Characterizing the Educational Effectiveness of STEM Demonstrations at Science-focused Events for Adult Audiences

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Science and its applications in engineering and technology are valuable tools to wield while addressing the plethora of environmental, ethical, and logistical concerns facing our modern society. It is not necessary for all individuals to work in a scientifically-focused industry, but a respect and understanding for the efforts of scientists is beneficial for large-scale collaboration to address these challenges. However, issues of trust persist between the scientific community and the general public. In this article, we show that a regional Science Center can be an effective facilitator of interaction between scientists and the general adult public by analyzing the experiences of content experts presenting demonstrations at an adult-oriented event series. This preliminary study found that adult audiences are excited to interact with live demonstrations and informally engage with experts from various disciplines to obtain new knowledge. The data shows that a Science Center hosted event is an effective way to curate experts and stimulate "just-in-time" learning by demonstrating concepts with a generally recognizable application or association. These results indicate an effective structure for distributing scientific information and facilitating communication between scientists and the general public, which could benefit public trust in science and societal wellbeing.

1. Introduction

1.1 Problem Identification

Concern for the relationship between scientists and the public at large is not unique to our current moment in society, and the notion of a growing communication gap has been debated for over a century [1, 2]. Attempts to characterize the relationship between the public and science have revealed large number of factors that affect this gap. These factors include parental and community influence, issues of trust related to interests and credibility, and inconsistent portrayal of scientific work in media [3, 4]. However, science and its applications in engineering and technology are valuable when addressing many societal and environmental concerns that exist in the modern world [5]. While not every individual needs to be personally working in a scientific field, a respect and understanding for science and scientists from all sectors of society supports collaborative efforts to address large scale sustainability issues in current systems [6].

1.2 Background on the Problem

Efforts to improve knowledge and engagement with science and technology at the K-12 school level have been extensively researched and developed, and often involve support from institutions of higher learning. There has been far less work done to examine the factors contributing to adult knowledge and perception of science and technology [7]. Interestingly, the limited data does show that advances in internet connectivity and content have brought change to the way adults are exposed to knowledge. The modern paradigm often involves less prior knowledge, instead opting to "just-in-time" system of immediate access to new concepts at the moment they are required to understand an observation [8]. Even with this emerging trend, there is an important utility in the traditional "warehouse" style of knowledge transfer from curated sources such as schools and museums due to the lack of regulation of information that is publicly available via online sources. Such distributors of knowledge offer a selection of content and experiences that are verified for accuracy and content. Science Centers, in particular, remain a valuable tool for increasing adult science literacy [9].

1.3 Proposed Solution

This work presents a hybrid of "warehouse" and "just-in-time" approaches as a way to teach scientific concepts to an adult audience. This hybrid experience is created by gathering curated sets of experts and demonstrations together into themed social events for adult audiences. Guests at the events are exposed to demonstrations of scientific concepts with experts on hand to explain and discuss the scientific concept required to understand the display in front of them. This setup is designed to respond to the research question: *Is an expert-guided demonstration in an informal setting an effective way to encourage adult learning of scientific concepts?*

The approach in this article to answering this question is to consider three aspects of guest interactions with the expert presenters. This work attempts to characterize the guests' incoming knowledge of a scientific concept, engagement during discussion with the expert, and relative understanding of the scientific concept after this interaction. The data presented was collected at two Eat Drink Do Science adults-only events hosted by the Kentucky Science Center (KSC) in Louisville, KY. The events were organized by KSC's Young Professionals Advisory Board.

2. Background

2.1 Kentucky Science Center

The Kentucky Science Center (KSC) is located in Louisville, KY, and is the largest hands-on science center in the state. The KSC works to provide informal science, technology, engineering, and math education by offering vast array of experiences for all audiences at its flagship location and surrounding region. Its mission is to encourage people of all ages to "Do Science", and is motivated by the notion that "Science Matters" to society, the workforce, and to individuals and families.

2.2 Young Professionals Advisory Board

A part of the mission of the KSC is to increase the science literacy of adult audiences. The Young Professionals Advisory Board (YPAB) was formed with the mission to support the Kentucky Science Center's Mission of "*encouraging people of all ages to Do Science in Engaging, Educational, and Entertaining Ways to Inspire a Lifetime of Learning.*" Specifically, this board was formed to implement strategies to make KSC an asset to young professionals age 40 and under. This YPAB has been responsible for planning and assisting in the execution of events that would be of interest to an adult audience. The targeted events by this board in 2022 were all under the "Eat, Drink, Do Science" series, with individual themes that differentiate each event.

2.3 Eat Drink Do Science Event Series

Planning for "Eat, Drink, Do Science" (EDDS) events was the primary goal of the YPAB's work in 2022. The events in this series have been designed for adult (21+) audiences and are scheduled to occur four times a year at the time of this article's publication. In general, each event gives guests access to all fixed exhibits in the KSC, catered food and drink options, and access to event-exclusive partner stations. The partners are invited to host a station that shows off their expertise and aligns with the specific theme of each event. The 2022 EDDS event themes during the data collection for this article were “Let’s Party”, which focused on the five human senses, and “Spooky Science”, which targeted Halloween and Scary Movie inspired partner stations.

3. Methods

3.1 Study Design

Each demonstration examined in this study was designed with a popular culture reference that was aligned with the event theme and also was intended to be broadly familiar with the guests to motivate discussion. This was also a starting point for the participants to inquire about the guests’ prior knowledge of the science on display at each station. Participants were provided with a demonstration and specific science and engineering concepts to convey through the explanation of the demonstration. Table 1 summarizes the popular references, demonstrations, and science and engineering concepts that were introduced. The details of each demonstration set up is expanded in Appendix section 6.1.

#	Popular Culture Reference	Demonstration	Concept(s) to Introduce
1	Jurassic Park movie, water ripples as a dinosaur takes a step	Sound-driven Surface Vibration	Wave energy conversion between various electrical and mechanical forms
2	Nearby object sensing in modern self-driving vehicles	Ultrasonic Distance Measurement	Calculating object distance from reflection time of a wave in a known medium
3	Playing a note on a wine glass rim as seen in various TV and movie scenes	Wine Glass Resonance	Mechanical vibration at resonance
4	Pumpkin association with general Halloween theme	Pumpkin-key Synthesizer	An electrical circuit must be a complete a conductive loop
5	Light and sound effects heard in the movie Frankenstein (1931)	Jacob’s Ladder	Charge buildup and imbalance as it relates to sparks and lightning
6	Electromagnetic fields as depicted in “Ghost Hunter” TV shows	Tesla Coil	Electron movement generates electric and magnetic fields

Table 1 – Summary of experiments presented and science concepts being demonstrated

The first three rows were developed to relate to sound, an element of the “Let’s Party” theme. The lower three rows were related to the “Spooky Science” Movie theme. Participants in the event were asked for their feedback on their guest interactions after the event had ended. Responses were then compiled and analyzed for recurring themes regarding the guests’ interaction with the participant and the demonstration.

3.2 Participation Information

Data collected from three college faculty and three graduated students from an Engineering Technology college within a large public university in the Midwestern United States. The individuals presenting a demonstration are discussed in this article as the "participants", while the attendees of the event are referred to as the "guests" and have not provided any data directly to the author. The participants each facilitated one of the demonstration tables outlined in Table 1 for the three-hour duration of one of the Eat Drink Do Science events. The event attendance varied between 150-250 guests that could have interacted with the participants.

3.3 Data Collection

After the event had ended, participants were asked to reflect on their experiences with the guests with a set of questions designed to judge guests' preexisting knowledge, active discussion and learning, and incorporation of new information into their existing understanding. The following table contains the prompt that was provided to each participant.

<table>
<tr><th colspan="2">Directions</th></tr>
<tr><td colspan="2">In a brief paragraph, could you please summarize your impressions of your guest interactions in response to the following questions:</td></tr>
<tr><td>Assessment Topic</td><td>Prompt</td></tr>
<tr><td>Preexisting Knowledge</td><td>How familiar or knowledgeable were the guests about the demo you were demonstrating? (did they indicate knowledge of what it was or elements of how it worked, etc.)</td></tr>
<tr><td>Active Learning</td><td>How willing were guests to ask questions about the demo and hold a discussion about the basic principles involved?</td></tr>
<tr><td>Incorporation of New Information</td><td>Did you feel that the guests' understanding of the demo was increased from the discussions they had with you?</td></tr>
<tr><td>Event-specific Reflections</td><td>Do you have any other comments or observations that you would like to share regarding the demos or event?</td></tr>
</table>

Table 2 – Data collection questions to participants after each event.

3.4 Data Analysis

In response to the research question "*Is an expert-guided demonstration in an informal setting an effective way to encourage adult learning of scientific concepts?*", the author reviewed the reflections from all participants and identified common themes among the responses for each of the assessment areas. Results were also analyzed through from the perspective of the constructivist learning theory. Bada and Olusegun [10] characterize this as "In the most general sense, it usually means encouraging students to use active techniques (experiments, real-world problem solving) to create more knowledge and then to reflect on and talk about what they are doing and how their understanding is changing." This theory is at the core of many inquiry and problem-based learning techniques that are common in many collegiate engineering degree programs [11-14].

4. Results

4.1 Reflections on Preexisting Knowledge

Overall, it appears that the general incoming knowledge level varied from guest to guest, but that there was frequently a recognition of the concept from popular media. A sample of quotes from the participants that characterize the guests' preexisting knowledge are:

- *"**It was a mixture** of very knowledgeable, some and none."*
- *"**I experienced a full spectrum of understanding** from one person being able to calculate on their own, to explaining the formulas used, all the way down to explaining basic division."*
- *"**Some had seen and/or heard** of making sound with stemware, **such as from a movie."***
- *"**Most knew that sound traveled** at a finite speed."*
- *"I would say a majority of people didn't seem to know too much about the different demos, but **enjoyed relating it to things they've seen in movies or basic principles**."*

It is interesting to observe that the scientific concepts on display were ingrained in popular media to the point that they were generally recognized by an adult audience. It is also of note that there were multiple entry points into the discussion based on the incoming guest's knowledge base.

4.2 Reflections on Active Learning

Guests that interacted with the presented were frequently curious, engaged, and asked discerning follow-up questions. A sample of quotes from the participants that characterize the guests' active learning through observation and discussion are:

- *"Guests were excited and asked **many questions, mostly regarding how the demos worked**."*
- *"**Most were interested** in the speed of sound calculations.**"***
- *"**The majority would interact** with myself and the demo"*
- *"It was better if I engaged them, but as **often I was greeted with "What is this showing us?**"*

The reflections from the participants support the idea that guests were motivated to learn about the demonstration on display once they observed action that they didn't already understand. It was beneficial to have experts nearby to engage with the curious guests and educate them on the principals at work in the demonstration.

4.3 Reflections on Incorporation of New Information

Respondents to the survey unanimously reported that guests left their station with new knowledge about a fundamental scientific principle. In one response, the participant elaborated on their response by saying "*Yes. Particularly those with no previous knowledge* ***seemed to walk away***

with more understanding of basic principles that drove our exhibits." Another respondent noted the added benefit of elaborating on an example of the scientific principle to make a connection with the guest, saying that "*Yes!* ***Especially once I hit upon the sound wave use in Jurassic Park*** *(water in the glass/footsteps/ripples)*". These quotes highlight the strength of a live demonstration and connection to prior exposure as motivation to learn about a new concept.

4.4 Discussion

This format of the active learning experiences can be classified as a constructivist pedagogy. Central to constructivist theory are the notions that students learn best when they are engaged in the learning experience and that learning is a social process [15]. Therefore, the constructivist goal is to facilitate the construction of knowledge rather than to just pass knowledge directly [16]. There is a large amount of analysis and debate of this theory as it applies to formal education [17], but constructivism is also recognized as a common mechanism of informal learning in settings such as public Science Centers [18]. The data collected from participants in this study is aligned with core components of the constructivist process: determining prior knowledge, observation and discussion of new knowledge, and reflection of what was learned.

Constructivist ideas have been shown to benefit student learning within formal school settings [19]. The preliminary results in this article give support to the idea that the approach also works well with adult audiences at informal EDDS events. Critically, the knowledge being presented has been curated for accuracy to support the educational mission of the KSC. This structure of curated "just-in-time" learning opportunities has been cited as a strong basis for forming modern learning communities to support lifelong learning [20].

4.5 Lessons Learned

Participants responded to an open-ended suggestion for comments about their experience for the last question of the reflection prompt. There were three themes that stood out among the responses. First, participants suggested avoiding a demo dependent on ambient conditions because the noise and lighting levels are not in their control. Second, that the demonstrations were instantly accessible without relying on academic-form detailed posters to present background information, as audiences rarely read accompanying posters. Finally, it was noted that prior preparation of specific talking points and goals is critical due to the limited time for conversation (typically under two minutes) due to the audience size.

5. Conclusions

5.1 Practical Summary

The reflections from the participants in this study indicate that the general adult public is interested in learning about scientific concepts that are being demonstrated in front of them. There may be implications on how important scientific information could be effectively conveyed to the general public. At a minimum, the data shows that the format of the EDDS events is a good way to curate experts, and stimulate just-in-time learning by demonstrating concepts with a generally recognizable application or association.

5.2 Limitations and Future Research

The conclusions drawn in this article are limited by the scope of the data collection. The data is based on one-sided assessment from the participants of guest interactions. There is also opportunity to learn more if guests are able to be surveyed more specifically related to their experience as it relates to their self-assessed learning at the event. Furthermore, assessment of the topics demonstrated would need to be expanded to areas outside of engineering technology to gain insight into how the type of content is related to guest engagement.

5.3 Author Association Disclosure

The author is a member of the KSC's Young Professionals Advisory Board. As described previously, this board is tasked with organizing and executing the adult programming events where the demonstrations above were on display. However, the opinions and conclusions in this article are strictly the views of the author from the viewpoint of an event partner based on the reflections of volunteers that were unaffiliated with KSC.

6. Appendix

6.1 Detailed Demonstration Summaries

	Demonstration	Experiment Details
1	Sound-driven Surface Vibration	This station is demonstrating sound acting mechanically and electrically. Participants will bang on a metal sheet pan and see rice "jump" on the thin plastic diagram over the glass bowl. The chaotic waveform is also captured on a microphone. Discussion includes how voices travel, eardrums vibrate, brain gets signals, etc.
2	Ultrasonic Distance Measurement	Science and parties have a long history. We all know that most of the good ideas aren't coming from in the office, but from social settings. There are many examples of sketches and calculations on cocktail napkins that ended up changing the world. This station will have a poster detailing napkin sketches that changed the world, and the participant has the chance to create their own by solving for the speed of sound on a napkin by calculating object distance from reflection time of a wave in a known medium (air). Reflection time is captured with an ultrasonic sensor and the object can be moved by the participants to observe the changing reflection time.
3	Wine Glass Resonance	This station will let participants discuss resonance, why opera singers can vibrate glass, and make a wine glass sing with a wet finger around the rim. The accompanying poster will talk about resonance and music, show piano keys and frequencies, and help them understanding "tuning" the glass by adding water. These glasses tune within roughly 380-730, or G4 to G5 on a piano.
4	Pumpkin-key Synthesizer	This station will demonstrate completing a loop in a circuit by electrically connecting pumpkins into a voltage divider, which is monitored by analog Arduino pins. An electrical circuit must be completed by the guest by using their hand to close a conductive loop. This change will be monitored by the Arduino and trigger a tone to be generated when a pumpkin is touched.
5	Jacob's Ladder	This station will demonstrate a large change imbalance being created by a neon sign power supply. The large change will cause electricity to

		spark across an insulating air gap, and heat will make the spark rise up the metal "V" that the spark is across.
6	Tesla Coil	This station will demonstrate that a small tesla coil with high AC charge buildup will cause electrical and magnetic fields to be created. This will be verified by demonstrating the wireless activation of nearby Compact Fluorescent Light (CFL) bulbs.

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