matter experts at the zoo. Because our original hypothesis was that zoo-based PD has the potential to improve teacher attitudes toward science, we would like to continue similar studies to control separately for content difficulty, courses taught, and attitudes.

We are further encouraged to continue with this model for future PD because of the relatively high percentage of teachers indicating the use of LPs in their classes. With 88 percent suggesting that they thought the workshop was useful, and similarly 89 percent using their LP within the first 12 weeks of the semester, it is clear that teachers valued their summer experiences enough to revisit the ideas with their students as frequently as they believed they would. This may be due in part to the sheer lack of time that U.S. teachers have for lesson planning within their normal work routine (Su, Qin, and Huang 2005). Opportunities to plan, reflect, and revise lesson plans, let alone in the company of such a diverse array of professionals, are rare. Thus, holding the workshop in an authentic and stimulating environment, providing teachers with expert support, and allowing them to work and develop a take-home product all contributed to their positive experience with the PD.

Analysis of participants' co-constructed lesson plans revealed further insight into teacher gains. The LPs presented novel approaches to teaching science topics addressed in the workshop and suggest proficiency with regard participants' ability to relate their pedagogical knowledge to content knowledge. Follow-up participant reflections on co-lesson planning indicated that they valued the co-planning portion of the workshop, taught the lesson created, and planned to teach the lesson again the following year. Teachers appeared to transfer experiences from the PD into the classroom with unmeasured enthusiasm motivating them to employ their new skills. Also notable is that the co-planning portion of the PD

allowed our pool of teachers from a wide range of grade levels to partner with others familiar with their specific age groups. As a result, through their LPs, teachers were able to tailor the advanced content learned to the needs of their own students and standards of their own districts. This, we feel, was a strength of our workshop design.

Our participants' ages may have affected our outcomes. On average they were in their 30s and 40s. Attitude and motivation may differ for teachers based on how long they have been in the profession. The work of Masuda, Ebersole, and Barrett (2013) demonstrates that trends in teacher purpose and topic for PD vary with career stage. Conceivably, then, a workshop of this duration, content focus, or methods of instruction will be selected for various intents with these different experience levels. Perhaps attitude changes or content scores would be more notable with teachers of less or more experience than our pool. Further investigation could help to illuminate this quandary.

Informal learning experiences can help facilitate a view of scientists as *real* people (Rham and Downey 2002), which can lead teachers to imagining their students having careers as scientists. Informal science centers may positively impact the enjoyment and interest in science learning and teaching through more than just knowledge and attitude shifts, but perhaps also through their illustration of authentic problem solving and genuine career pathways. Perhaps another more appropriate measure to improving our grasp of STEM subject promotion is in studying how such workshops highlight career opportunities and make personal connections for educators and then their students.

Conclusion

This research suggests that providing an enjoyable and interactive learning environment, providing access to authentic learning experiences, collaborating with science professionals, and providing support for incorporating challenging content into lessons through co-planning are indeed enough to improve teachers' science content knowledge and maintain positive attitudes toward science. Furthermore, the LPs resulting from this workshop were of practical use to participating teachers. However, we still hypothesize that PD such as ours has the potential to improve content, pedagogy, and attitudes beyond what ours has demonstrated to date. While grade-appropriate and challenging content may be a key determinant in helping to promote desired attitude changes, these decisions will have to be balanced with the goals of the participating institutions against the already highly positive attitudes of our participants.

Much in line with Coll et al. (2003), who claim that formal education should support informal learning opportunities, our overall workshop experiences compel us to believe that PD workshops are critical to increasing

STEM interest, and that a wide range of informal science centers can provide a complimentary environment to help bring about this change. Our experiences highlight the importance of collaborations with professionals and teachers in developing the content and design of PD experiences in order to maximize both positive content and attitudinal outcomes. While we have not perfected our gains in content knowledge or attitudinal shifts, we are eager to explore more ways to promote such results. Improved teacher attitudes can lead to improved educational strategies and student attitudes, which can positively play out in classroom student-teacher dynamics (Osborne and Dillon 2008). If teachers with strong science content knowledge and positive attitudes toward science are more likely to inspire their students and cultivate potential interest in STEM disciplines, administrators and teachers should seek out quality PD opportunities at informal learning environments. Partnerships among informal science centers, universities, and the community are avenues for the development and implementation of PD experiences that draw on readily available subject-matter experts and authentic learning environments.

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