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Effects of Engagements and Presentation Order in Informal Science Presentations

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EFFECTS OF ENGAGEMENTS AND PRESENTATION ORDER IN INFORMAL SCIENCE PRESENTATIONS

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This work is dedicated to my family. To Anita, Mikey, and Ellie, thank you for putting up with my "third job." I appreciate your patience with me when I could not attend a swimming pool trip, or a parade due to this work. Anita, thank you for taking up the slack when I could not. Mikey and Ellie, thank you for I hope that this inspires you in your own journey through life.

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ABSTRACT

Science museums conduct presentations for their audiences to attract and educate visitors, yet research on presentations has primarily concentrated on whether individual presentations were effective. This mixed-methods, quasi-experimental study looks at how the presenter's mental and physical engagements within a presentation affects audience members by altering sociocultural context of the presentation.

Physical engagements involve asking audience members to physically participate, while mental engagements involved asking audience members to make predictions prior to observing a demonstration. Audiences were given presentations containing: 1) Both mental and physical engagements, 2) Physical engagements only, 3) Mental engagements only or 4) No engagements (control).

This study utilizes Falk and colleagues' (Falk & Dierking, 2000, 2016; Falk & Storksdieck, 2005) contextual model or learning framework to explore how changes in engagement effect the sociocultural context of the presentation. Shifts in sociocultural context potentially change the resulting interpretations and understanding of the presentation by shifting the roles of audience members from those of observers to participants.

Audience members were interviewed and given pre/posttests that measured science interest, content retention and interpretation. Evidence suggests that audience members were more likely to view presentations without engagements as entertaining shows, and those with engagements as science activities. These results suggest that engaging the audience physically and mentally may help audiences identify with doing science, as opposed to simply observing science.

Science interest and content learning were similar for all presentations.; however, audience members attending multiple shows exhibited chains of causal reasoning when explaining what interviewed. This suggests that a carefully planned series of shows, or collaboration with local school systems could serve to increase the depth of understanding.

The order of demonstrations was a found to be a factor that could cause misconceptions. When presentations were ordered from simpler to more complex demonstrations, audience members developed a misconception. Presentations starting with a complex demonstration, that then used simpler demonstrations to explore potential misconceptions no longer generated misconceptions at a significant level. The results suggest that misconception generating demonstrations should occur at the beginning of the presentation, followed by demonstrations exploring potential misconceptions.

INTRODUCTION

In the late 1990's and early 2000's I was working in a museum on exhibits and doing occasional outreach programs for the public. During that time, I would see arguments about evaluation, demonstrations and exhibits on the Association of Science and Technology Center's email listserv. People would argue over whether evaluation was worth the expense, how to engage visitors, and what constituted a compelling exhibit experience.

One argument stuck with me from around the early 2000's. People were arguing about museum presentations. Some took the view that museum presentations were educational, while others— including a very prominent presenter—took the opposite view.

The prominent presenter argued that the audience wanted to be entertained and inspired instead of being educated. He claimed to know the audience wanted that because he would start each presentation by telling his audience that he could present one demonstration and explain it, or he could present thirty different demonstrations. The audience always chose the thirty demonstrations. This approach struck me as a false argument, and I continued questioning whether science museums should simply present science as entertainment, education or some blend of entertainment and education, sometimes referred to as edutainment. This question requires further exploration to determine how much educational content should be put into a presentation, and how that content would that affect the presentation's ability to inspire audience members so that they become more interested in STEM (Science, Technology, Engineering, Mathematics) topics. This question leads to more basic questions I began to ponder: Are we increasing the audience's interest in STEM topics? Are we communicating STEM content in a way that people can recall and use? Does it even matter? Why should we care about museums

and engage in this thing loosely called *informal education*?

The Case for Studying Informal Environments

Interest in informal education has grown, as evidenced by publications such as *Surrounded by Science* from the National Research Council (2010), special issues featuring articles on informal science education in the *International Journal of Science Education*, the inclusion of an ongoing special section on informal education within *Science Education*, and the National Science Foundation's support for the Center for Advancement of Informal Science Education[1]. One reason for this concentration on informal education is that individuals "spend as little as nine percent of their lives" (Fenichel & Schweingruber, 2010, p. 1) in formal educational settings; therefore, it is worthwhile to examine their experiences in other types of educational settings (Sosniak, 2001). Assuming a third of people's lives are spent sleeping, roughly fifty-eight percent of their lives remain for exposure to *informal* educational environments. Staus et al. suggest that "virtually everyone engages in ISL (Informal Science Learning) activities on a regular basis, from reading a news article about climate change or looking up health information on the internet to visiting a science museum" (2021, p. 1). This indicates that a majority of science educational experiences in someone's life may be outside of formal schooling (Falk & Dierking 2010, Sosniak 2001). According to Staus et al. this means "out–of–school experiences such as visiting science centers or watching nature documentaries appear to be particularly important in contributing to people's science understandings over time" (2021, p.1).

Some scholars have called presentations in museums *nonformal* education (Ainsworth & Eaton, 2010), because the education is not in a formal school but is still structured, while they

[1] For more information on this effort, visit: http://www.informalscience.org/

call learning by oneself *informal* education. Meanwhile, most museum practitioners call learning in a museum *informal education*– not using the same nomenclature that scholars use. More recently, Tal and Dierking (2014), Stofer (2015), and Bevan (2017) have eschewed such labels, preferring instead to either call *informal* and *nonformal* learning *free–choice* learning, or even detailing the activities and environments separately. For example, museum presentations which past scholars called *nonformal* might now be called *structured activities conducted in informal, free–choice environments*. For the context of this dissertation, I will use this more detailed description.

There are two elements that both formal, and informal, free–choice educational environments have in common: classes and presentations (see Table 1). Presentations, in particular live presentations, are one of three educational formats that span both the *formal* and *informal, free–choice* educational environments. Of the various elements within *informal free–choice* environments, live presentations are one of the least studied. Classroom experiences have been studied extensively. Exhibits have been studied for characteristics that might yield higher satisfaction rates or better understandings (Allen, 2004; Borun & Dritsas, 1997; Borun et al., 1997; Humphrey & Gutwill, 2005), but studies of live presentations in informal environments typically focus on whether audience members enjoyed the particulars of a single presentation or attained some benefit from the presentation. Live presentations in this context means a live presenter with an audience, not a recorded presentation, nor a video–conference presentation.

The limited research in formal, structured live presentations in informal, free–choice environments suggests that live presentations can help people develop basic understanding of science concepts and improve attitudes towards science (Cadenhead, 2017; Cantor, 2015; Falk & Dierking, 2000, 2010, 2016; Price et al., 2015), but such research is limited to evaluation of

Table 1. Means of formal and informal science engagement

Activity	Traditional means of science engagement in	
	Formal Education	Informal/Free Choice
Classes	Yes	Yes (Museums)*
Presentations	Yes	Yes (Museums)
Videos	Yes	Yes (Museums)
Worksheets	Yes	No
Teacher-directed projects	Yes	No
Textbooks	Yes	No
Novels/Popular Science reading (magazines/books)	No	Yes (rarely in Museums)
Self-directed projects	No	Yes
Exhibit	No (rare)	Yes (Museums)
Mentorship	Not currently (Atypical)	Currently yes (Typical)

* Museum includes science centers

specific presentation programs, not studying the techniques used within the presentation itself. In other words, research suggests some presentations are useful, but what engagement techniques make those presentations useful is still an open question. Past research on live presentations within formal classrooms suggests that simply asking students to predict the result of a demonstration prior to doing the demonstration results in increased cognitive gains, as compared to just running the demonstration and explaining the results afterwards (Crouch et al., 2004; Zimrot & Ashkenazi, 2007). Asking people to predict can then be thought of as a *presentation*

engagement technique. Whether or not the results from the formal classroom environment hold in an informal, free–choice setting is also still an open question. The research in formal education from Crouch et al. and Zimrot and Ashkenazi suggests the question: Do presentation engagement techniques change the effects of the presentation when done in an informal, free–choice environment?

Problem Statement

In this study, I examine whether specific presentation elements in live museum presentations promote changes in audience members' attitudes towards science and content knowledge of science. I utilize a concurrent, mixed–method, quasi-experimental design to collect both quantitative and qualitative data detailing how audience members' attitudes and understandings change from the beginning of the presentation to the end. I expand upon the work of Crouch et al., (2004) and Price et al., (2015), as well a pilot study I previously conducted in 2017. Together those past three studies suggest:

1) Increased content retention may result by asking audience members to predict the results of a demonstration before seeing the demonstration. Predictions can be elicited by having the presenter ask answerable 'what if' questions. For example, if the demonstration entails pulling a tablecloth from under a plate, the presenter might ask: "What would happen to the plate if I pulled on the tablecloth slowly?"
2) More positive attitudes towards participating in science may occur by inviting audience members to increase their physical participation within a presentation. Physical participation can be elicited by the presenter inviting select audience members up on stage with the presenter, and the presenter can ask the full audience to physically participate in their seats.

Although the prior research suggests that predictions cause increased content retention in live presentations in formal university settings, there was no prior research on predictions in live presentations in informal, free–choice museum environments. Furthermore, prior research never looked to see if the act of predicting caused any attitudinal or enjoyment changes–a critical factor in an environment where the participant is free to leave (thus the moniker *free choice*). The theoretical underpinnings of this study assume that people learn in the socio–constructivist manner described by Vygotsky (1980), and that mental reflection as defined by Dewey (1916/2015, 1938) and Rogers (2002) is an essential part of this development. The study further utilizes the ideas of engagement and identity as theorized by Lave and Wenger (1991), and the idea of temporary museum roles as discussed by Falk (2006). These ideas are subsumed in Falk and colleagues' contextual models (Falk & Dierking, 2000, 2016; Falk & Storksdieck, 2005). I have chosen a mixed method design to triangulate the results, and to better understand the effects on the audience of the different presentation engagement techniques.

The central goal of this research is to find ways of *improving* formal museum presentations in informal, free–choice learning environments. By improving, I mean:

A) Increasing the audience's correct science content knowledge.

B) Strengthening the audience's positive attitudes towards science—particularly their desire to participate in science.

C) Beginning to build up a library of effects that different engagements may have upon an audience.

These improvements should enable presenters to create more effective presentations in informal, free–choice learning environments.

Research Questions

To provide a resource for others to improve their own presentations, I examine the effects of specific presentation elements within a specific science museum presentation. Although many presentation elements could be studied, the ones I am choosing to study are based upon past research (Crouch et al., 2004; Zimrot & Ashkenazi, 2007) and conjecture by others (Price et al., 2015) as well as a pilot study I conducted on the use of predictions within informal, free choice learning that I presented at the Louisiana Educational Research Association conference in 2017. I start by asking the overarching research question (RQ): What effects do presenter engagements have on the audience member's experience of a formal presentation within an informal, free–choice learning environment such as a science museum.

This main research question has the following sub–research questions:

RQ1: How does a presenter's mental engagements of the audience affect an audience member's resulting science content knowledge gained from a presentation?

RQ2: How does a presenter's physical engagements of the audience affect an audience member's resulting science content knowledge gained from a presentation?

RQ3: How does a presenter's mental engagements of the audience affect an audience member's resulting attitudes towards science?

RQ4: How does a presenter's physical engagements of the audience affect an audience member's resulting attitudes towards science?

RQ5: How do audience members interpret and value presentations differently if the presentations have physical and mental engagements?

A sixth research question was added once data revealed a common audience member misconception (conflating gravity with rotational motion) being generated by the presentations:

RQ6: For this particular presentation, can the presentation engagements of audience members be redesigned and re-ordered to prevent the presentation from causing a misconception that was found? If so, how?

Definitions

For clarification, I define the terms as follows:

Presentation Form: I define *presentation form* to be the style and structure of the presentation. I ask whether the presentation form incorporates mental and/or physical engagements. I am studying whether altering the presentation form via physical and mental engagements alters the experience for audience members. The same basic presentation had four different forms: Control (no engagements), mental only form, physical only form and both mental and physical form. For the purposes of this study, I am not looking specifically at whether individuals choose to engage, but rather if the presenter utilizes an engagement within his or her presentation format that might alter the audience member's experience. In the text I will often refer to these presentation forms by calling the presentation a "mental only presentation," leaving the word form off for expediency.

Mental Engagement: I define *mental engagement* to be the presenter asking all the audience members to predict what might happen prior to doing a demonstration, and asking audience members investigable questions such as "What do you think will happen if …?" The audience members then find out the answers to these questions through the demonstrations. RQ1, RQ3, and RQ5 asks whether this invitation for mental engagement substantially alters the audience member's experience.

Physical Engagement: I define *physical engagement* to be the presenter's inviting audience members to physically interact with the presentation. This interaction includes selected audience members coming up to be with the presenter as part of the presentation, and audience members being invited to physically participate at their seats. RQ2, RQ4, and RQ5 asks whether the presenter's physical engagement significantly alters the audience member's experience.

Overview of Prior Research Leading to Current Research Questions

Past studies by Crouch et al. (2004) and Zimrot and Ashkenazi (2007) suggest that asking students in a university environment to make predictions prior to a demonstration has a significant, positive impact upon the students' resulting science knowledge and recall of the presentation. These studies provide the research basis for the content–based questions (RQ1, and RQ2).

The two prior studies also formed the basis of a 2017 pilot study I conducted to investigate whether mental engagements (only predictions) would affect audience members' content understanding and attitudes about science. Based on this pilot study, I realized that for my future studies:

1) Mental engagements should include not just asking the audience to make predictions, but asking the audience investigable questions such as "What do you think will happen if …?"

2) I should collect data about physical engagements as well. Physical engagements are another method of engagement—one I had been doing the whole time during the pilot study without collecting data on its effects.

These realizations were reinforced by the work of Fusion Science Theater (Cantor, 2015; Kerby et al., 2010) and the research by Price et al. (2015) on the effects of a presentation on visiting school groups. Both studies conducted presentation projects in which they saw increased knowledge and increased positive attitudes towards participating in science, thus providing the research basis for RQ3 and RQ4. Price et al. (2015) further conjectured that the resulting increase in attitudes toward participating science were due to the presentation's use of audience participation and physical interaction (RQ4). Whether or not physical interactions within a presentation generates larger positive impacts than a presentation without physical interactions is still an unresolved question. Price et al.'s (2015), Cantor's (2015), and Kerby et al.'s (2010) research in informal settings seems to reflect the importance of active learning as examined in formal settings by Franklin et al. (2014) and Freeman et al. (2014). Whether or not active learning requires physical activity has not been fully explored. It could be that the underlying process of engagement—whether through predictions or physical interactions—might have similar effects, or we might find that physical interactions have complementary, but different, effects than people predict. The effects may then be intertwined with the way people interpret and value the engagements—giving rise to RQ5.

Study Overview

To answer these research questions, I adapted a previous presentation created to work for both my 2017 pilot study and my work with the public. In adapting the presentation, I created

Table 2. Science presentation styles mapped to RQ with primary means of evaluation

	Control (No Engagements)	Mental Only Engagements	Physical Only Engagements	Both Mental & Physical Engagements
RQ1	Quantitative	Quantitative	Quantitative	Quantitative
RQ2	Quantitative	Quantitative	Quantitative	Quantitative
RQ3	Quantitative & Qualitative	Quantitative & Qualitative	Quantitative & Qualitative	Quantitative & Qualitative
RQ4	Quantitative & Qualitative	Quantitative & Qualitative	Quantitative & Qualitative	Quantitative & Qualitative
RQ5	Qualitative	Qualitative	Qualitative	Qualitative
RQ6	Quantitative	N /A	N /A	Quantitative

four different versions of the presentation that utilized different presenter (physical and mental) engagements (see Table 2). I then presented these programs to different audiences at Louisiana Arts & Science Museum[2] (LASM). I collected both quantitative and qualitative data to answer the research questions. RQ1, RQ2 and RQ6 relied primarily on quantitative data; RQ5 relied on qualitative data; RQ3 and RQ4 relied on both quantitative and qualitative data.

Physical and Socio–Cultural Contexts

The presentations occurred with audience members that chose to be at LASM and watch a presentation in the museum auditorium as part of their visit. This is in keeping with most past

[2] Louisiana Arts & Science Museum always uses the "&" instead of "and" in their title.

museum studies that use museum–going audiences instead of the general public.

This research took place in a traditional museum presentation setting, similar to Cantor's (2015), Kerby et al.'s (2010), and Price et al.'s (2015) settings. This is considered a more naturalistic setting, which is thought to keep the learning situations authentic (Rennie et al., 2003; Tal & Dierking, 2014), and therefore more immediately applicable to museum situations. There is a growing understanding that "being situated in a real educational context provides a sense of validity to the research and ensures that the results can be effectively used to assess, inform, and improve practice in at least this one (and likely other) context." (Anderson & Shattuck, 2012, p. 16).

The study was conducted at LASM from October 2018 to December 2019. Since there was just one site, the physical contexts were basically the same across multiple presentations; however, the audience varied in composition which affected the sociocultural context from day to day (Falk & Dierking, 2000, 2016; Falk & Storksdieck, 2005).

LASM was chosen as a site due to its (1) classification as a science museum, (2) its proximity to my home as the researcher and presenter, (3) the prior personal relationships I created with the administration and educators and (4) my familiarity with conducting research at this locale due to its previous use in my 2017 pilot study.

LASM was built in a renovated train station, and includes art galleries, interactive science galleries, a digital projection planetarium, and an auditorium with a stage where presentations can take place. LASM's stated mission is "to enhance the understanding and appreciation of art and science for general audiences and students by presenting unique, educational and entertaining experiences that encourage discovery, inspire creativity, and inspire the pursuit of knowledge" (Who We Are, n.d., para 1). According to LASM's website, it "envision[s] a

community of lifelong explorers inspired by art and science" (Who We Are, n.d., para 2). LASM sees roughly 175,000 visitors[3] per year, and is located in Baton Rouge, Louisiana. LASM's audience varies from art or science interested adults to families with kids. The science presentations at LASM are generally geared towards families with kids.

Every month LASM has one day when the general public can attend free of charge, normally resulting in higher attendance for that day, and quite probably a change in audience demographics. I generally presented at LASM on a monthly basis during these free days (see Appendix A for specific dates). In addition, I presented on special occasions when LASM thought they might have more general traffic.

LASM's auditorium stage layout has the entrance and exit at the rear so that audience members will not disturb the presentation when entering or exiting. LASM generally leaves the lights on throughout the auditorium and allows audience members to come and go freely during most of their presentations. This happened throughout my presentations as well. Often audience members would ask if they could leave a bit early in order to catch a show in the planetarium that they had tickets for. The answer I always gave to these queries was 'yes,' which although lessening the amount of useable data, maintained an authentic environment with the free–choice characteristics I desired for the study.

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[3] Where a visitor is loosely defined as a single paid entry, so a person who comes to the two programs would count as 2 visitors. These numbers were for 2019 and earlier, prior to a 2020 pandemic that temporarily closed museums and depressed attendance Figures.

Summary

While some past research exists on the field of presentations within informal science centers and museums, most of it is evaluative in nature; few studies exist that investigate how changes to a presentation format might optimize its cognitive or affective effects upon audience members. Most science centers and museums see their mission as educational (cognitive) and inspirational (affective) (Friedman, 2010). They would like to accomplish both missions, but since the affective component determines whether or not people return to the museum, the museums are careful to stress that component, sometimes at the expense of the other cognitive component.

Through this research, I hope to provide other presenters with information on how different presentation formats might positively impact their presentations. For example, if I found that using questioning and predictions within a presentation increases knowledge retention and attitudes, this information could be used in planning for new presentation programs. Meanwhile, if I found that using questioning and predictions within a presentation decreases positive attitudes toward science, then a science center might decide to forego such questioning techniques in order to increase attitudes, thereby increasing return attendance and accomplishing its mission of inspiration (Beetlestone, Johnson, Quin, & White, 1998). Understanding how small but purposeful changes to presentation formats (mental and physical engagements of audience members) affects the audiences content understanding and attitudes towards science can allow science centers and museums to maximize their impacts.

LITERATURE REVIEW

Introduction

The central goal of this research is to find ways of improving formal museum presentations in informal, free-choice learning environments by better understanding the effects of different engagement elements upon audience members. In essence, I seek to use a case study that examines engagements so that others can use data in deciding whether to use these engagements to create presentations. I propose that engaging the audience members in practices of science, as if they were mini-scientists, might make them more desirous to do science, and more apt to remember relevant science content. Essentially this research centers on shifting the role of the audience member from passive audience member to active science participant. I then examine what effects this attempted role shifting has upon the audience.

I have divided this chapter into subsections. During this chapter I first lay out what is meant by informal / free choice education. Next, I present the reasons for studying museums as a subset of informal / free choice education. Thirdly, I explore what it means to learn science. Then I present past research on increasing engagement in informal settings by increasing interactivity in specific ways. Finally, I describe the theoretical framework that I utilize for this study.

Only after laying the previous groundwork, do I look at specific studies and theoretical lenses one can use to look at how engagements affect audience members. This chapter explores studies that underpin the mental engagements used to increase content, and it looks at possible theoretical reasons the mental engagements might work. Then I explore the research on physical engagements, and how they might work. Next, I look at how roles can be shifted to create learning environments, and how demonstrations could be re-ordered to decrease misconceptions.

In each subsection I give a brief overview of relevant studies, as well as the theoretical reasoning that might explain the effectiveness of a particular engagement. Finally, I reflect on the perceived importance by practitioners of increased interactions between presenters and audience members.

> In doing this literature review, I take William James' pragmatic position that:
> No theory is absolutely a transcript of reality, but that any one of them may from some point of view be useful. Their great use is to summarize old facts and to lead to new ones. They are only a man-made language, a conceptual shorthand, as someone calls them, in which we write our reports of nature. (2013, Lecture II, Para 20).

With these statements in mind, I approach the literature that informs informal science presentations as *educational shorthand*. I consider the results from past studies as experiments whose results are valid. Such results never prove any underlying theory; they merely lend credence to particular interpretations or create questions about theories that cannot account for the results. This *educational shorthand* builds towards practical changes that can be examined to see if they can improve science education informal presentations.

What is Meant by Informal / Free-Choice Learning?

Scholars have subdivided education into three separate classes: formal education, informal education and nonformal education. (Ainsworth & Eaton, 2010; Merriam et al., 2012) According to Ainsworth and Eaton (2010) *formal* education refers to "intentional organized and structured" (p. 10) learning – or what is known as school. *Nonformal* education generally refers to education that is organized but is not graded or for credits – such as classes at a museum or an art studio. Informal education refers to all the other contacts that educate a person – such as listening to others' conversations or experimenting on your own. These should not be viewed mutually exclusive categories, rather they should be viewed as part of a spectrum of educational activities stretching from everyday encounters on the one hand to formal classroom

environments on the other extreme.

More recently, other scholars such as Tal and Dierking (2014) and Stofer (2015) have discarded such labels, preferring instead to call all informal and nonformal learning *free-choice learning*. Bevan (2017) argued similarly that learning bridged these artificial boundaries and that "language is a central barrier in any process of boundary crossing" (para 3). Essentially the language of formal, informal, nonformal might deter proper studying of the learning taking place, that takes place across all these boundaries. For example, a student might see an exhibit about flight in a museum, read a book about flight at home, and learn principles of flight within a school – each element reinforcing one another. When we segregate the learning, we might not realize that learning accumulates across multiple boundaries – not simply in one location.

Bevan (2017) would classify the settings as formal and informal and the activities as *structured and supervised*, *self-directed*, and *everyday learning activities*. In other words, one can have a supervised activity in a formal classroom or an informal setting such as a park, or one can have self-directed learning activities in either location as well. This approach emphasizes how various levels of structure and self-direction can occur in different settings.

I will follow Bevan's (2017) lead and generally use the terms *formal* education for school settings, *informal* education for out of school settings –such as interacting with exhibits in museums, and *free-choice learning* when the participants can choose whether to do an activity. When I need to cross boundaries with higher specificity, I will differentiate the activity from the setting. Since the structured education I am focusing on is a live (not pre-recorded) presentation, I can include this in the description. The specific research I present here focuses on *structured live presentation* in an *informal*, *free-choice* environment.

The Case for Investigating Informal Free Choice Environments

The astute researcher may ask, "Why study such a small element of informal, free-choice education, when society uses formal education to train the next scientists, engineers, and policy makers?" Yet informal, free-choice education is getting more attention precisely because it has an incredible potential to impact and even help create future scientists. According to a 1998 survey conducted by the Roper Starch organization (as cited in Friedman, 2010) 76% of scientists identified science museums as playing a role in their interest in science.

Various institutions have begun to realize the importance of non-school settings as well. In 2009 with the publication of *Learning Science in Informal Environments*, the National Research Council recognized "the potential for science learning in non-school settings, where people actually spend the majority of their time" (p 1). Interest in informal, free-choice education has been growing for the past two decades, as evidenced by the:

1) The National Association for Research in Science Teaching (NARST) 1999 establishment of the Informal Science Education Ad-Hoc Committee.
2) The inclusion of an ongoing special section on informal education within *Science Education*.
3) The three recent publications from the National Academies Press: *Learning Science in Informal Environments* (2009), *Surrounded by Science* (2010), and *Identifying and Supporting Productive STEM programs in Out-of-School Settings* (2015).
4) The National Science Foundation's continued support for the Center for Advancement of Informal Science Education (CAISE)[4].

[4] For more information on this effort check out: http://www.informalscience.org/

One reason for this concentration on informal, free-choice education is that "average Americans spend less than 5% of their life in classrooms" (Falk & Dierking p. 486). Other sources put the percent as a bit higher, but the average American spends more time outside of formal educational settings than inside them (Falk & Dierking, 2010; Fenichel & Schweingruber, 2010; Staus et al., 2021). With this dearth of time inside formal education, it stands to reason those elements outside of formal education influence science knowledge (content) and attitudes towards science and therefore, are worthy of studying to maximize their effects.

Science museums and science centers are one set of informal educational environments that can be studied where people learn science. Museums are embracing the idea of science learning, as museums now see their role in alignment with active forms of education. According to Falk and Dierking (2016), "all museums now place an emphasis on education that they never did in the past" (p. 14). This emphasis may present a dilemma, as Allen (2004) states:

> Science museum staff face a constructivist dilemma as they design their public spaces: the exhibits should facilitate science learning, yet they also need to support a diverse visiting public in making their own personal choices about where to attend, what to do, and how to interpret their interactions. To be effective as teaching tools, exhibits need to be highly intrinsically motivating at every step of an interaction in order to sustain involvement by an audience who views their visit primarily as a leisure activity. (p. S17)

Essentially science museums must balance the attitudes (the desire to be at the museum doing museum activities, and the desire to come back to the museum) with learning science knowledge that might conceivably cause frustration. Thus, research looking at both the affective elements and the cognitive elements benefits museums since it includes both elements. Even without such research, most modern science museums actively embrace both aspects, employing free-choice and experiential models of interaction. The programs and exhibits within science museums fall along a spectrum of educational philosophies, but they always stress free-choice

learning. At their best, science museums may fulfill Dewey's (1899/2011) vision of optimal child education, where

> the child has a question of his own and is actively engaged in seeking and selecting relevant material with which to answer it, considering the bearings and relations of this material–the kind of solution it calls for. The problem is one's own; hence also the impetus, the stimulus to attention, is one's own. (p. 94)

Science museums provide a variety of experiences from exhibits to presentations, and the audience member decides which experiences to partake in. The audience member's own questions and interest guide what in the museum to pay attention to, and how long to pay attention for. The motivations or *stimulus to attention* is due to the audience member's own interest in that particular experience that is influenced by the design of the museum's experience. This means each audience member has the internal motivation to pay attention to the museums' educational experiences, and thus learn science.

Museums can be places for audiences to learn the science that they choose to learn, as guided by the museum's experiences. Museums can also be a space for researchers to study how people learn that science. Yet, what does it mean to "learn science" and how can mental and physical engagements affect that learning?

What Does It Mean to "Learn Science?"

To examine what learning science entails, I must first define what science is and secondly how people learn science. According to Wikipedia, science "is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe," ("Science," 2021). Merriam-Webster concurs, defining science as "a department of systematized knowledge," and "a system or method reconciling practical ends with scientific laws" ("Science," 2021). Thus, learning science isn't just about learning science content, it's about organizing content in a meaningful, systematic way so it applies to real world contexts.

Science and engineering practices have revolutionized the way we experience and interact with the world. These practices influenced the way we view knowledge and the way we view reality. While at times science has led to an overuse of quantification and incorrect assertions as demonstrated by Gould's (1998) *MisMeasure of Man*, science itself is a self-correcting work in progress – one where the leading theory can be overthrown by a series of observations contrary to its conclusions, and a new idea that makes sense of these conclusions (Kuhn, 2012).

Science's strength is that it is self-correcting. Science self-corrects through a process of predicting and experimenting to test those predictions. Essentially while Plato (380 BC / 2016 AD) maintained that the idealized chair was more real than the chair you sat on, science embraced the opposite conclusion: The chair you sit on is more real than an idealized chair that you hold in your mind ("Theory of Forms," n.d.). This is in step with Locke's version of reality –that reality can only be interpreted through our senses, imperfect as they are (Freemann & Mathison, 2009; Johnson & Christensen, 2013). Unfortunately, as pointed out by Gould (1981), such an idealized situation often fails when people become too invested in the ideas they have taken to heart, and they "began with conclusions, peered through their facts, and came back in a circle to the same conclusions" (p. 117). Thus, one should be cautious when making claims, starting with the actual experimental results, and searching for ways of poking holes in one's conclusions, not beginning with the conclusions and searching for experimental results that might support them.

Experiments and theories that can be tested via experiments are critical elements of science. Yet, if one is too invested in a particular interpretation or theory, then one can be blind to its faults. As Feynman (1985) said, "The first principle is that you must not fool yourself and

you are the easiest person to fool" (p. 343). Theories are there to help us make sense of the data, and make predictions for the future, but we should not put complete faith in a theory, as they are only models for understanding the world around us. Thus, it seems theories, predictions, and physical experiments are central within science, and thus they should be placed in the center of efforts to teach science or elements of the science will be lost. Two of these elements are what my research centers upon: Predictions (mental engagements) and performing physical experiments (physical engagements).

The Next Generation Science Standards agrees that predictions and experiments are central to all science teaching (National Research Council, 2013). The standards list three separate dimensions: Disciplinary core ideas, crosscutting concepts, and science and engineering practices. Disciplinary core ideas are the broad science concepts, students should learn. Disciplinary core ideas are the science content. Cross-cutting concepts are broad ideas that cut across sciences such as patterns, and cause and effect. These cross-cutting concepts enable students to connect broad ideas from one discipline to another. Science and engineering practices are the processes students need to do in order conduct science or to do engineering. These practices are where experience and exploration are codified as central to science learning.

The standards' science and engineering practices encompass predictions and experiments within the eight practices:

1) Asking questions and defining problems
2) Developing and using models
3) Planning and carrying out investigations
4) Analyzing and interpreting data
5) Using mathematics and computational thinking
6) Constructing explanations and designing solutions
7) Engaging in argument from evidence
8) Obtaining, evaluating, and communicating information (National Research Council, 2013, p. xx)

Although predicting and experimenting are not specifically called out in the standards, their components are. When one asks questions and defines problems, one begins making testable questions. That is the heart of asking questions. Scientific questions are testable, as are good educational questions. A testable question likely comes from a mental model or theory of how things work. This then leads to framing a true prediction and carrying out an experiment or investigation! Testable questions are good educational questions precisely because they are testable (Harlen, 2001), allowing a student to participate in the scientific process as the student learns the answer to the question. Thus, the Next Generation Science standards codifies that predictions and experiments are central to learning science.

Returning to the Wikipedia definition for science, the last portion of the definition says that these explanations and predictions should be “about the world” (“Science,” 2021). Since science entails understanding the world around us, it makes sense that using everyday real-world materials that audiences can relate to would help enable audience members connect the science to the world that they know. Essentially while cross-cutting concepts are about getting students big picture ideas that cut across the sciences, every day, real–world materials help students connect the science they are doing to the world around them,

Now that I’ve defined science, I should define what is meant by “learning science?” Learning science could indicate an understanding of the processes of science (practices), an understanding of the content (disciplinary core ideas) and understanding of general heuristics of science (cross-cutting concepts). Learning science can include learning to like science and related affective attributes. All those elements contribute to learning science. For the context of this research, I will examine just two of these elements: developing correct science content and developing more positive attitudes towards science—particularly the desire to participate in

science. I attempt to measure how those two aspects are affected via this research study. To do this, I attempt to change the amount of interaction by experimenting with the presence of mental engagements and physical engagements.

Increasing Engagement Through Interactions

Although research on increasing interactions within presentations in informal environments is sparse, there have been some significant studies on changing interaction levels within the exhibit environment. Early science exhibits did not begin as interactive exhibits, instead they were artifacts with labels – essentially textbooks with three-dimensional objects attached – to look at (not touch). Other slightly more interactive exhibits that are still being produced today include quiz-style games that ask you to pick the correct answer from a variety of answers. These exhibits are sometimes called 'didacteractives' – since they are both didactic and have a low level of interactivity (Beetlestone, Johnson, Quinn, & White, 1998). Such exhibits are similar in nature to a set of questions at the end of a textbook's chapter – inviting you to answer them and possibly to learn, but not to learn from the direct phenomena. The more complex versions of these 'didacteractives' might use computers to guide you through activities that could engage you, but the computer retains the locus of control as if it were the all-knowing, all-powerful teacher.

According to Hein, as recounted by Humphrey and Gutwill, many early science center exhibits were "Exhibits of arresting phenomena, often counterintuitive" and "were designed to illustrate scientific purposes," (Humphrey and Gutwill, 2005, p. ii). These exhibits often took after colorful science demonstrations from teachers that were intended to inspire and delight – either by illustrating a basic concept or by showing a surprisingly discrepant event. A simple version of this might be a Jacob's Ladder, in which the visitor presses a button and sees a plasma

arc climb up between two metal poles. This allows the user to see a phenomenon but not experiment with it— again, there was no real inquiry taking place—although there may have been engagement.

Moving a bit closer to open-ended inquiry are those exhibits that allow a user to run a rudimentary experiment with an exhibit. An example of this style exhibit might include the Jacob's Ladder in which an additional element is mixed in such as the existence of a fan that the user can control to try to blow the plasma arc down and keep it from climbing. An exhibit that allows the visitors to control how quickly a magnet is moved near a coil of wire to producing electricity that powers a light bulb also allows a limited form of inquiry. This allows visitors to investigate along a singular dimension of inquiry. I will call the exhibits with a single result, or one variable that can be controlled, planned discovery exhibits as Humphrey and Gutwill (2005) called them. These planned discovery exhibits provide experiences and encourage a very limited version of inquiry.

While planned discovery exhibits often have one variable that can be controlled in a limited manner, more open-ended exhibits normally have multiple variables that can be controlled, leading to a series of different results. Although open-ended exhibits allow for multiple different pathways, this doesn't mean that open-ended exhibits always encourage inquiry. Many museums have an open-ended lens and optics table that consists of some parallel light beams and a series of mirrors and lenses that allow visitors to fully manipulate them. This style exhibit is very open-ended, and has a very constructivist, learner-centered approach, but often students do not know what to do at these lens tables. Complexity theorists Davis and Sumara (2006) might say that such an exhibit lacks an enabling constraint since the boundaries and purpose of the exhibit do not suggest that people work towards a common goal. Enabling

constraints are those constraints that focus activity of multiple people toward a common goal. The lens and optic tables are incredibly open-ended, and without an enabling constraint, visitors rarely see the purpose of the exhibit. Anecdotally I have had more visitors ask me what they were supposed to do at these tables, than any other exhibit. Without this sense of purpose, or enabling constraint, the exhibits fall into dis-use. This is perhaps the quandary of all inquiry-based strategies, and is one reason why constructivism received a bad name in certain circles (Kirschner et al., 2006). Essentially if you throw a child in a room with a bunch of lenses, what will they learn? It is quite possible they will learn, but it is far from guaranteed. This is where the idea of enabling constraints from complexity theories comes in – the enabling constraints focus the activity much as a skilled teacher focuses an activity. That is one thing the planned discovery exhibits did well—they focused the activity.

So, across the history of museums, exhibits became more interactive. In the 1990's Borun and others conducted a landmark study that researched family learning across four museums (Borun & Dritsas, 1997; Borun et al., 1997). This was a three-phase project attempting to create a guideline for increasing family learning at exhibits. The third phase of the project included a research element to see if the museum's list of family characteristics for exhibits were useful in creating exhibits that created better family learning. The third phase of the project looked at the way 50 families at each museum (200 families total) interacted with test exhibits, then looked at the way 50 new families interacted with exhibits that were modified according to a list of family learning characteristics that were developed. This involved a total of 400 families across 4 museums. The results demonstrated that modifying exhibits with family characteristics resulted in better family learning outcomes. The family learning characteristics are:

- Multi-sided - family can cluster around exhibit.
- Multi-user - interaction allows for several sets of hands (or bodies)

- Accessible - comfortably used by children and adults.
- Multi-outcome - observation and interaction are sufficiently complex to foster group discussion.
- Multi-modal - appeals to different learning styles and levels of knowledge.
- Readable - text is arranged in easily understood segments.
- Relevant - provides cognitive links to visitors' existing knowledge and experience. (1997, p. 280)

All the characteristics increase interactions with the exhibit or with other participants. The characteristics also encourage social experiences building upon interactions with the exhibit. Multi-sided, Multi-modal, Multi-user, and Accessible are all characteristics that encourage collaborative work, often considered essential for inquiry within the classroom, and certainly considered critical components by Dewey (2012) and social constructivists. Bybee (2002) requires collaborative work within the Explore stage of the formal educator's 5E method: "how do my exploration and explanation of experiences compare with others?" (p. 32) Lambert and Whelan Ariza (2008) also noted that the collaborative group work was a critical part of why inquiry activities helped ESL students within the classroom. Collaboration requires interaction.

Collaborative work requirements also find their way into other literature such as the literature on creating emergent learning environments from the Complexity theorists. Davis and Sumara (2006, 2008) state that there are several criteria necessary to create an emergent learning environment where the result is greater than the sum of its parts. Essentially complexity theorists maintain that social interactions are critical to large-scale leaps in understanding. Of Davis and Sumara's criteria, three criteria (internal diversity, internal redundancy, and decentralized control) are features that must be present in social groups in order to ensure such emergent learning systems. The decentralized control aspect is built into inquiry—as it is necessary to enable students to compare their explanations with each other!

Borun and colleague's multi-outcome requirement relates to the open-ended experiential

nature of exhibits that allow for experimentation and experience building (Borun & Dritsas, 1997; Borun et al., 1997). Essentially this requires getting beyond the cookbook style laboratory approach and enabling the visitors to interact more like scientists. For example, one exhibit consisting of a single sand pendulum was expanded to a multiple-station exhibit that enabled the visitors to see how differently constructed sand pendulums changed the outcome – a multi-outcome exhibit, that allowed visitors to compare outcomes. This also helped move exhibits beyond the planned discovery type exhibits as those were narrowly focused with singular outcomes. Such multiple outcome exhibits could enable a visitor to move through the exploration, concept development and expansion phases of learning that Marek (2008) detailed, but such a complete motion through the learning cycle probably is not typical – particularly with just one exhibit.

The characteristics contained in Borun's studies encourage interactions around exhibits, largely by making the physical aspects (multi-user, multi-modal, accessible) more useable by a group of people. (Borun & Dritsas, 1997; Borun et al., 1997). The interactions were also encouraged by making the mental aspects (readable, relevant, and multi-outcome) more accessible.

Humphrey and Gutwill used Borun's ideas as they attempted to begin *Fostering Active Prolonged Engagement (2005).* Throughout this four year, thirty exhibit study Exploratorium staff tried to increase the length of time that active engagement in an exhibit was occurring. At an early version of one exhibit Humphrey and Gutwill saw "wonderful investigatory behavior: people making predictions, generating and testing hypotheses and drawing conclusions" (2005, p. 5). Investigation - was just one of the interactions visitors engaged in. In the end Humphrey and Gutwill saw four main styles of interactions in the prolonged engagements "Exploration,

Investigation, Observation and Construction" (2005, p. 7). These behaviors are critical to an experiential learning model – as they entail having an experience and reflecting on it to attempt to influence the experience.

During Humphrey and Gutwill's (2005) project they further identified characteristics of successful Actively Prolonged Engagement (APE) exhibits. First the exhibits were more open-ended than previous exhibits that they termed planned discovery exhibits. These APE exhibits encouraged more interaction. The visitors still knew what to do – the exhibits were open-ended but there were not difficulties trying to figure out what the point of the exhibit was – these demonstrated Davis and Sumara's (2006) enabling constraints that helped focus the activities. As Allen (2004) said about exhibit interactions "more is not necessarily better" (p. S25). This is particularly true if the extra interactivity takes away from the primary interactive feature. Essentially the interactive portions should address the variables that visitors can have success manipulating in the experiment – multiple variables may be manipulate-able, but if all the variables are manipulated at once then often this defeats the learning objectives and eliminates early successes. By limiting the variables, the visitor interacts with the exhibit designers creating a form of scaffolding for the visitor!

A second reason the APE exhibits have extended active investigations was the use of multi-sided and multi-user exhibits– which fits in with Borun's work (Borun & Dritsas, 1997; Borun et al., 1997). When examining exhibits, they found that some multi-sided exhibits worked—encouraging engagement across multiple individuals while others did not. For example, one exhibit was a set of pulley stations across multiple tables (see Figure 1). Visitors would hook up the pulleys across the tables and they would sometimes hook one contraption into

another contraption, adding on to each other's creations. This setup allowed visitors to interact

Figure 1. Pulley table encourages interaction among visitors. Source: © Exploratorium, www.exploratorium.edu (Gutwill & Thogerson, 2005)

with other visitors' past creations. This broadened the neighbor interactions beyond those currently present at the exhibit. This also meant that walking up to the exhibit could be a different experience each time! Within this example each visitor changed the exhibit often by adding elements (pulleys, belts) to the exhibit. Since the starting condition of the exhibit could change, this means that the experience could change, illuminating different ideas for different people it was accessible and multi-modal (Borun & Dritsas, 1997; Borun et al., 1997). This means that the very fluid role of teacher and student talked about by Boyer and Roth (2006) in their article "Learning and Teaching as Emergent Features of Informal Settings: An Ethnographic Study in an Environmental Action Group," becomes in a sense even more fluid

since a past individual could have set up the pulley table so that it ended up teaching a visitor a different concept hours later! The exhibit experience could change, illuminating different ideas for different people—it was accessible and multi-modal (Borun & Dritsas, 1997; Borun et al., 1997).

Sometimes multi-user exhibits were problematic and instead the exhibit designers had to go to multi-sided exhibits where the users did not directly interact with the same objects. This happened if the interactions tended to be destructive in nature. Knowing that multi-sided and multi-user exhibits encouraged family learning, the original Spinning Patterns table (see Figure 2) was a large sand table that spun around slow enough so as to not throw off the sand. When it


Single-station version of Spinning Patterns

Figure 2. Single large sand table. Source: © Exploratorium, www.exploratorium.edu (Gutwill & Thogerson, 2005)

was used on the exhibit floor it was quickly discovered that "visitor interference shut down engagement" (Humphrey & Gutwill, 2005, p.19). Visitors had tools with which they could draw on the sand, experimenting with patterns. When multiple visitors gathered around the exhibit, designers found that instead of adding to an existing pattern, visitors were drawing over someone

else's pattern—essentially destroying the other people's contributions. This is reminiscent of failed group work talked about by Saraiki in the *Wisdom of Crowds* (2005). Essentially the problem with this set up is that people's contributions could not be aggregated correctly. Instead, the last person's work dominated, destroying the work of others. With "teamwork" from juries to corporations and even NASA, Surowiecki stated that the first person talking often had undue influence over the opinions of others—simply by being the first person speaking. In this case the last person drawing effectively became the 'voice' drowning out the other 'voices.' This is a failed group-work strategy where there is a singular dominant voice.

The exhibit design team changed the spinning designs table to a multi-sided, multi-station table (see figure 3) and found that people conversed more effectively—and positively influenced

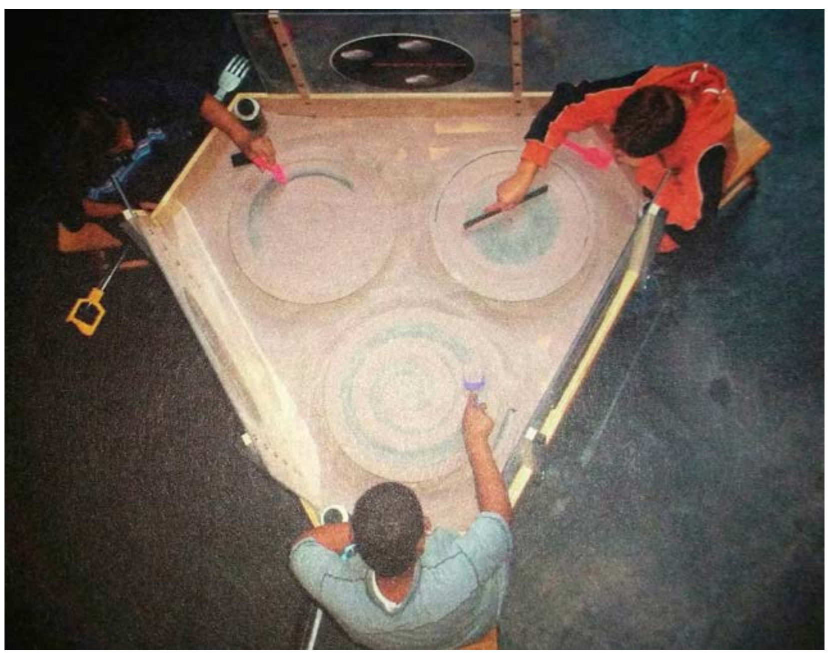


Figure 3. Revised version of the sand table. Source: © Exploratorium, www.exploratorium.edu (Gutwill & Thogerson, 2005)

the work of others working on the nearby stations! This revised design effectively allowed for better, more respectful interactions. With the multiple sand tables, we find that better results

emerged because the individuals were able to add to ideas without easily destroying other visitors' creations. Essentially the revised sand table exhibit design encourages positive social interactions while highly discouraging harmful interactions –encouraging an inter-group sharing. This ability to work in groups collaboratively and effectively share is an essential feature noted by Borun as well (Borun & Dritsas, 1997; Borun et al., 1997).

Szechter and Carey (2009) found that exhibits created in the vein of APE style exhibits were particularly associated with increases in science related behaviors such as making predictions and describing evidence. APE style exhibits were designed to encourage inquiry and active experimentation. As visitors use these exhibits, the visitors begin to ask more questions, make connections, and start to reflect upon exhibit experiences. APE exhibits were found to encourage people to engage in what Esthetes (2001) called "Action Questions" (Harlan, 2001, Chapter 3, p. 28). According to Esthetes "These are the 'what happens if' questions" (Harlen, 2001, Chapter 3, p. 28). This style question along with explanation-oriented questions occurred far more often at the APE exhibits Humphrey and Gutwill studied. These 'what if' questions are central to the inquiry process – particularly at exhibits – because they encourage testable predictions. These are the types of questions that people must answer when asked to predict the results of an experiment: What will happen if we attempt this experiment? These questions form the basis of mental engagements used in RQ1 and RQ3.

Influences on Science Content and the Basis for RQ1 and RQ2

Science museums have had positive science content impacts, yet studying these impacts has not been easy. In 2010, Falk and Dierking looked at children's trends in cognitive tasks such as The International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA). There was an upwards trend in the cognitive tasks,

and Falk and Dierking maintained that a portion of the cognitive increase was due to the increasing prevalence of informal science education outlets such as museums.

Correlation does not equal causation, so there have been several attempts to see whether specific science museum experiences impart positive science content gains. In particular, live presentations have been found to increase knowledge (Cadenhead, 2017; Price et al., 2015), or at least increase the belief that one obtained knowledge (Fogg-Rogers et al., 2015). For example, in 2017 Cadenhead released a summative report for an IMLS Museums for America Grant that involved live demonstrations using *Science on a Sphere* video setup within their Exploring Earth Systems Science grant. The *Science on a Sphere* setup used projections on a sphere so that one could model what happens on Earth. The *Science on a Sphere* presentation seemed to be effective on imparting knowledge according to the evaluation. Price et al. (2015) evaluated the effect of a live presentation in conjunction with an exhibit experience versus the effect of just visiting an exhibit, which allowed researchers to differentiate the effects of the two elements. Price et al. (2015) found that "the Live Show had a modest but positive impact on science learning in the form of basic knowledge building," (p. 204).

As I've laid out, informal science education positively impacts content learning; however, I am interested in knowing what elements contribute to increasing these impacts. Some literature exists on factors that may affect content impacts in formal settings. Crouch et al. (2004) looked at presentation usage within undergraduate physics classroom presentations. According to Crouch et al. (2004), demonstrations are "commonly believed to help students learn science and to stimulate student interest" (p. 835). They continue: "demonstrations are among students' favorite elements of introductory undergraduate physics courses," (p. 835). This belief that demonstrations are a favorited element may have led to science museums using

active presentation programs featuring demonstrations. Crouch et al. (2004) also note that "traditional demonstrations may not effectively help students grasp the underlying scientific concepts or recognize and correct scientific misconceptions they may have" (p. 835).

Crouch et al. (2004) tried taking demonstrations further by implementing seven demonstrations to 133 students utilizing three different modes of presentation. The first mode was traditional — where the students watch the teacher demonstrate and listen to the teacher's explanation. The second mode used a mental engagement as the students were asked to predict the demonstration outcome prior to the demonstration occurring. The third mode utilized prediction as well as a discussion time for students to talk to each other prior to having the teacher provide the explanation. In addition, a subset of the students do not see any presentation as a control. The results of the study yielded significantly increased cognitive gains for students who predicted or predicted and discussed, rather than those who just saw a traditional demonstration or saw no demonstration. Furthermore, those who just saw the demonstrations presented in a traditional manner had no statistically significant difference from those who saw no demonstration. These findings seem to suggest that demonstrations that encourage mental engagements maximize their effectiveness at giving cognitive gains. Zimrot and Ashkenazi (2007) conducted similar experiments with undergraduate chemistry students and found that student engagement through mental engagements (predictions) increased the students' conceptual understanding as well as the students' recall of what had occurred. Whether or not these results would hold in a museum environment remains an open question and would be worthwhile to examine as contexts will have changed.

Cognitive Load

Another study looking at how content gains changed via presentation format used video to teach concepts. The video research conducted by Muller (2008) may shed some light on what could happen to a student's disposition and cognition when the student encounters different formats of presentations. Muller (2008) looked at video-based education projects and subjected students to one of two specific presentation formats on subjects ranging from *quantum tunneling* to *Newtonian mechanics* using undergraduates for his dissertation. Muller (2008) used a pre/posttest format to gauge understanding of content. For each subject, the students were randomly assigned a video to look at and the video either (a) had a single speaker say the correct science with appropriate illustrations and examples, or (b) created a dialogue between speakers with alternative conceptions as well as the correct explanation. Students reported the first presentation format (single correct speaker) was easier to understand than the second presentation format (multiple speakers with multiple ideas), which they reported as more confusing. Not surprisingly, students listening to the single correct speaker explaining an answer were more confident in their posttest answers than the students who listened to multiple speakers with multiple explanations. However, students who were exposed to the multiple speakers with multiple ideas had higher conceptual gains than the students who were exposed to the single speaker. Those who listened to the single speaker had virtually no change in their pre/posttests, while those who listened to the multiple speakers had statistically significant gains.

Muller (2008) attributed the doubt and confusion to the increased cognitive load that contributed to an increased conceptual understanding. Muller called that increased cognitive load germane instead of extraneous, since the increased cognitive load contributed to the understanding instead of distracting from understanding. Cognitive load refers to the work that

one's mind takes on. As more objects are seen or presented, the mind spends more effort recognizing these objects, increasing the cognitive load. If for example I asked you to memorize everything that was red in a picture and it used thirty red objects, this would entail a large cognitive load, straining your mental resources, as you sought to first identify the red objects then commit them to memory. Lower cognitive loads could be achieved by just presenting the thirty objects to be memorized, or by reducing the objects to just five random objects, without any extraneous objects in the picture. Even lower cognitive load would result if the objects to be memorized were all related, such as a rooster, a hen, an egg, a hen house, and a red fox.

In learning concepts, a germane cognitive load would entail items that add to the final understanding instead of items that are unrelated to the final learned concept. Thus Muller (2008) defined germane cognitive load in his study as increased cognitive load that contributed towards a final correct understanding. In Muller's study having multiple speakers with multiple ideas increased the cognitive load, but in a manner that contributed towards a final learned concept. Perhaps such cognitive loads also occurred during Crouch et al. (2004) and Zimrot and Ashkenazi's (2007) studies. Essentially while Muller used multiple speakers espousing different positions to increase the cognitive load in a germane manner, Crouch et al. (2004) and Zimrot and Ashkenazi's (2007) studies used the predictions and the demonstration to increase the cognitive load in a germane manner. These three studies together raise the prospect that learners can increase their understanding via mentally active states where they are actively reflecting on experience.

Reflecting on Experience

Dewey has written extensively on education, experience, and reflection (1899/2015, 1902/2015, 1903, 1910, 1916/2015, 1938). Dewey (1903) considered reflective thought critical

in “the thinking of everyday practical life” (p.1) and that the thinking used in “science is of this reflective type” (p. 1). Across Dewey’s lifetime he wrote about reflection in several different manners—ascribing different steps to the process of reflection in different papers. According to Dewey (2010) reflective thought “alone is truly educative in value” (p. 2). Dewey (2010) states that “*Active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends*, constitutes reflective thought” (p. 6).

Rodgers (2002) in summarizing Dewey’s writings, talks of six phases in the process of reflection. These phases include:

> 1. an experience;
> 2. spontaneous interpretation of the experience;
> 3. naming the problem(s) or the questions(s) that arises out of the experience;
> 4. generating possible explanations for the problem(s) of questions(s) posed;
> 5. ramifying the explanations into full–blown hypotheses;
> 6. experimenting or testing the selected hypothesis. (p. 851)

Having people predict prior to seeing a demonstration might shortcut part of this process, as the presenter jumps directly to naming the problem or question (step 3), where “there is a distancing of the problem as it were—getting enough distance so that one can see” (Rodgers, 2002, p. 853). In shortcutting this process, steps 1 and 2 aren’t really eliminated, the steps are instead conducted with the audience members referring to past experiences. The audience members are then thrust into generating explanations, developing preliminary hypothesis (their predictions), and experimenting.

Since the process of reflective thought iterates using multiple demonstrations this likely causes audience members to engage in process reflection which “connects reflective incidents into a cyclic progression that refines ideas through experimental action” (Ricks, 2010, p. 251). While this is part of the process of constructing one’s own understanding, the process is not as

effective as active experiential education methods (Crouch et al., 2004); however, there is also relatively little time invested in such approaches.

Rodger's phases of reflection (as distilled from Dewey's writing) reflect the eight practices of science (National Research Council, 2013), although there are elements that each do not have in common. Rodgers (2002) begins with the experience and then the "spontaneous interpretation of experience." The experience and spontaneous interpretation of the experience are not alluded to greatly in the National Research Council's (2013) work, although obtaining, evaluating, and communicating information parallels this initial experience as does the engaging in argument from evidence. Essentially at these beginning steps, one makes sense of the data, and considers what the data says.

The practices concentrate on the intellectual portion: asking questions and posing problems. Rodgers (2002) notes that the question phase of Dewey's reflective thinking entails distancing the description to get at the intellectual questions or problems of the experience. A well posed question then leads into generating possible explanations which seamlessly flows back into full hypothesis generation including testable predictions. Whereas Dewey (1910) and Rodgers (2002) have put generating possible explanations and hypothesis generation into two steps, the National Research Council's (2013) practices list this as four practices developing and using models, analyzing, and interpreting data, constructing explanations, and sometimes using mathematics and computation. Dewey's sixth step in reflective though involves experimentation or testing the hypothesis which reflects the NGSS (National Research Council, 2013) practice of planning and carrying out investigations. Essentially by framing testable questions, the presenter acts as a teacher, or more knowledgeable guide to help move the audience member along through the process of reflective thought.

Informal Influences on Science Attitudes and the Basis for RQ3 and RQ4

As informal science education can impart knowledge, it also encourages positive attitudes towards science ((Fenichel & Schweingruber, 2010; Mills, 2016; Mills & Katzman, 2015; National Research Council 2015, 2009; Price et al., 2015; Szechter & Carey, 2009; Wulf et al., 2010*).* While the Price et al. (2015) research mentioned earlier found a small increase in knowledge, they found that there was a more profound "positive effect on the attitudes of children" (p. 204). Price et al. (2015) looked at attitudes towards participating in science activities, whether science was considered fun, and preferences to learn within group settings. Those attending the live presentation along with a visit to the exhibits saw higher increases in all attitudinal measures than those just interacting with the exhibits. Price et al. (2015) found that the live presentation's "largest impact was in attitudes toward participating in science" (p. 204). Price et al. (2015) conjectured that the physically interactive nature of the show might "inspire normally passive science learners to become more engaged in the learning process" (p. 205). Price et al. (2015) study forms the basis for the idea that physical interaction encourages participants to form more of a desire to participate in science which I explore in this research dissertation.

Attitudes towards science are inherently important to informal education, as well as formal education as recognized by The Next Generation Science Standards (National Research Council, 2013):

> The affective domain—the domain of learning that involves interests, experience, and enthusiasm—is a critical component of science education. As pointed out in the Framework (National Research Council 2012), there is a substantial body of research that supports the close connection between the development of concepts and skills in science and engineering and such factors as interest, engagement, motivation, persistence, and self-identity. (p. xviii)

The Next Generation Science Standards (National Research Council, 2013) were preceded by *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012) which argues that "motivation and interest in science and engineering can also play a role in their (students) achievement and pursuit of these fields in secondary school and beyond," (p. 279). Thus, the National Research Council (2012) has concluded that attitudes towards science are one element that can lead towards a path as a STEM professional.

Roles and RQ5

Science attitudes are one socially embedded element that work to create one's science identity. According to the National Research Council (2012) "Learning science depends not only on the accumulation of facts and concepts but also on the development of an identity as a competent learner of science with motivation and interest to learn more," (p. 287). The National Research Council bases this partially upon Lave and Wenger's work on legitimate peripheral participation.

According to Lave and Wenger (1991), learning is a key aspect of participation, and it represents the beginning of a socially embedded task that can eventually culminate in one's identity shifting from novice to expert. Lave and Wenger (1991) stress that "learning and a sense of identity are inseparable: They are aspects of the same phenomon (sic)" (p. 115). Lave and Wenger stress that one's identity evolves out of participatory educational experiences as a part of a group. When a presenter engages an audience member within a presentation, the presenter establishes a rudimentary level of participation in the presentation—altering the audience's experience into a more socially participatory experience. Could this social experience serve to help shift audience member's self-perceived science identity? Lave and

Wenger's work doesn't answer that question since their work concentrates on long-term participatory apprenticeship situations such as membership in Alcoholics Anonymous, or apprenticeship as a Yucatec Mayan midwife. Other researchers such as Falk and Dierking worked on more transitory role shifting.

Falk and Dierking (2016) talk about museum visitors taking on transitory roles when they visit a museum, which is largely based upon Falk's (2006) research. For example, one audience member may go to the museum as a facilitator to facilitate that audience member's children's experiences. Alternatively, an audience member may simply visit a museum to experience the museum, or for a particular exhibit that was advertised. According to Falk and Dierking (2016) "the reasons people give for visiting museums and their post-visit descriptions of the experience have tended to cluster around only a few basic categories, which in turn appear to reflect what the visiting public perceives a museum visit affords" (p. 46). Each one of these reasons for attending the museum puts the visitor in a temporary role and sets the visitor up to do certain things. Falk and Dierking (2016) have established seven distinct identity-related roles that visitors assume when they visit museums. According to Falk and Dierking (2016), "museum visitors may see themselves as explorers, facilitators, professionals/hobbyists, experience seekers, rechargers, respectful pilgrims, and/or affinity seekers, and these various identities color and characterize their museum experiences" (p. 9). For example, if a visitor attends a museum as a *facilitator* for her/his child, the visitor will likely take the child to the pieces he/she thinks would appeal to the child. Furthermore, the visitor may act as interpreter for the child—encouraging the child to learn and grow via the museum visit.

Falk's (2006) work on roles suggests they might be transitory and therefore malleable. For example, an audience member may approach a museum as a facilitator for children, but this

role could be disrupted, if museum staff act to facilitate the visit for children and some other experience intrigues the audience member such that the audience member takes on a new role such as professional/hobbyist if an experience related to the audience member's profession presents itself.

If Falk and Dierking's (2000, 2016) transitory role work fuses with Lave and Wenger's (1991) roles and identity work, then a new picture of transitory role shifting affecting one's self-identity starts to appear. Instead of viewing an audience member's science identity as only alterable via multiple experiences over a prolonged time via multiple experiences, an audience member might take on a transitory role due to surrounding conditions. This transitory role would affect one's current views and actions, just as roles in Falk and Dierking's work affects the actions of those entering museums. If we view those roles as transitory identities, then audience members might take on transitory identities, where increased participation in an environment reinforces that transitory identity.

Consider an audience member. If an audience member approaches a museum presentation with the view of it as an entertaining experience, then the audience member expects for an entertaining, passive experience. A typical audience member might also expect the presenter to entertain and dispense knowledge, like a sage from the stage. Furthermore, the audience members will act as a typical audience member within the museum auditorium—in the United States culture this typically means acting respectful of the performers without the expectation of personal interaction.

If a presenter engages the audience of a presentation in a manner that surprises the audience, then the audience might conceivably shift their assumed roles, moving from passive observers to active participants within the presentation. When engaging audience members in the

practice of predicting an outcome, the presenter attempts to shift the audience roles from passive audience members to active engagement in a practice reminiscent of a theoretical scientist—making a prediction. Participants who start making predictions might now start viewing themselves as scientists, since the participant will be engaging in the practice of prediction – a hallmark of scientists. When engaging audience members in the practice of physically conducting an experiment, the presenter attempts to shift the audience roles from passive audience members to active engagement in a practice reminiscent of an experimental scientist. Participants who physically interact might see their own role as science experimentalists—one actually conducting the experiments—another hallmark of scientists. Mental and physical engagements may serve to shift the audience members from viewing themselves as audience members, to viewing themselves as rudimentary scientists.

Although studies around live presentations haven't concentrated on the roles audience members take on, a few studies seem to shift audience member roles by engaging participants in informal settings, such as around exhibits. These studies have looked at how participant behaviors such as investigation, reflection and engaging in science talk change when the participants have specific interventions. If we consider acts of investigation, reflection, and increased science talk as indicators that audience members are taking on different roles, then studies by Gutwill and Allen (2009, 2010) and Carey (2014) role shifting as evidenced by changing audience behaviors.

Gutwill and Allen (2009, 2010) conducted a study focused on using experimentation to change the behavior of participants around exhibits by training them to use science-like inquiry games. Gutwill and Allen's (2009, 2010) study used 200 family groups and 184 field trip groups to the Exploratorium, a well-known science museum. In their study, they tried to influence the

behavior of visitors by exposing them to one of four possible conditions at a science museum: (1) no interaction with staff around an exhibit, (2) an explanation of the science and history of an exhibit, or one of two inquiry games, (3) the Juicy Question game or (4) the Hands Off game. Inquiry games are thought to deepen, lengthen, and enrich the exhibit exploration. During the explanation of the science and history of an exhibit, the docent acted simply to explain the background of the exhibit. During the Hands Off game, any participant could yell hands off so that the participant yelling Hands Off could explore their own experiment. During the Juicy Question game, after initially exploring the exhibit, all participants would brainstorm Juicy Questions that would entail experiments that could be done at the exhibit. Then, at least one of those Juicy Questions would be explored. Such questions often took the form of 'what if,' and were investigable just like Jos Elstgeest's "Action Questions" (Harlen, 2001, p. 28). For example, with the aforementioned spinning designs (sand table) exhibit, a non-investigable question might be: What if the turntables were vertical, or at an angle? An investigable question might be: What shapes do I get when I hold my hand still as the turntable moves underneath it? Or: What shape would I get if I try to draw a large square on the turntable while it moves? During the Hands Off game, after initially exploring an exhibit, any family group participant could say "hands off," in order to allow that participant to state an observation, or to suggest an experiment that could be conducted. In this manner, the Hands-Off game allowed for more spontaneity, but less brainstorming.

Gutwill and Allen (2009, 2010) conducted the experimental study on these approaches in a separate environment just off the museum floor, which may have influenced what Falk and Dierking (2000, 2016) and Falk, and Storksdieck (2005) call the physical context. Gutwill and Allen's (2009, 2010) study was done with groups utilizing four exhibits that were expressly

open-ended, multi-option, and multi-user. These exhibits encouraged experience making and social interaction. Although not expressly stated, these four exhibits fit all seven of Borun's Family Learning Characteristics and demonstrate APE-like structures (Borun & Dritsas, 1997; Borun et al., 1997). Gutwill and Allen (2010) found "evidence that Juicy Question can enhance visitors' inquiry behaviors at exhibits and improve their collaborative interactions" (p. 73). Groups that were taught these inquiry games more frequently proposed actions and interpreted results more than other groups, beating the other groups by one more interpretation per minute. The Juicy question game increased the number of interactive experiences (via proposed actions) and reflections (interpreted results) that the visitors engaged in, which are important precursors to legitimate scientific inquiry by visitors. These same groups also made more high-level interpretations of their results (suggesting scientifically accurate reasoning). Nearly half of the Juicy Question groups self-reported using the games at other exhibits within the museum, and approximately one-fifth of the inquiry game groups reported using similar strategies outside the museum afterwards, indicating some lasting effect. The Juicy Question game stops just short of making a prediction – essentially the juicy question game explores making an investigable question while RQ1 and RQ3 provide the question and ask for a prediction.

Carey (2014) conducted another form of mental engagement that was tied to exhibit-related behaviors. Carey (2014) explored the effects of a general inquiry activity held in a museum classroom on family groups' later explorations of museum exhibits. Since the explorations were on the exhibit floor, the physical contexts of the experience remained essentially the same. Carey's (2014) study found that participation in a guided inquiry activity prior to exhibit hall exploration "significantly increased parents' high-quality learning talk, specifically providing explanations and making connections to prior experience" (p. 3).

Since Carey's (2014) study was done amid exhibits that were classified as a combination of actively prolonged engagement exhibits (as well as more traditional, less open-ended exhibits), Carey examined how the exhibits might have interacted with the visitors. Carey (2014) found "significant interaction effects indicating that the combination of participation in the inquiry intervention and exhibit type (i.e., APE) led to the greatest use of spontaneous explanation and science terms among parents" (p. 74). In this case, the exhibit, the family grouping, and the family grouping's prior experience all interacted with each other to change the experience so that more positive inquiry behaviors emerged as a result of the interaction among all the components. This APE type exhibits featured Borun and colleague's family learning criteria, and the families had a shift in initial conditions created by the inquiry activities previously conducted —making them more likely to exhibit science related behaviors within the exhibit hall (Borun & Dritsas, 1997; Borun et al., 1997).

Carey (2014), Gutwill and Allen (2009, 2010) all prepared the participants to take on the role of scientists by engaging them mentally and physically as scientists prior to letting them interact with exhibits. They accomplished this role switching by asking the participants to engage with activities both physically and mentally. Participants were asked to do an investigation either through an interaction at an exhibit or through a guided inquiry classroom activity. Both Carey's (2014) and Gutwill and Allen's (2009, 2010) studies found increases in behavior that are associated with science role switching. Carey (2014) found increases in science explanation and terms while Gutwill and Allen (2009, 2010) found increases in interactions and reflections.

RQ5 is the last question research question to focus on the effects of engagement. While RQ1 and RQ2 deal with content shifts due to engagements, and RQ3 and RQ4 deal with

attitudinal shifts due to engagements; RQ5 looks at how audience member roles change with engagements. Meanwhile RQ6 looks specifically at improving content by eliminating the generation of a misconception likely caused by this particular presentation.

Anchoring Phenomena and RQ6

RQ6 deals with eliminating a misconception, or alternative conception created in a statistically significant portion of the participants. While many scholars use the term alternative conceptions, to denote that a conception is not standard and may lead to incorrect predictions, some scholars use the term misconception due to the use of the term misconception within the standard vernacular (Wandersee et al., 1994). Since many past science conceptions become alternative conceptions as science progresses, I view the term alternative conception as more accurate, but I primarily use the term misconception in this work so that a wider diversity of people can read this and immediately gain a basic understanding of the research. However, I use the terms interchangeably throughout.

The literature on misconceptions details a number of alternative conceptions, particularly those dealing with naïve ideas of motion (Wandersee et al., 1994). An alternative conception is a non-standard conception of reality that doesn't agree with the current view of science. These alternative conceptions may result in incorrect interpretation and predictions of what will happen.

According to DiSessa (1993) knowledge comes in pieces based upon observations and physical experiences that are later rearranged into various conceptions. The presentations provided participants with observations, but when posttest questions were asked of the participants, they organized these observations into various conceptions of how things work. The alternative conception that participants developed when looking at the presentation

amounted to conflating an attractive force like gravity with the inertial effects on objects that are rotating. Although the past literature points to the difficulties in getting rid of alternative conceptions, such alternative conceptions are possible to change, as detailed in literature on misconceptions and conceptual change (Posner et al., 1982; Sahiner et al., 1987; Wandersee et al., 1994).

Fusion Science theater (Kerby et al., 2010) took an interesting approach to presentations that I considered when attempting to combat the alternative conceptions seen in RQ6. While Fusion Science theater (Kerby et al., 2010) created guidelines for creating science center play formats, there is one element of interest that may bridge beyond science plays. First, Kerby et al. (2010) state that "the audience becomes engaged in the play because they want to learn the answer. This device, known by playwrights as the "dramatic question", sparks curiosity, elicits attention, and motivates the audience to wrestle with the problems presented as the play unfolds" (p. 1024).

Kerby et al. (2010) realized that the dramatic question for these plays should be the scientific question the play investigates. The Next Generation Science Standards (National Research Council, 2013) features questioning as the first practice in the list of science and engineering practices. Particularly complex scientific questioning relates to the newer concept of *anchoring phenomena*. Anchoring phenomena are a concept embedded in the Next Generation Science Standards (National Research Council, 2013), which serve to anchor K-12 lessons around. To understand an anchoring phenomenon, students need to conduct multiple investigations (Achieve, 2016). Since Fusion Science theater's plays center around a dramatic question that is a scientific question, these questions parallel K-12 anchoring phenomena.

Whether Kerby et al.'s (2010) approach would work to eliminate the creation of

alternative conceptions that were generated by the demonstrations was an open question. According to Posner et al. (1982), in order to change an alternative conception to a new (ostensibly more correct) conception, several criteria must be met including dissatisfaction with the existing conception. Within the presentation, since the demonstration that foments the misconception is a later demonstration, there are no demonstrations afterwards that really defy the alternative conception. Situating the alternative conception causing demonstration at the start allows for arranging other demonstrations that would create the dissatisfaction with alternative conceptions— a requirement for eliminating the alternative conception (Posner et al., 1982). Put in another manner: positioning the confusing demonstration first, allows for the participants to first create a few possible conceptions, and test each of these alternative conceptions one at a time until they are left with the most correct conceptions of what happened.

Kerby et al.'s (2010) research complements exhibit research conducted at the Museum of Science in Boston on productive struggle (May et al., 2018; May et al., 2022; Paneto et al., 2020). The productive struggle research found that exhibits where audience members first failed, then struggled and succeeded generated strong feelings of satisfaction. The researchers then pursued creating exhibits that focused on providing the productive struggle along with appropriate supports. The original task that audience members struggle with in an exhibit seems akin to the struggle students might have when confronting an anchoring phenomenon. The phenomenon creates confusion and disrupts the audience members expected understanding of what should happen. The audience then struggles to understand the confusing concept, and when properly supported via other demonstrations, the audience comes to a new understanding of what happened during the original phenomenon.

Using Kerby et al.'s (2010) research, the concept of productive struggle (May et al.,

2018; May et al., 2022; Paneto et al., 2020) along with the National Research Council's (2013) work, I decided to try placing the misconception generating demonstration as the anchoring phenomenon to be explored via other demonstrations. This approach of centering confusing phenomena as the central investigable question within a presentation forms the basis for the reordering of exhibits in RQ6.

Interactivity and Engagement in Presentations

Along with dramatic questions, Fusion Science Theater used physical engagements, or in their own words, they decided to:

> 'make metaphor concrete' by developing segments we called 'act-it-outs.' In these segments, children from the audience were invited to the stage to play the role of a molecule, atom, or electron in a dynamic model of the chemical concept. (Kerby et al., 2010, p. 1025)

These "Act-it-outs" increase interactivity and provide a form of active learning for those participating— similar in nature to Price et al. (2015) study. Audience members who do not physically participate directly still might have felt a form of active learning through mirror neurons. Mirror neurons are neurons in primates that fire when they see a different primate performing an action.

Even if motor neurons are not involved, Vygotsky's zone of proximal development (1978) may help explain why people can still learn on a cognitive level, Vygotsky maintains that educational growth can occur "through problem solving under adult guidance" (p. 86). Essentially, a presentation consists of a guided activity where the individual's attention is directed to various aspects to yield mental and/or physical experiences.

While research in formal education suggests that active, experiential inquiry methods maintain or improve conceptual gains over and above what traditional lecture methods have achieved (Franklin et al., 2014; Freeman et al., 2014), people do not refute that presentations can

also work. When the Fusion Science Theater had a grant where they evaluated their project, they found increases in both content understanding and attitudinal assessments using a pre-post concept survey (Cantor, 2015).

Cantor (2015) and Kerby et al.'s (2010) work with Fusion Science Theater, along with Price et al. (2015) work, stress an interactive nature that seems to engage visitors.

The studies' authors take the view that the museum presentation work requires interactivity for success. These studies demonstrate that live presentations can engender increased basic knowledge of a subject and more positive attitudes towards a subject. Interactive presentations require presenters engaging with the audience so that the audience can engage back with the presenter to make it interactive. Although the studies' authors suggest engagements are necessary, they never try the presentations without those engagements. One might infer that such interactivity enhances students' conceptual gains and their positive attitudinal shifts. Yet, nobody has researched how changes in mental and/or physical engagement techniques by presenters of live presentations at science museums may alter the content knowledge and attitudes towards science of audience members.

Prior to conducting research on engagement, one can ask why would engagements work? The idea of motor neurons might suggest physical engagements could work for those who are not physically engaged, but why would physical or mental engagements help audience members increase content knowledge or attitudinal growth? Why would reflection increase content gain? One possibility involves the act of engagement. Essentially an audience member who engages with the presentation becomes involved in the presentation, meaning the audience member has a stake in the outcome of the presentation. When audiences involve themselves in presentations whether physically or mentally, they gain a stake in the outcome of that presentation. They care

more about the presentation's outcome because they are personally involved. How to meaningfully encourage engagement so that people engage with and learn from presentations is a question that vexes educators worldwide and is an intrinsic a part of this new research. Encouraging engagement was a large part of Dewey's (1938, 2015) work, and I attempt to extend that work in informal education under a more modern theoretical framework.

Theoretical Framework

This study uses the *contextual model of learning* (Falk & Storksdieck, 2005; Falk, & Dierking, 2016) framework, developed by Falk and colleagues to describe the elements and interactions occurring during informal science education experiences such as those present in science museums. Although studying informal science education has become more mainstream, there have been few efforts at framing informal science education research in an organized manner. Dierking and Falk researched the subject of informal education prolifically, founded the Institute for Learning Innovation, as well as Oregon State's STEM research center. Most relevant to this work, Falk and Dierking along with their colleague Storksdieck developed the contextual model of learning to frame informal science education efforts (Falk & Storksdieck, 2005; Falk, & Dierking, 2016).

Contextual Model of Learning

The contextual model of learning (Falk & Storksdieck, 2005; Falk, & Dierking, 2016) contends that there are three main contexts within all informal educational spaces that must be considered when studying informal educational efforts. The three contexts are the personal context, the sociocultural context, and the physical context. Each context interacts with the other contexts to help determine what happens in an informal educational experience in a complex environment reminiscent of the educational research paradigm of complexity. Feedback loops

between the different contexts provide for multiple outcomes, however in spite of the complexity, the actual results of study suggest that generalizable patterns emerge. First though one must understand the three contexts.

Personal Context

The personal context entails personal roles and motivations that the individual brings to bear on the individual's experience. These individual motivations (Falk, 2006) determine whether the individual will engage in the informal educational experience. In the case of museums such as LASM, the personal context largely determines whether an individual will come to the museum. Thus, for the purpose of my study on engagements, I am only looking at the subset of the populace that would attend a museum during their free time, then choose to attend a presentation within the museum, limiting the personal contexts of the individuals. This also means that the results may not hold for those who attend a museum as part of a field trip.

Personal contexts are based upon an individual's interests and motivations. Personal contexts interact with sociocultural and physical contexts to determine whether an individual will attend a museum at all, and what the individual will expect when attending that museum. With the interaction between individualized context, and sociocultural context, one might think that there are an infinite number of reasons why an individual might choose to attend a museum. Yet, Falk's research suggests motivations fall into seven categories: Explorers, Facilitators, Professionals/Hobbyists, Experience Seekers, Respectful Pilgrims, and Affinity Seekers (Falk, 2006; Falk & Dierking, 2016). At the beginning of this dissertation research, I considered whether to separate individuals into these separate categories for analysis but could not find a quick reliable means of differentiating. Furthermore, the initial motivation was determined to be

less germane to the study, partially because "these identity-related motivational categories do not represent permanent qualities of the individual" (Falk & Dierking, 2016, p. 49).

Sociocultural Context

Sociocultural contexts include aspects such as social perceptions and social expectations. In the case of a museum visit, sociocultural contexts influence who goes to the museum. According to Falk and Dierking (2016) a museum also "exists as an independent sociocultural construct that resides in the minds of individuals living within a community" (p. 78). This sociocultural construct interacts with the individual's own identity to determine whether they attend the museum. The sociocultural and personal context interact in a complex and iterative manner, so that one person's personal context can affect the sociocultural context. According to Falk and Dierking, "Most people acquire their views of the world through indirect experiences such as the depiction of museums in the media or through conversations with friends and family" (2016, p. 79). These indirect experiences are part of the surrounding sociocultural context that helps determine individuals' motivations and perceptions.

Physical Context

The physical context represents the final contextual category of the contextual model of museum learning (Falk & Storksdieck, 2005; Falk, & Dierking, 2016). The physical context of the environment provides various affordances that suggest behavioral patterns when coupled with the sociocultural and personal contexts. Physical affordances suggest behavioral characteristics. For example, a button suggests being pressed and a lever suggests being pulled. In the case of our presentation within an auditorium, the chairs afford the opportunity to sit in it, so when presented with a chair in a museum, one is likely to sit in it. In a similar manner a stage, such as the stage at LASM suggests that one will observe a show. According to Falk and

Dierking, “When we combine these perceived affordances with the personal context variables of prior experiences and expectations, as reinforced by socialcultural (sic) norms, the effect can be a channeling of behavior into a relatively few, relatively predictable trajectories” (2016, p. 132). Thus, U.S. audience members attending a presentation at an auditorium might be likely to sit down and observe as if it were a show when seeing the setup.

Physical context intertwines largely with sociocultural context to produce behavioral patterns. For example, a chair, universally suggests sitting down on, but may not suggest that to someone who has never seen a chair. For a less common example, we can look at the affordances provided by an arena. An arena can be used by a basketball team, a science fair, or a stage show. In each instance the basics of the arena stay the same, but the details of the look, lighting and social expectations change. A basketball game might elicit yelling, a science fair might elicit conversations, while a stage show might elicit a quiet observational behavior. In each case the social expectations change due to the surrounding sociocultural fabric of the attendees. The sociocultural expectations for a presentation in the United States could be very different from the sociocultural expectations in Europe, Africa, South America, or Asia. Even within each of these locations the normal social behavior might shift, giving rise to a different experience for each cultural backdrop.

Re-Framing Dewey and Vygotsky

Dewey’s work on reflection (1903, 1910) largely views the process of reflection at the individual level. This means that Dewey’s work within Falk and colleagues’ contextual model (Falk & Storksdieck, 2005; Falk, & Dierking, 2016), should fall squarely within the personal context. The process of reflection changes an individual’s personal context, as it alters the individual’s beliefs and understanding.

Even though Dewey's views on reflection fall within the personal context, his views and work with education (1938, 2015) are largely about situating the student within social situations where the students are likely to be motivated to reflect due to social situations the students relate to. This means Dewey's later works (1938, 2015) are about altering the socio-cultural context to impact the individual student. Put another way, Dewey's work in education involves altering the socio-cultural context to change elements of the personal context. Vygotsky's work (1980) largely takes a similar approach – that of altering the socio-cultural context such that the student's personal context changes.

Reframing Prior Informal Science Education Research

Past work on increasing interactivity within the museum largely focused on experimenting with the physical contexts of museum exhibits to engender social interactions and influence the socio-cultural and personal contexts. For example, Borun and colleagues' work largely involved changing the physical context of exhibits: making the exhibits accessible to more people of a wider range of ages. These changes in the exhibits physical contexts afforded the opportunity for increased family social interaction around the exhibits (Borun & Dritsas, 1997; Borun et al., 1997).

In a similar vein, Humphrey and Gutwill's (2005) work on creating actively prolonged exploration involved altering the physical contexts of the exhibits. Exhibits were created with more than one possible outcome due to the physical changes within the exhibits. These changes in the physical contexts encouraged people to increase their time experimenting with the exhibits. Sometimes the physical contexts of the exhibits—such as that of the pulley exhibit (Figure 1) —not only encouraged social interactions but the physical context changed over time as participants altered the physical setups.

Gutwill and Allen (2009, 2010), Carey (2014) experimented with changing the sociocultural context by having interventions with participants. These shifts in the sociocultural contexts, influenced the way that participants experienced the exhibits, increasing scientific-related behaviors around the physical exhibits. Both Gutwill and Allen's research (2009, 2010) and Carey's research (2014) were done in non-typical museum environments. Gutwill and Allen's research (2009, 2010) was performed in a different physical environment, off the exhibit floor, while Carey's research (2014), was performed after-hours when the museum was closed, changing the socio-cultural backdrop of the museum.

Price et al., (2015) and Poarch (2014) also experimented with socio-cultural context interventions. Poarch used written guides to influence the discussions and interactions while people visited an aquarium. Price et al. (2015) experimented to see if presentations made a difference in individual's attitudes and understanding. Both Price et al., (2015) and Poarch (2014) research was largely conducted with the typical museum physical and socio-cultural context. Price et al.'s research, (2015) and Poarch's research (2014) lends credence to the idea that purposeful experimentation in socio-cultural contexts within a museum environment can be studied within a typical museum setting.

Altering the Socio-Cultural Context within the Presentation

In this dissertation research the main physical context remains the same as detailed in the introduction. The sociocultural context changes. Sociocultural context entails not just the social expectations surrounding the environment, but the social environment within the museum. By changing engagements, I change the social environment within the museum, which the museum experience depends upon because "the museum experience is, first and foremost, a social one," (Falk & Dierking, 2016, p. 148).

The social environment changes because the social expectations shift when the engagements change. When no interactions are invited, the expected socio-cultural role of participants is that of observers. When either physical or mental engagements are used, the social-cultural environment shifts, as audience members are asked to engage in new manners (either physically, mentally, or both). The presence of the engagement shifts the social expectation. With the physical engagement, the audience conducts an experiment in their seat, and engages as volunteers—altering their perceived socio-culturally expected roles. With the mental engagements, the audience makes predictions, and answers questions. According to Falk and Dierking, "social interaction during the museum visit includes the questions and discussions generated," (2016, p. 148), meaning that the very questions asked during mental engagements adjust the social interactions, changing the socio-cultural context.

With the realization that misconceptions were being caused we made the change to center the misconception within the presentation. This can be seen as a sociocultural shift since we shift educational approaches. The original approach built up knowledge piece by piece until we get to the misconception causing demonstration, while the new approach starts with the puzzling phenomenon as an anchoring phenomenon to explore (Achieve, 2016). In some ways this parallels the act of prediction, but it organizes that act of prediction around a central theme, a mystery to be solved, switching the sociocultural context of the demonstration set-up so that the audience doesn't just predict one result after another, but rather positions multiple predictions in the context of understanding a greater puzzle.

Since learning is a socially embedded phenomena (Vygotsky, 1980), one can reasonably expect that changing the sociocultural context should influence the amount of content learned, as

well as transitory attitudes towards the experience of learning. Indeed, Falk and Dierking realized the potential of socially mediated experiences when they wrote:

> One form of such social mediation that is increasingly common in museum settings is the use of theatre, performance, demonstrations, and/or first person interpretation. These strategies have been effective at increasing the interactivity and engagement of visitors in museums, as well as providing an ability to add context and personalize the experience. There is evidence that these experiences enhance visitor learning of content, as well as the visitor's ability to articulate complex issues and ideas. (2016, p. 164)

The research conducted in this dissertation should further explore this fertile environment.

MATERIALS AND METHODS

There are presenters who believe a science show-person should be the ultimate performer —wowing the audience with dramatic presentations—while other presenters believe the secret is involving audience members in the presentation. As described in the previous chapter, no research yet exists that examines how individual elements within a presentation affect audience members' understanding of and reaction to the presentation. This study attempts to better understand the effects of different engagements on audience members' science content knowledge and attitudes.

This research looks at one presentation topic to examine how changing specific engagements within this presentation changes audience members' content knowledge and attitudes towards science. I conducted twenty-nine similar presentations across fourteen months, each shown to distinctly separate audiences. I kept the presenter and the locale the same to minimize their impacts on the study. I also kept demonstrations within the presentation the same with just two minor exceptions detailed later in this text.

Study Approach

To converge on a more complete understanding of the effects of mental and physical engagements I utilized a four-part study to investigate six research questions.

1) I utilized a quasi-experimental setup using myself as both the researcher and presenter at LASM. As a quasi-experimental setup, the experiment doesn't use randomly assigned participants (Johnson & Christensen, L., 2014). As a presenter I delivered four different presentation forms: the control (no mental or physical engagements utilized by the presenter) and three separate experimental presentations (mental engagements only, physical engagements only, and both mental and physical

engagements). I used pretests and posttests that examine the control and experimental condition effects. These were presented to different audience groups. Sample pre- and post-tests are listed in Appendices B, C and D.

2) Partway through the study, preliminary results from this study indicated that every presentation form caused a misconception whereby audience members conflated gravity with rotational motion. I utilized an iterative design–based–research (Brown, 1992; Collins et al., 2004) method to eliminate causing of the misconception. According to Collins et al., design–based research seeks to "improve the way a design operates in practice" (p. 34) by taking "steps to fix whatever problems appear to be the reasons for failure" (p. 34). This approach led to primarily changing the order of demonstrations and verbiage exploring these demonstrations to see if these changes could prevent the presentation from causing this misconception. The iterative approach involved making small changes, briefly looking at the data to see if the misconception was still present and making further changes until there was the suggestion in the data that the misconception might not be prominent. The resulting change in order and verbal context was tested using the same quasi-experimental setup as part 1 of the study, except that the new setup was delivered in only two forms: the control form and the form that utilized both mental and physical engagements.

3) I video–recorded all enacted presentations to document each presentation. These video–recordings were then viewed to verify that the control and experimental conditions were being adhered to. If the presentation form was not generally consistent with the presentation format (as seen in Appendix E), then the related data

for that particular enacted presentation was not included in the study. One presentation did have the data disqualified for RQ6 due to a missing demonstration.

4) I conducted 24 recorded (23 video, one audio) focus group interviews of audience members in social groups from across all presentation forms. Social group size varied from one individual to five individuals. As part of the 24 focus group interviews, I did a focus group interview of audience members in a control form presentation that didn't use pretests and posttests to gain insight into how the pretests and posttests affected the audience members' responses. Initial interview questions are listed in Appendix F.

Data

This research utilizes a concurrent mixed methods quasi-experimental design (Tashakkori, & Creswell, 2007). Concurrent mixed methods research collects quantitative and qualitative data simultaneously. The mixed method design is defined as "research in which the investigator collects and analyzes data, integrates the findings, and draws inferences using both qualitative and quantitative methods in a single study or a program of inquiry" (Tashakkori & Creswell, 2007, p.4). In keeping with Tashakkori and Creswell's (2007) definition of concurrent mixed methods, the quantitative and qualitative data were gathered to triangulate the results and converge on a better understanding. In general, quantitative data yields better objectivity, and more generalizability around a very limited number of aspects, while the qualitative data gathered supports or modifies these results, and yields more context, providing information that could explain the results of the quantitative data or bring about further questions to study (Tashakkori & Creswell, 2007).

Quasi-Experimental Setup

This research used a quasi-experimental design that did not randomly assign audience members to different presentation forms, rather the research used naturally occurring groupings. To ensure that the lack of random assignment didn't hamper the validity of this study, different presentation forms were presented on each day that more than one form was presented, and the times they were offered varied. This means that at one o'clock in the afternoon one day any audience member attending might attend a both mental and physical form of presentation, while on another day the timeslot presentation would be a control, mental only or physical only presentation form. Presentation times and forms are listed in Appendix A.

I collected a combination of qualitative data (audience members' group interviews, video–recorded presentations) and quantitative pretest and posttest data. The qualitative data consisted of audience members' group interviews, and video–recorded presentations. The quantitative data included attitude analysis utilizing Likert schema, content using multiple choice as part of the pre-post data, along with post-only survey questions. Additionally portions of the qualitative data were viewed through a quantitative lens for comparisons of groups. The basic structure of the data collection is detailed in Figure 4, where all four presentation forms are grouped together.

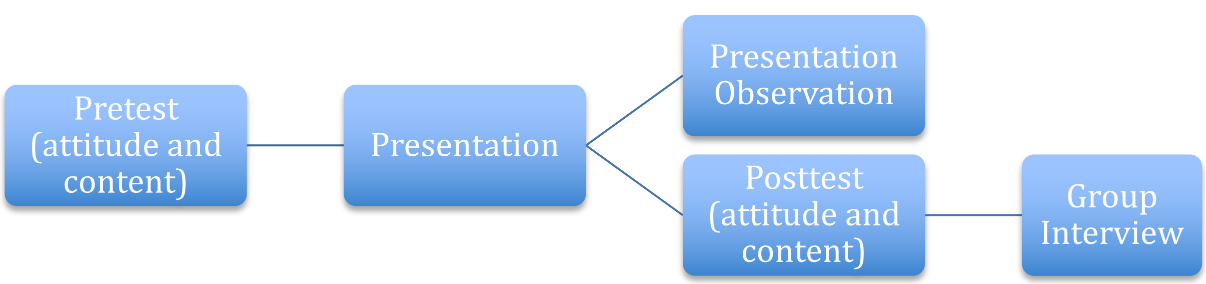


Figure 4. Basic diagram of data collection

The research's quasi-experimental setup used real–world audience members recruited

from people who attended LASM presentations between November 2018 and December 2019. I acted as the sole presenter and researcher at LASM for the quasi-experimental research. I performed the presentation in the following four presentation forms the control, mental only engagements, physical only engagements and both mental and physical engagements. The presentation forms are explained briefly below, using a single demonstration to show how implementing the demonstration varies by form. For a more complete understanding of the presentation forms, look in Appendix E.

1) Control Presentation: During the control presentation the audience *observes*. The control presentation form consists of a traditional presentation format where the presenter acts as a performer without physical or mental engagements. One demonstration involved pulling a tablecloth from underneath some dishes on the table. The dishes are preset on the tablecloth. The presenter pulls the tablecloth slowly and the dishes move with the tablecloth; a dish begins to tip off the table, falling to the floor when it reaches the edge of the underlying table. The presenter then uses an identical setup where the dishes are on the tablecloth. The presenter now pulls out the tablecloth quickly, and the dishes remain on the table, relatively motionless.
2) Experimental Group One: Mental Only Engagements Presentation: During the mental only engagements presentation the audience *predicts* and *observes*. As previously defined, mental engagements involve the presenter engaging audience members by asking them to predict the results of a demonstration prior to conducting the demonstration. Throughout the mental–only engagements form the presenter uses investigable questions and asks audience members to predict what might happen in

demonstrations prior to conducting the demonstrations. Audience members are not involved physically, although they are free to yell out their predictions if they wish. The aforementioned tablecloth demonstration would be modified from the control form with the addition of the presenter first asking audience members to predict what would happen to objects on the table when the tablecloth gets pulled out slowly or quickly. After allowing the audience to make their mental predictions, the presenter performs the demonstration–pulling the tablecloth out from under the dishes at different speeds.

3) Experimental Group Two: Physical Only Engagements Presentation: During the physical only engagements presentation the audience *does* demonstrations and *observes*. During this format the audience physically participates and observes. As previously defined, physical engagements involve the presenter engaging the audience members physically within the demonstrations. The presenter asks for volunteers to come up in front to participate in the presentation, and for one demonstration the presenter asks audience members to participate physically while in their seats. The tablecloth demonstration would be modified from the control form with the addition of the presenter first asking audience members to conduct simple exploration themselves at their seats using materials previously provided—in this case, pulling an index card from underneath a penny quickly or slowly. Finally, an audience member is invited to the stage to try pulling the tablecloth out from under the dishes slowly or quickly.

4) Experimental Group Three: Both Mental and Physical Engagements Presentation: During the both mental and physical engagements presentation the audience *does*

demonstrations, *predicts,* and *observes*. The both mental and physical engagement format of presentation combines the elements from both the 'mental only engagements' presentation and the 'physical only engagements' presentation. The presenter engages the audience members mentally in the demonstration by asking a question before enacting the demonstration as well as involving audience members physically in the demonstration (either individually in their seats or inviting someone to the front of the stage as a physical participant with the presenter). The tablecloth demonstration would be modified from the control form by the presenter in two manners. First, the audience members would be asked to predict what will happen to objects on a table when the tablecloth gets pulled on slowly or quickly. Then, audience members would be invited to investigate their mental predictions through a simple physical exploration in their seats, such as by pulling an index card from underneath a penny (using materials previously provided). Finally, an audience member is invited on stage to physically participate with the presenter using a real tablecloth and dishes.

As the presenter I ran all four presentation formats using the same nine demonstrations. I conducted 29 presentations at LASM's auditorium between November 2018 and December 2019 (see Appendix A for details). For each of the presentations, eight of the demonstrations were essentially identical, but one demonstration on rotational speed (Twirling Stick) had to be slightly changed to accommodate physical engagement by audience members. When physical engagements were not used, a pole was spun around, and the ends of the pole blurred due to their increased speeds, while the center stayed relatively unchanged. During any presentation with physical engagements of this demonstration, audience members helped move the pole around the

stage, and the rest of the audience could see that the person in the middle of the pole was staying almost still while those at the ends of the pole had to run to keep up.

Sample

The sample for this study consisted of 334 individuals that participated in one or more of 29 science presentations I conducted in the auditorium of LASM between November 2018 and December 2019. The sample was chosen from an estimated 460 audience members who participated in science presentations at LASM. Sample participants are defined as attending the entire presentation and participating in the research which included: Either (1) participating in the social unit interview, and/or (2) picking up a unique Plickers® card upon entering the auditorium, (3) taking the pretest via the Plickers® card system, and (4) taking the posttest via the Plickers® card system. Of the 334 participants, 325 participants were included in the quantitative surveys, and 49 were included in the qualitative interviews. Most participants in the qualitative interviews also participated in the quantitative surveys, although 9 qualitative participants were not eligible to participate in the quantitative survey, since the presentation did not have a useable quantitative survey.

Personal Context of Full Sample

Individuals participating in the sample were asked about their age range as well as the social grouping they were attending the presentation with, and whether they had seen this presentation previously. The sample consisted of 124 individuals who were twelve years old or younger, 24 individuals who were between thirteen and seventeen years old, 15 individuals who were between eighteen and twenty-five years old, and 173 individuals who were over twenty-five years old.

The individuals primarily attended in social groupings. Most individuals (288) reported

attending the presentation with their families. Of the remaining sample, 31 individuals came to the presentation with their friends, 8 individuals came with a school or after-school group and 8 individuals came to the presentation by themselves. Only 20 individuals reported previously attending the presentation. The results presented so far encompass the entire study. Since the study breaks into quantitative and qualitative subsamples, those contexts are listed within the subsample sections.

Quantitative Sampling

Although audience members were free to choose whether to participate in the research, by using Plickers® cards (explained below), the vast majority (90% by manual estimates) of those over the age of five took cards and attempted to participate. Accurate numbers on participation rate do not exist because people could come in or leave at random, keeping consistent with the general expectation of presentations set up at LASM. While the presentation was occurring, a person could come into the auditorium, observe, and leave without being counted. People could also come in after the initial card voting and then participate in the postsurvey without participating in the presurvey, or they could leave prior to the postsurvey. People would enter after I had begun the explanations but prior to the data collection, which would result in my giving out voting cards while explaining them, making the number of cards handed out difficult to keep track of. Multiple times audience members approached me prior to the beginning to tell me that they may need to leave early to catch their planetarium show. I always reassured the audience members that leaving early was permitted, which resulted in missing data. Essentially the sanctity of accurate percent participation rates was sacrificed to engender continued good will from the audience, and to keep in line with LASM's prior policies.

Quantitative Subsamples

The quantitative sample used case by case exclusion; meaning one missing piece of data would exclude that piece of data from the analysis and would not result in the rest of the person's data being excluded. Therefore, each quantitative subsample has its own subset of data, and its own demographic mix based upon the number of cases excluded. A quantitative subsample involves the sampling for a particular test. The separate quantitative subsamples include: Content (RQ1, RQ2), Attitude (RQ2, RQ4), Interpretation (RQ5) and Misconceptions (RQ6). All the quantitative subsamples consist of individuals who attended one of 26 presentations and were primarily composed of adults over twenty-five and children under the age of twelve. For more detail on these tests and the reasoning for running separate tests instead of a MANOVA check out the quantitative analysis section.

Quantitative Content Subsample (RQ1, RQ2)

The quantitative content test consisted of a battery of four questions. Although case by case exclusion was utilized, a single answer missing from the four questions on either the pretest or the posttest resulted in that data's exclusion from the analysis. Missing data was analyzed for patterns and detailed in the quantitative analysis section.

The quantitative content subsample consists of 187 individuals. Approximately 27% were under thirteen years old, 58% were over the age of twenty-five, with 10% being thirteen to seventeen and 4% being eighteen to twenty-five. The vast majority (85%) of the group consisted of individuals viewing the presentation as part of a family group. Of the remainder, 2% came with an organized school-related group, 11% arrived with friends and 2% came alone.

Each presentation format was analyzed to look at how presentation formats change the content, so each presentation format's age breakdown was analyzed as well for those who filled

out the pre/posttest sections on science content. Table 3 shows the distribution of age ranges

Table 3. Age distribution of content subsample

Presentation Format	Sample size (n)	Age 0-12 years	Age 13-17 years	Age 18-25 years	Age 25+ years
Control	58	33%	15%	0%	53%
Physical Only	30	26%	15%	4%	56%
Mental Only	28	30%	0%	0%	40%
Both Mental and Physical	80	23%	9%	9%	59%

across presentation formats. The distribution had a particularly uneven distribution of ages 13-25 years old between presentation formats, as well as some differences in social groupings (see Table 4), so the quantitative analysis was performed with the full group, then with a subsample

Table 4. Social group distribution of content subsample

Presentation Format	With a School-related group	With My Family	With My Friends	By myself
Control	0	80%	16%	4%
Physical Only	4%	82%	14%	0%
Mental Only	4%	96%	0%	0%
Both Mental and Physical	1%	86%	10%	3%

that excludes those who were 13-25 years old, as well as those who did not attend the presentation with their family, resulting in a subset consisting of 136 individuals.

Quantitative Attitude Subsample (RQ3, RQ4)

The quantitative attitude subsample consists of 248 individuals who attended one of 26 presentations and was primarily composed of adults over twenty-five and children under the age of twelve. Approximately 34% were under thirteen years old, 53% were over the age of twenty-five, with 8% being thirteen to seventeen and 5% being eighteen to twenty-five. The vast majority (85%) of the group consisted of individuals viewing the presentation as part of a family group. Of the remainder, 1% came with an organized school-related group, 12% arrived with friends and 2% came alone.

Each presentation format was analyzed to look at how presentation formats change the desire to participate in science, so each presentation format's age breakdown was analyzed as well for this subsample. Table 5 shows the distribution of age ranges across presentation formats,

Table 5. Age distribution of attitude subsample

Presentation Format	Sample size (n)	Age 0-12 years	Age 13-17 years	Age 18-25 years	Age 25+ years
Control	80	41%	9%	0%	51%
Physical Only	28	33%	15%	8%	45%
Mental Only	32	33%	0%	3%	63%
Both Mental and Physical	108	30%	9%	9%	53%

while Table 6 shows the distribution in social groupings.

Table 6. Social group distribution of attitude subsample

Presentation Format	With a School-related group	With My Family	With My Friends	By myself
Control	0	81%	18%	1%
Physical Only	4%	71%	18%	7%
Mental Only	0%	97%	3%	0%
Both Mental and Physical	2%	88%	8%	2%

Since roughly 60% of the sample came to the presentation "topping out" in their desire to participate in science, this sample was re-run excluding those who started with the highest possible desire to participate in science. Removing those who "topped out" resulted in a subsample of 111 individuals with shifted age ranges as seen in Table 7 and in social groupings as seen in Table 8.

Quantitative Interpretation Subsample (RQ5)

The quantitative interpretation subsample consists of 317 individuals who attended one of 26 presentations and was primarily composed of adults over twenty-five and children under the age of twelve. Approximately 36% were under thirteen years old, 52% were over the age of twenty-five, with 8% being thirteen to seventeen and 4% being eighteen to twenty-five. The vast majority (85%) of the group consisted of individuals viewing the presentation as part of a family group. Of the remainder, 2% came with an organized school-related group, 10% arrived with

Table 7. Age distribution of attitude subsample—perfect pre-tests removed

Presentation Format	Sample size (n)	Age 0-12 years	Age 13-17 years	Age 18-25 years	Age 25+ years
Control	41	32%	18%	3%	47%
Physical Only	10	33%	11%	0%	56%
Mental Only	20	44%	0%	0%	56%
Both Mental and Physical	40	21%	18%	8%	54%

Table 8. Social group distribution of attitude subsample—perfect pre-tests removed

Presentation Format	With a School-related group	With My Family	With My Friends	By myself
Control	0%	75%	25%	0%
Physical Only	0%	100%	0%	0%
Mental Only	0%	100%	0%	0%
Both Mental and Physical	3%	85%	13%	0%

friends and 2% came alone.

Since each presentation format was analyzed to look at how presentation formats change the interpretation of the presentation, each presentation format's breakdown was examined as well. Table 9 shows the distribution of age ranges across presentation formats for those who

answered the interpretation survey questions, while Table 10 shows the distribution of social groups across presentation formats.

Table 9. Age distribution of interpretation subsample

Presentation Format	Sample size (n)	Age 0-12 years	Age 13-17 years	Age 18-25 years	Age 25+ years
Control	93	42%	8%	1%	49%
Physical Only	56	35%	17%	7%	41%
Mental Only	56	27%	0%	0%	73%
Both Mental and Physical	112	34%	8%	8%	51%

Table 10. Social group distribution of interpretation subsample

Presentation Format	With a School-related group	With My Family	With My Friends	By myself
Control	1%	81%	15%	2%
Physical Only	7%	70%	17%	7%
Mental Only	3%	95%	3%	0%
Both Mental and Physical	2%	89%	7%	2%

Quantitative Misconception Subsample (RQ6)

The quantitative misconception subsample consists of 287 individuals who attended one

of 26 presentations and was primarily composed of adults over twenty-five and children under the age of twelve. Approximately 34% were under thirteen years old, 53% were over the age of twenty-five, with 8% being thirteen to seventeen and 4% being eighteen to twenty-five. The vast majority (87%) of the group consisted of individuals viewing the presentation as part of a family group. Of the remainder, 2% came with an organized school-related group, 11% arrived with friends and 2% came alone.

Since each presentation was looked at prior to the RQ6 intervention and during iterations of the RQ6 intervention and after the RQ6 intervention, the breakdowns for the different RQ6 interventions were examined. Table 11 shows the breakdown by age range, while Table 12 shows the breakdown by social grouping. These tables show very similar samples for pre and post RQ6 interventions, indicating that any analysis on misconceptions should not need to take

Table 11. Age distribution of misconception subsample

	Sample size (n)	Age 0-12 years	Age 13-17 years	Age 18-25 years	Age 25+ years
Pre-RQ6 Intervention	160	32%	9%	5%	54%
RQ6 Transition	27	42%	8%	0%	50%
Post RQ6 Intervention	91	36%	8%	4%	52%

Table 12. Social group distribution of misconception subsample

	With a School-related group	With My Family	With My Friends	By myself
Pre-RQ6 Intervention	3%	85%	9%	3%
RQ6 Transition	0%	75%	25%	0%
Post RQ6 Intervention	1%	87%	11%	1%

these age and social factors into account unless the factors have outsized affects. To ensure the factors weren't critical, an analysis on whether age affected misconceptions was performed.

Qualitative Interviews Subsample (RQ1, RQ2, RQ3, RQ4, RQ5)

Interviews were conducted with social groupings after the presentations. Targeted social groupings had both children and adults, although one single adult was also interviewed to take advantage of his having attended multiple shows. I conducted 25 group interviews, 24 of which were successfully recorded and coded, and one of which was thrown out due to an audio issue. Of the 24 interviews, there were 20 unique social groups each attending one or more of 19 separate presentations.

Social groups varied in size from two adults and three children to a single child who was interviewed. Most of the adults and children were interviewed together, but on four occasions the adults declined interviews, while the children were interviewed, representing the social group. Appendix A lists the groups interviewed by day showing what age the children were in each the groups interviewed, while listing the adults without ages. Table 13 summarizes group interviews by type of presentation attended. Interview time ranged from just over two minutes to just under thirty minutes.

Table 13. Interviewee age range by presentation type

Presentation type	Number of interviews	Number of interviewees	Adults >18	Children <17
Control	8	24	10	14
Mental Only	3	5	1	4
Physical Only	3	4	1	3
Both Mental and Physical	10	31	11	15

Several interviewees saw the presentation more than once. One social group consisting of two adults and two children, attended the same format presentation twice (control) and was interviewed both times, one social group consisting of one adult and one to two children (dependent on day) attended a control presentation, then a both mental and physical engagement presentation and gave interviews each time, and one interviewee—my own son –attended three different format presentations (mental only, control and both mental and physical), and gave three separate interviews. One interviewee, a single adult attendee had attended twice, but was

only interviewed the second time. These interviews, which allow for direct comparison of the presentation formats were specifically encouraged. Although these were the same individuals, they cannot be said to have the same personal context, since seeing the presentation the first time changes the personal context for the individual, and likely affects the individuals' reactions.

Presentations

The 29 presentations each followed one of four formats: control (no engagements), mental-only engagement, physical-only engagement, and mental and physical engagement. Twenty participants attended two or more presentations. Each of 29 presentations was conducted at LASM in the auditorium between November 2018 and December 2019. LASM's physical context is fully described in the introduction. Eight of the presentations were conducted on regular admission days while 21 of the presentations were collected twice on the first Sunday of the month, when all audience members get in free. Anywhere from one to three presentations were given in a day, with most days having two presentations. The days were chosen to maximize non-school attendance, and to honor the desire of LASM to fill out their presentation schedule on special dates. Several times, I had to forego a month due to external conflicts or I added an additional day of collecting data due to special events happening at LASM (see Appendix A for a complete listing of dates and presentations). Audience members came from LASM's natural attendance on the days of the shows. All audience members were invited to participate in the quantitative sample, while qualitative samples were taken from a select subset of the audience.

The presentation consisted of nine separate demonstrations about linear and rotational motion as shown in Table 14. During the presentations, the participants were shown the nine demonstrations in the same order, regardless of the presentation form. Each group experienced

Table 14. Presentation demonstrations

#	Demo	Scientific principle shown	Brief Description
1	Tablecloth	Things at rest stay at rest	Tablecloth is yanked out from under dishes.
2	Ball on Car	Things in motion stay in motion	Rolling car hits an object, ball keeps moving.
3	Twirling Stick	Points on rotating objects move faster the farther they are from the axis of rotation	Twirling stick blurs at the end, while the center can be seen. People at the end of a moving stick run, while the center person barely moves.
4	Cup on platform	Inertia can pin two objects together	Platform is swung around with a cup on it filled with water. The water stays in the cup which stays on the platform even while upside down.
5	Ball on turntable	Objects travel in a straight line absent other forces	Presenter twirling around on a platform lets go of a ball, the ball goes tangentially to the side.
6	Person on turntable	Objects brought from outside of a spinning object keep their inertia, causing the object to spin faster	Person on the turntable moves his/her limbs inwards and starts spinning faster. When the limbs go outwards the person spins slower.
7	Tire on Ground	Spinning objects keep spinning in the same direction, keeping upright	Tire that is not spinning, falls over. A tire that is spinning stays upright and rolls forwards.
8	Tire on hand	Spinning objects keep spinning in the same direction, keeping upright	Tire spinning on its hub, balances on end of the hub upright on the presenter's hand precessing.
9	Tire and Turntable	Spinning objects interact with each other conserving their spin	Presenter stands on the turntable and moves a spinning tire from in front to overhead—causing the presenter to rotate on the turntable.

the same presentation—but in four different forms– either as a presentation (control), with physical only engagements, with mental only engagements or with both physical and mental demonstrations. For a complete list of presentation changes by form see Appendix E.

After the posttest, at the end of each presentation, audience members were allowed to come up and try out a few of the demonstrations for themselves. Then I conducted the interviews. Since the interviews came after the chance for audience members to physically engage with a few of the demonstrations, this could be viewed as a physical engagement contamination of the interview data. To counter this element, I queried the interviewees to see if this post-presentation interaction was being referred to within their interviews.

With the addition of RQ6 three-quarters of the way through the research I added one additional demonstration, resulting in ten total demonstrations for the post RQ6 presentations. This additional demonstration was used to help dispel a misconception another demonstration caused.

I videotaped all presentations and reviewed them when analyzing the data to ensure my presentation format kept using the engagements, and all the demonstrations were conducted. This allowed me to note anything that might have occurred out of the ordinary within that particular presentation, and to exclude data if necessary. One presentation on October 6th, 2019, was excluded from analysis for RQ6, since the demonstrations were performed out of order.

I spent over a year collecting data at LASM, and transcribing interviews. The first two months were spent developing the initial instruments and attaining the permissions from LSU's Institutional Review Board to conduct the study. The next two months involved the first few presentations where I attempted to collect data, and found I had to modify the data collection methods and discard the paper survey. From January 2019 to May 2019, I presented and

collected data. In June and July of 2019, I did preliminary analysis, resulting in the addition of RQ6. In August to December of 2019, I collected the final pieces of data. A timeline of the research is shown in Table 15.

Ethical Human Subject Research in Informal Education

The study collected all data in accordance with procedures filed with LSU's Institutional Review Board. An exemption was filed for and granted (see Appendix L), allowing for collection of anonymous data via the Plickers® app (described in more detail under Data Collection, below), written survey data, and video recorded interviews. Each participant was informed of their rights and given opportunities to opt out as detailed under the data collection section below and stated in the scripts (as seen in Appendix E). Informed consent with signatures were obtained from all interviewees and written survey participants (described below).

These participant consent forms are included in Appendix G. In the case of the interviews, participants could choose one of three options including:

1) Allowing the use of the video and audio recordings to be used within presentations,
2) Allowing the use of video and audio to be transcribed, whereby the answers could be used for research, but would remain anonymous,
3) Allowing the use of audio recording only, whereby the answers could be used for research, but would remain anonymous.

Quantitative Data Collection: Plickers®

All presentations utilized a pretest and posttest format, along with a few pretests only questions that asked demographic information about the person answering and a few posttest only questions that asked specifically about the presentation (Appendices B and C). When

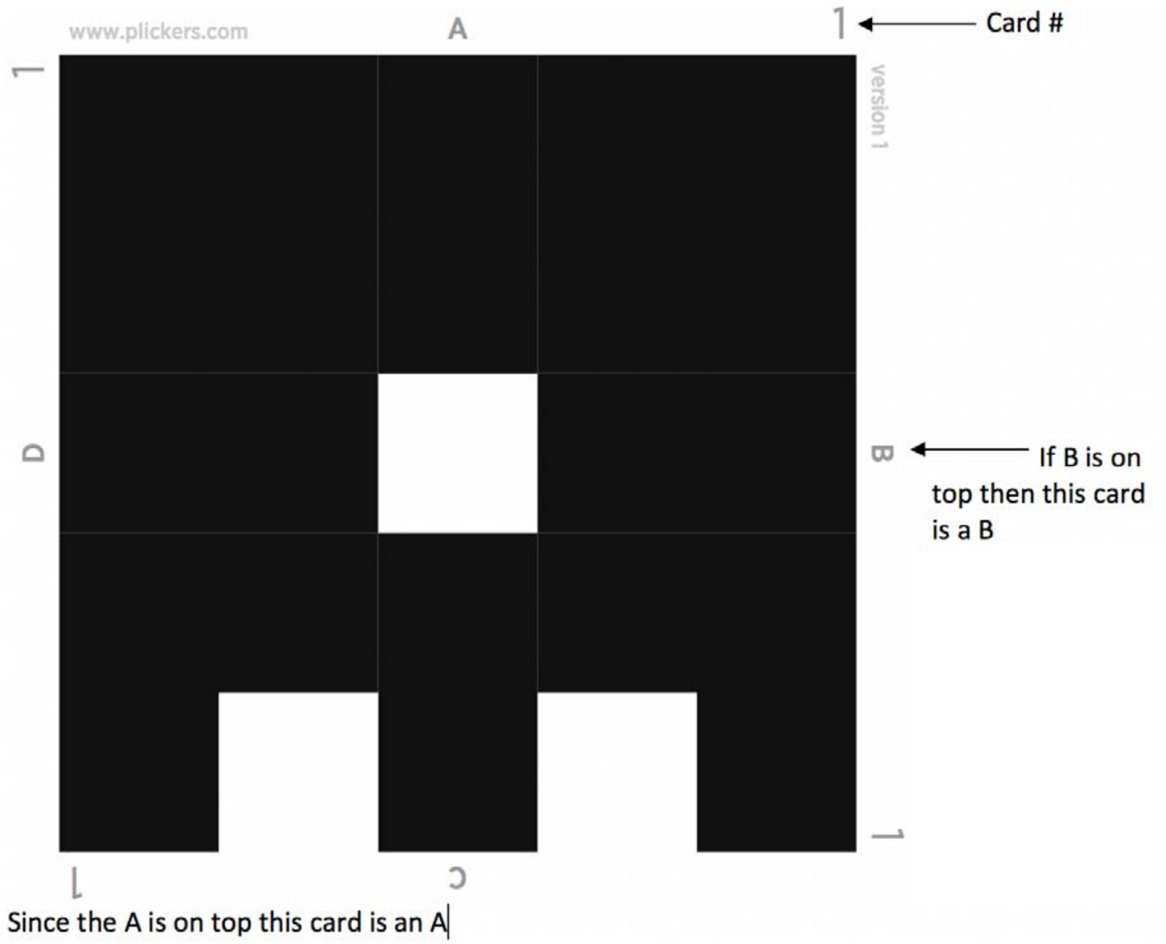
Table 15. Research timeline

	Sept 2018- Oct. 2018	Nov. 2018- Dec. 2019	Jan 2019- May 2019	June 2019- July 2019	Aug. 2019- Dec. 2019	Jan. 2020 - Present
Logistics	File IRB & train on presentation				Present initial results at ASTC	Present results at ASTC
Collect Qualitative Data		Collect data	Collect data		Collect data	
Collect Quantitative Data		Collect data	Collect data		Collect data	
Qualitative Data Analysis			Transcribe interviews		Transcribe interviews	Transcribe & code interviews
Adjustments		Revamp instruments		RQ6 added	RQ6 implemented	
Quantitative Data Analysis				Preliminary Quantitative Analysis		Final Quantitative Analysis
Data Merge				Preliminary data merging		Final data Merging
Write					Create ASTC presentation	Write dissertation

audience members entered the auditorium they were asked if they would like to participate and handed Plickers® cards (seen in Figure 5). All audience members—adults and children—were given the Plickers® cards, so that they could participate if they chose to. At the end of the session the cards were collected to be reused in future sessions with new audience groups. Plickers® cards are designed for collecting data sets from an audience in a classroom or auditorium setting using photographic software. Each audience member is given a unique Plickers'® card when they enter the auditorium. Each card represents four possible multiple-choice answers; the audience member indicates their personal answer to a presenter's multiple-choice question displayed on a projection screen by holding the card in one of four orientations—each orientation corresponding to a different answer. Each Plickers® card uses a unique symbol (see Figure 5). The Plickers® app interprets each card's symbol and the orientation of the symbol to determine both, the card number and which answer it is (A, B, C or D). By scanning the audience with a phone that is running the Plickers® app, the votes are recorded for each individual card without taking pictures of the individuals holding the cards.

Plickers® card answers were recorded by the Plickers® app, but the app only recognizes the cards' symbols and orientations of the symbols—not the faces of the audience members—so the card holders remain anonymous. In other words, strictly speaking the person who holds the card is not tracked, but the card itself is tracked. In this manner Card X's answers in the pretest and posttest can be directly compared. Furthermore, the ABCD answers on the Plickers'® cards are written relatively small, so that only the card holder can easily read them, which discourages people from looking at others' answers before deciding which answer to display.

Prior to the beginning of each presentation, as the presenter, I took a few minutes to describe the research project, following the script in Appendix E, and instruct audience members



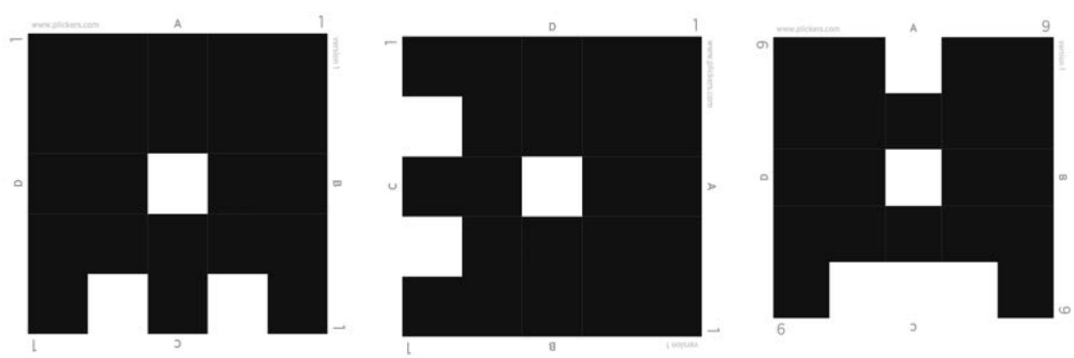


Figure 5. Plickers® Card Examples. Top: example of Plickers card with areas pointed out. Bottom left: Card 1 registers as an “A” to the software when scanned with the Plickers App. Bottom middle: Card 1 is rotated 90 degrees clockwise and represents a “D” answer. Bottom right: Card 9 showing an “A” answer.

in the use of the Plickers'® cards. This presentation included talking about how the Plickers'® cards allowed anonymous information gathering from the audience before and after the presentation (the pre/posttest), and that each audience members' use of the Plickers'® cards and therefore participation in the research project was optional. I then told audience members how to use the Plickers® cards—by holding them up so that the answer they wanted to indicate (either A, B, C or D) was on top of the card.

I quickly learned that I had to be very explicit and tell audience members that they had to keep their fingers from covering the symbol on the front of the Plickers® card. I furthermore found that I would have to remind the audience that f their finger was in front of the symbol it would not be recorded. The Plickers® software that displayed the multiple choice question would also display whether a card's answer was captured, enabling audience members to see if their card's answer was captured. Unfortunately, even with all these data safeguards, roughly two-thirds of the data collected was missing at least one piece of data, primarily due to stray fingers going in front of the card's symbols. Only 120 audience members had

After this initial discussion, as the presenter, I conducted the pretest (Appendices B and C) where demographic, content, and attitude information were collected using the Plickers'® cards. At the end of each presentation, the posttest was administered, where audience members were asked a similar series of questions. Afterwards, as the presenter, I revealed the correct answers for the content–based questions asked in the pretests and posttests.

Quantitative Data Collection: Pretests and Posttests

The pretest and posttest included both content–related questions and attitude–related questions. The content part of the pretest and posttest (Appendices B and C) was created and tested in a pilot study (Katzman, 2017) in order to judge the content knowledge that the presenter

imparted to audience members. The content questions were reviewed and approved of by three individuals: an expert in physics, a veteran teacher, and myself, as the researcher.

For the attitude survey, something like Fraser's (1981) pencil–and–paper–based Tests Of Science-Related Attitudes (TOSRA) would be ideal for assessing attitudes due to its completeness and reliability, but the test was deemed to too long for use in the presentation environment. Instead, I utilized Szechter's (2009) attitude surveys (Appendix D)–which are shorter pencil–and–paper Likert–style attitude surveys. The attitude surveys took five to ten minutes to fill out; therefore, anyone who filled out the attitude surveys had a chance at winning a $25 gift card in exchange for filling out the card.

I quickly found that the written survey was also too long and cumbersome in the presentation environment, especially when combined with the Plickers'® pre/post-tests; two questions from Szechter's (2009) survey were inserted as a part of the Plickers'® pre/post-tests. In addition, I used a modified question from Price et al.'s (2015) pre/post-tests design, and an original question that forced participants to choose between options to help me determine whether audience members interpreted the presentations differently. These changes resulted in three additional pretest and four additional posttest questions in the Plickers'® survey (Appendix B). These adjustments took place at the end of December 2018.

Eventually, when examining the data, I realized that the data from two of Szechter's (2009) survey questions was suspect–as some of the data showed either no change or very large changes. depending on the respondent. The questions that were suspect were the negatively scored statements: "Knowing science means only knowing the facts and Figures," and "Thinking like a scientist is only useful when taking a test in science class." Answering either of these positively, meant that one felt science was less useful. I have come to believe that such

negatively scored questions are not suitable for a quick test given in a presentation environment, because little time exists for reflection on the word “ONLY” which was present in both questions. Simply removing the word only in either of the sentences turns the sentence from a negative statement to a positive statement. Once, I was confused myself as I read a question to the audience. Because these two data pieces, while considered reliable in a paper survey form, yielded unreliable results when administered quickly via the Plickers’® cards, I discarded those two pieces of data for all the presentations.

Creating and Eliminating Misconceptions (RQ6)

In June of 2019, I realized that the presentation was causing a statistically significant misconception –some audience members conflated gravitational effects (where objects are attracted towards each other) with rotational motion effects (where objects move outwards). This misconception was present across all test groups. This misconception was shown in the answer to one of the content questions that asked people to extend their knowledge to an unknown situation. The content question asked what would happen if the earth spun much faster. The correct answer was: “We would be flung off the earth’s surface,” but the demonstrations were resulting in audience members instead thinking: “We would be stuck on the ground unable to move.”

The results from a prior pilot study (Katzman, 2017) had shown the same misconception occur but in a non-statistically significant manner. An audience member in the pilot study noted that things seemed to cling together as they moved faster: “Because after you did the demonstrations … the water didn’t come out of the cup with as fast as it got.” This referred to the cup on platform demonstration, where water is put in a cup that is on a platform and the presenter swings the platform around. The water stays in the cup, while the cup stays on the

platform—even as the platform temporarily turns upside down (see Figure 6). This likely led to the misconception that as things spin faster, they cling to each other more—as if gravitational attraction between the water, the cup and the platform had increased. This conflation of rotational motion effects with gravitational effects would account for audience members believing that we would be stuck on the ground unable to move.

Figure 6. Cup on platform demo. Presenter/researcher spins a platform with an open cup of water, completely around in a full circle, without spilling any of the water.

I originally thought that I might be able to eliminate the generation of this misconception through changes to the demonstration order. During my pilot study (2017) I tried reordering the demonstrations, playing with whether the demonstration fostering the misconception (cup on platform) was immediately before or after a demonstration (ball on turntable) that could counter the misconception generated. With the cup on platform demo, when the water in a cup is spun, the water sticks to the cup and the cup sticks to the platform, because the water is thrown against the cup, and the cup is thrown against the platform (sometimes inaccurately referred to as centrifugal forces). The platform is pulled inward by the string—keeping it all together. If the

string were let go then everything would soar outwards. During the ball on turntable demo when the presenter spins around on a platform, and the ball is let go by the presenter the ball soars outward along a straight tangent–because there is nothing to keep the ball in. I thought the misconception of quickly rotating objects sticking to each other (created by the cup on platform demonstration) would be eliminated by the ball on turntable demonstration, and early anecdotal indications in my pilot study suggested that such a simple change would eliminate the misconception. Unfortunately, more data revealed that the misconception remained.

During this study, once the statistically significant misconception was detected in May 2019, I decided to implement a design–based research iterative process (Brown, 1992; Collins et al., 2004) as shown in Figure 7. This approach centers around making design changes in

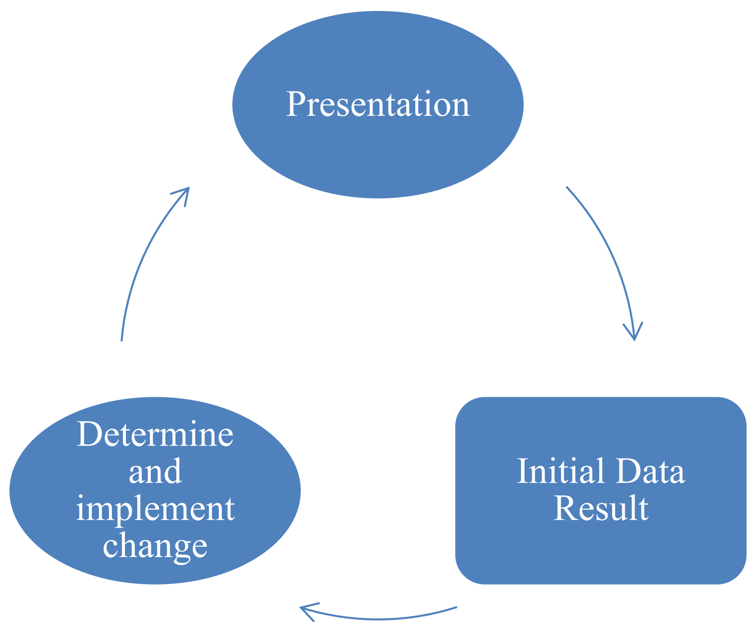


Figure 7. Iterative design-based research process

particular real–life situations (not lab–based), with the expectation that these approaches will inform future design choices for that particular situation, and possibly related situations.

Design–based research approaches have been previously used in informal education circles (Humphrey & Gutwill, 2005; Paneto et al., 2020), with positive results.

To eliminate the statistically significant misconception, I considered the idea of *anchoring phenomena* embedded in the Next Generation Science Standards (National Research Council, 2013) and discussed on both the nextgenscience.org website (2016) and the researchandpractice.org website (Penuel & Bell, 2016). *Anchoring phenomena* are complex phenomena that require multiple experiments to understand the various science concepts underpinning the phenomena (Achieve, 2016). Each experiment helps the experimenter understand one portion of the science underpinning what happens in the initial anchoring phenomenon. If the cup on platform demo became the anchoring phenomenon, then the other demos could explain the concepts underpinning the anchoring phenomenon. Perhaps using the cup on platform as the anchoring phenomenon of the presentation could serve to focus people's attention into understanding that particular phenomenon, minimizing the misconception where audience members conflate gravity with rotational motion.

In the auditorium presentation, as the presenter, I could hypothesize various explanations for the anchoring phenomenon, then test each of these explanations via the other demonstrations. The idea of testing out different hypotheses for the same phenomenon is similar to what Muller (2008) studied —where competing hypotheses were proposed for the same demonstration. This approach could conceivably dispel the alternative hypotheses that lead to misconceptions.

The anchoring phenomena approach I took echoes the approach taken by the Fusion Science Theater (Cantor, 2015; Kerby et al., 2010), which centers around exploring a single scientific question throughout the entire presentation. However, instead of centering my approach around a single scientific question, it centers around a phenomenon—from which

questions and hypothesis arise. Furthermore, my approach uses more demonstrations to extend beyond understanding the original phenomenon. This was an important element for me, since restricting the demonstrations to those that just explained the cup on platform phenomenon would introduce yet another variable—that of the limiting number of concepts covered. For my study, roughly half of the current demonstrations could serve to explore and explain the cup on platform demonstration, while the other half of the demonstrations could serve to extend the concepts of rotational motion beyond the cup on platform demo.

Since I wanted the pre-RQ6 and post-RQ6 experiments to use the same set of demonstrations, hitting the same number of concepts, I used all the current demonstrations and rearranged them as shown in Table 16. Four demonstrations that were not related to the anchoring phenomenon remained at the very end, while the first five demonstrations were all incorporated as a method of understanding the anchoring phenomenon. The very first demonstration of this post-RQ6 presentation was the cup on the platform.

I continued using both a control presentation and a presentation with mental and physical engagements, so I had to differentiate between the versions. In the control version, I hypothesized out-loud with the audience that the cup needed a high speed to stay on the platform and then that speed kept the objects stuck together. In the mental and physical engagement version, I asked the audience what factors might cause the water to stay in the cup. The audience normally came up with the idea that speed played a role. If the audience didn't come up with speed as a factor, then I would pose the question as to whether speed played a part in the water staying in the cup.

Table 16. Demonstration order changes

Pre-RQ6 (initial) demo order	Post-RQ6 demo order
1. Tablecloth	Cup on platform (originally 4) - Anchoring Phenomenon
2. Ball on Car	Twirling Stick (originally 3)
3. Twirling Stick	Tablecloth (originally 1)
4. Cup on platform	Ball on Car (originally 2)
5. Ball on turntable	Ball on Turntable (same location)
	Repeat Cup on Platform (originally 4) a second time
	Add item to bottom of Cup on Platform demo 5B
6. Person on turntable	Person on turntable
7. Tire on Ground	Tire on Ground
8. Tire on hand	Tire on hand
9. Tire and Turntable	Tire and Turntable

The second demonstration then explored whether the cup was going fast by doing demonstrations on the speed of items in circular motion—indeed, it was going fast. The third demonstration explored whether items that were going fast tended to stick together–by exploring if yanking a tablecloth quickly caused the items to stick to the tablecloth (it does not). The fourth demonstration explored what would happen to an item going in a straight line if the item carrying it stopped (the item keeps going). Finally, the presentation explored what would happen to a ball if it was let go on a rotating platform—would it be pulled towards the center of the platform or go outwards (it goes straight outward in a tangent).

After two presentations, I added one more demonstration (called 5B in Table 16) that asked what would happen to an object on the other side (the outside) of a platform—bringing the situation closer to the extension question of what would happen to humans on the outside of the earth if the earth spun faster. This additional demonstration utilizes a situation closer to the situation tested by the question about a spinning earth. The final demonstration order and reasoning is further detailed in Appendix H.

I maintained this demonstration order for the remainder of the study. The final process for tackling RQ6 is shown in shown in Figure 8. This design–based research process yielded three categories I could examine for misconceptions: Pre-RQ6 demonstrations, transition

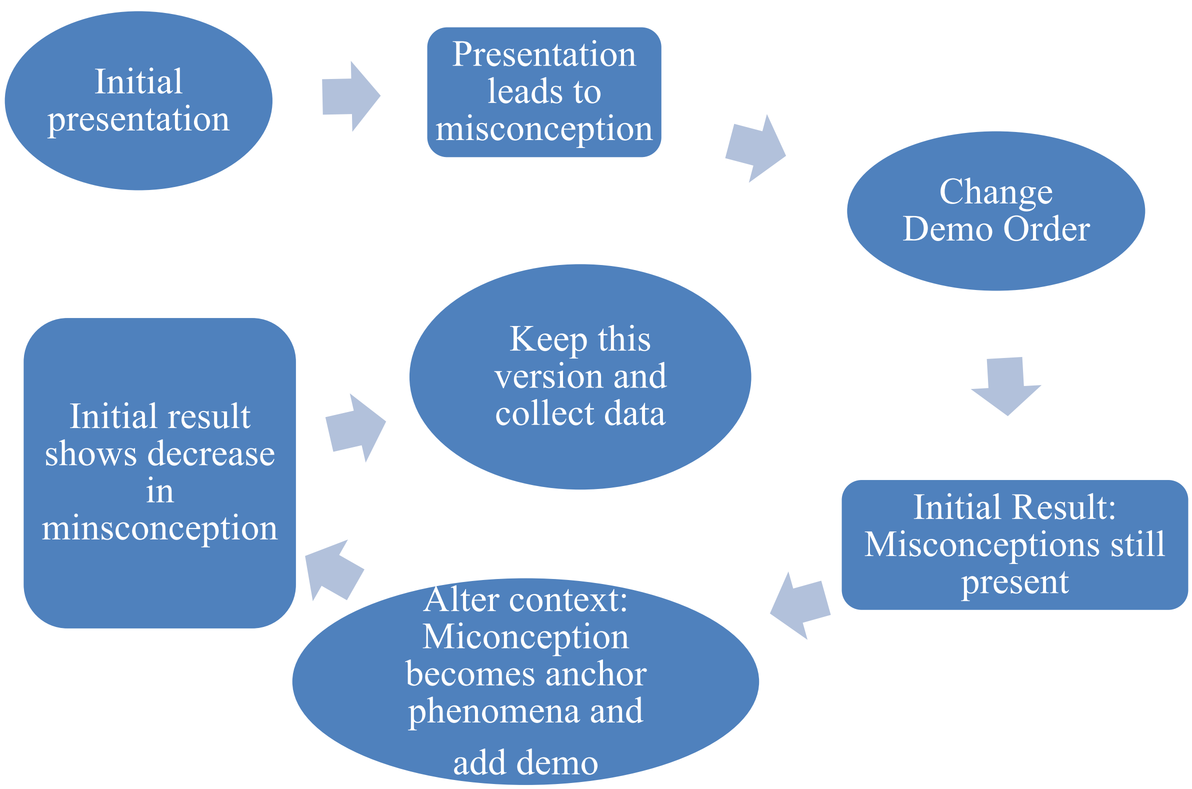


Figure 8. Final RQ6 iteration approach

demonstrations (occurring during the iterative process), and Post-RQ6 demonstrations that kept the same order and number of demonstrations.

The addition of RQ6 changed the overall data collection model since there were now pre-RQ6, transition RQ6 and post-RQ6 data groups. Since RQ1-RQ5 are nested within RQ6's intervention, this produces a nested research approach that is fully detailed in Figure 9.

General Quantitative Data Analysis

I analyzed the pre/posttest data using matched pair analysis using IBM® SPSS® Statistics version 26 for each condition. Concurrently, I analyzed post-only survey data using a t-test. Cases with missing data were eliminated on a case-wise basis. I conducted the pair analysis on raw data as well as on normalized gains (score increase divided by the possible score increase), though I report on the analysis on raw data since there is some dispute about whether normalized gain analysis seems to indicate those with stronger backgrounds have higher growth (Coletta & Phillips, 2005; Korff et. al, 2016) and the results were only nominally different for content gains. Although the multiple paired sample analysis will raise the chance of a type I error, where I erroneously discard the null hypothesis, I was not able to run a MANOVA without violating normality assumptions. Since a MANOVA was not a viable option, I utilized the ANCOVA, ANOVA and Chi Square for varying elements of data.

Each pre-post question was considered separately, except for four content questions—which were considered as a group. To deal with the missing data, I first analyzed the missing data to see if it was random. Each category of data (pre/post-test content data, pre/post-test participation test, and posttest descriptive attitudes test) was analyzed for missing content by assigning a dummy variable for each category (age, group, presentation format) of data. Missing data in that category resulted in a 0 assigned to the dummy variable, while the presence of data

Figure 9. Data collection interventions

resulted in a 1 assigned to the variable. The dummy variables were compared across "age" and "social group" "format of presentation" via a chi-square to check for patterns in the missing data.

Quantitative Data Analysis: Content (RQ1, RQ2)

Since one focus of this research was whether the physical and mental engagements produce significant changes in content understanding, I utilized paired samples test, and an ANCOVA using the physical and mental engagements as the independent variables, the net content gain as the dependent variable and the pretest score as the covariant. The ANOVA is a test run to see if the variance between experimental conditions is beyond the random variance that would naturally occur. The ANCOVA expands this test to consider other covariant factors that could affect the test. In this case a covariant factor was the initial score. This takes into account affects from the pretest score which could act as a predictor variable for the posttest score. Since normality issues plagued the ANCOVA, I switched to the non-parametric Kruskal Wallis ANOVA (1952) test to see if the ANCOVA result was reliable.

The data were analyzed as a full data set. Then, to ensure the personal context variables of age, and group did not change the results, the data were analyzed to see if there was a difference due to age ranges. Next the data were re-analyzed with a sub-sample that only included family groups composed of children under 12 years old and adults over 25 years old who had not previously seen the presentation.

Quantitative Data Analysis: Attitude (RQ3, RQ4)

Since another focus of this research was whether the physical and mental engagements produce significant changes in attitudes, and specifically the desire to participate in science, data was analyzed in a manner similar to the quantitative content data analysis. I utilized paired

samples test, along with the non-parametric Kruskal Wallis ANOVA (1952) test to determine significance.

The data were analyzed as a full data set. Next, the data was re-analyzed, removing all pretests that ranked the desire to participate as high as possible. Finally, to ensure the personal context variables of age, and group did not change the results, the data were analyzed using ANOVA and paired samples tests to see if there was a difference due to age ranges.

Quantitative Data Analysis: Interpretation (RQ5)

Since another focus of this research was whether the physical and mental engagements produce significant changes in the manner participants interpret the presentation, a single multiple choice question on the posttest involved what the presentation caused audience members to think. Possible answers included: “Science is more useful than I thought,” “Science is more fun than I thought,” “Science is something I would like to do more of,” and “Scientists are smarter than I thought.” These phrases correspond to Szechter’s attitude instrument (2009). To analyze this data a chi square test was conducted to look at the distribution of answers as compared with the presentation format, and an additional chi square was conducted to see if age range or social group affected the distribution of answers in a significant manner.

Quantitative Data Analysis: Misconceptions (RQ6)

To test to see whether a misconception was generated (RQ6) I analyzed for the three categories of redesigned formats (pre-RQ6 intervention, transitional, and post-RQ6 intervention) to see if the presentation was generating a misconception. I analyzed the data using a pre-post pairwise comparison test with the particular misconception generating a 1 and all other answers generating a zero. Next, I then subtracted the pretest from the posttest resulting in a net change of misconception score yielding a total from -1 to +1 depending on the pre and post answers. I

analyzed the resulting net change for the three formats using the non-parametric Kruskal Wallis ANOVA (1952).

The data were analyzed as a full data set. The data were the re-analyzed by presentation format to see if there was an effect due to the presentation format. The re-analysis consisted of the pre-post pairwise comparison test. Then, to ensure the personal context variables of age, did not change the results, the pre-RQ6 intervention and post-RQ6 intervention paired tests were re-run using pairwise comparison tests with sub-groupings by age to analyze whether age was a factor.

Qualitative Data Collection: Group Interviews

Content and attitude inventories reveal only limited amounts of information about participants' experience attending a presentation. To better understand how audience members interpreted the different experimental conditions, and to better answer RQ2, RQ4, and RQ5, I conducted group interviews at least once for each experimental group at LASM.

At the end of each presentation, I asked for one social group (if available, a family group) to participate in an interview that was recorded for research purposes. Interviews varied in length, but were expected to take 15-45 minutes; therefore, interviewed groups' members were offered the chance to win a $40 Amazon gift card for participating in the interview.

I chose to interview social groups with people who materially participated the engagements and did not immediately get up to leave. Those individuals were chosen in order to maximize the likelihood of interviewees talking freely. For example, a group who had a member come up on stage for a physical engagement, or a group who had a member call out a prediction for a mental engagement would be chosen over other groups whose members did not participate. In the case where multiple groups materially participated in engagements, I asked the group that

was closer to the front of the audience to participate in the social group interview. If the group refused and another participating group was still in the auditorium, I would ask that group for an interview. In the case of the control presentations, I chose social groups that seemed more engaged as shown by their apparently paying attention to the presentation itself, those that came to the stage to try out a demonstration afterwards, and those that were closer to the front of the audience.

To understand the effects of the survey instruments themselves, I interviewed one additional focus group for the control group where I did not administer any of the pretest and posttest surveys for that group. I realized that the surveys might act as a form of mental engagement; therefore, I see this particular focus group interview as a means of understanding whether the pretest and posttest surveys alter the audience members' states of mind. I decided that if differences were detected, I would conduct more interviews of audience members without the pretest and posttest, but this was not necessary.

The chief purpose of each social group interview was to better understand how the audience members interpreted the presentations they attended. This interview was primarily related to answering RQ5. During the interviews I asked what they thought the presentation was about, what they liked about the presentation, what they disliked, what they thought it was about and what they thought about the general approach of the presentation in general. The complete interview protocol for these interviews can be seen in Appendix F.

With social groups, it is entirely possible that different social groups give such disparate answers that they are incomparable due to the makeup of the particular social groupings. To minimize this possibility, I originally invited social groups back to see similar presentations that utilized different engagements. Unfortunately, few social groups were easily scheduled in this

manner—many groups promised to come back only to back out at the last minute. Thus, for repeat visitors, I ended up with just two groups that attended multiple presentations and participated in interviews both times, and one group that attended twice and was interviewed the second time. I also had my own son (age nine to ten) watch three different format presentations and was interviewed after each presentation to help compare across presentation formats.

Qualitative Data Analysis

The group interviews investigated how people interpreted the presentations, so they may be considered a phenomenological category of research. Since I am investigating a phenomenological element, I approached the qualitative analysis in a method similar to Douglass and Moustakas' (1985) heuristic inquiry approach. My approach wasn't as comprehensive as Douglass and Moustakas' (1985) approach since their approach was designed for a purely qualitative approach.

I transcribed the interviews using ExpressScribe, software that allowed me to slow down the interviews while transcribing. I sometimes used Amazon Web Services computer transcription to do a rough transcription, then I personally edited the rough transcriptions through ExpressScribe. I then coded the focus group interviews. I then coded the focus group interviews. I utilized TAMS Analyzer software v. 4.49 to label and keep track of the common and disparate themes among the interviews and to organize the interviews into thematic codes.

When coding, I started by listing expected codes based upon listening to the interviews. Then as I reviewed the transcripts, I added codes, and began to hierarchically refine the codes so that the top–level code was for a general concept, and the secondary code would indicate a subset within that general concept (Weinstein, 2010). For example, many interviewees felt that the presentation was interactive, but what each interviewee called "interactive" varied. Thus, the

interactive code had five subcodes. The code Int>cards indicates that the interviewee thought of the presentations as Int(eractive), but when probed by the interviewer, the interviewee expressly talked about the Plickers® Cards quiz as the interactive element. After establishing these codes, I reviewed each transcript again through an iterative process, looking over earlier interviews to put in codes that were established or refined in later interviews. This yielded 34 thematic codes by the end of the coding process (Appendix I). This approach was similar in nature to Glaser's constant comparative methodology (1965), as I coded and recoded the data in a cyclical method refining the codes.

In addition to the 34 thematic codes, I also created context codes which identified whether the interviewee was a child or adult, whether the interviewee identified as male or female, whether the presentation occurred before or after the RQ6 intervention and what the presentation format was that the interviewee. All interviewees except one were in social groupings, so I did not code for that. Context coding commenced after initially coding all the interviews, in order to minimize any bias that seeing the context codes could conceivably produce when coding. I used the four context codes which allowed me to cross compare to see if there were differences or similarities in codes between the interview groups (Appendix I).

Next, I utilized online word cloud software from www.wordcloud.com to quantize the word usage in all the interviews and produce word clouds for each presentation form. Word cloud software quantizes how often each word is used, then produces a graphic that changes the relative size of the word to demonstrate how often it is used. This software can also produce a word count of each word used. Word clouds were used as a guide to understand what might have changed between different format presentations. With the information from the word

clouds, I went back to review the interviews, refine the codes, and reengage in the final iterative coding process.

Not all the codes I created were useful for each research question, and some weren't used at all in the final analysis. Since I had six research questions, I added a final element of filtering the codes by research question. The qualitative data process of coding and recoding, then filtering the final codes is illustrated in Figure 10.

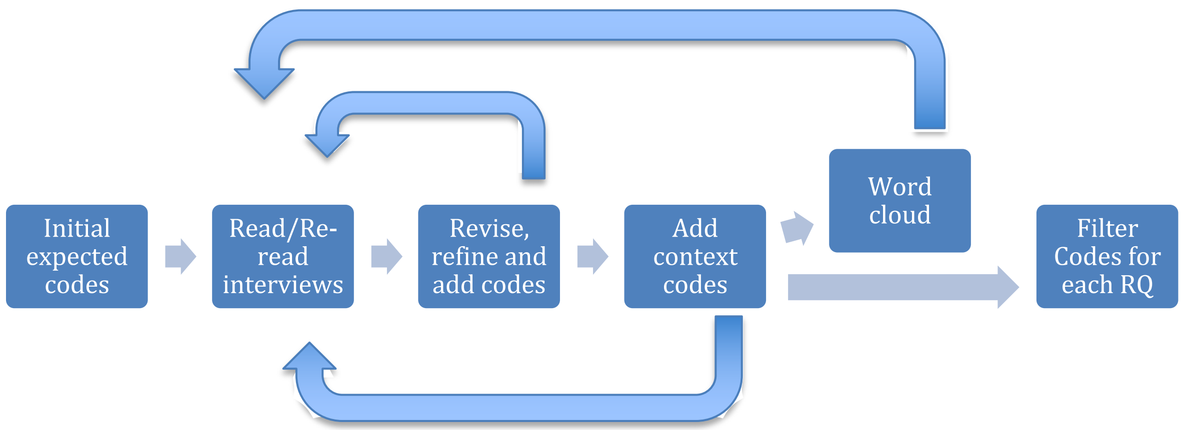


Figure 10. Qualitative coding

Data Analysis: Merging Quantitative and Qualitative Data

After analyzing the quantitative and qualitative data, I merged the two data types to come up with conclusions based upon the data. This merging of data is in keeping with Tashakkori and Creswell's (2007) definition of a mixed–methods design "in which the investigator collects and analyzes data, integrates the findings and draws inferences using both qualitative and quantitative methods in a single study or a program of inquiry" (p.4). These separate pieces of information were used to answer each research question as illustrated in Table 17.

Validity and Reliability Issues

Although mixed methods approaches address validity issues and reliability issues through

Table 17. Data corresponding to each research question

	Quantitative Data	Qualitative Interview Data
RQ1 Mental Engage Content RQ2 Physical Engage Content	Content: Pre/Post-Paired Samples, ANCOVA, ANOVA, descriptives	Specific information recall and evidence of causal reasoning
RQ3 Mental Engage Attitude RQ4 Physical Engage Attitude	Attitude: Pre/Post-Paired Samples, ANOVA, descriptives	Themes that reflect attitudes
RQ 5 Visitors' Interpretations of Engagements	Single posttest question Chi Square, Interview word cloud	Themes, concentrating on theme variations
RQ6 Intervention to prevent misconception	Pre/post intervention T-Test, descriptives	N/A

the use of multiple means of measurement, there still are error sources within this research. First and foremost, the interactive survey itself may bias the sample and may act as a form of mental engagement, since participants were asked questions within the pretest. The survey itself might invalidate the control group, making it similar to the Mental Only Engagement form. Although I could eliminate this early mental engagement by eliminating pretests, this would eliminate a valuable source of information—pretest and posttest. Therefore, I have chosen to keep the pretest/posttest format. To help check on whether I have invalidated the control group, I interviewed members of the control group with and without the quantitative pretest and posttest measurements to see if there were major departures in the interviews.

Another source of validity error is the quantitative measurement devices themselves. The

content pieces have not been thoroughly tested, therefore I relied on several experts in the field to review them, giving me some limited confidence in their validity. The attitude questions from Szechter's attitude analysis (2009) have been used before, but the questions were removed from the instrument and have not been individually vetted. I mitigate this somewhat through using qualitative data sources. In the end, I discarded Szechter's two attitude questions because they appeared to provide inconsistent results**.**

The qualitative sources all have generalizability issues; they also may suffer from researcher bias which should be mitigated somewhat when merged with the quantitative data sources. Furthermore, a presenter might alter the presentation in–the–moment resulting in a presentation not adhering to the form or leaving off demonstrations. Since I was aware of this possibility I reviewed the video–recordings of the presentation to disqualify presentations where the different engagements weren't faithfully implemented. In allowed some variation from the scripted form, since rarely is the dialogue identical. Variations that involved not implementing the form or not including a demonstration would cause the presentation to either be reclassified or discarded. One post-RQ6 presentation did have issues with the demonstration order, therefore it was discarded from the post-RQ data analysis. Since this research uses the presenter as the evaluator, it is conceivable that despite the video evidence, I, as the researcher, ignore subtle cues in the video that a separate external evaluator might have noticed.

RESULTS

Due to the missing data noted in the methods section, I first conducted a missing data analysis across all the data as described in the methods section. Only one significant correlation was found. The youngest group of participants were significantly more likely to have missing data on the content portion of the pretest. The content pretest consisted of a battery of four questions and either a stray finger across any one of the four questions or too much hesitation in holding up the card (perhaps due to indecision) resulted in a missing value for the content pretest. Unfortunately, more young audience members nullified some of their Plicker's® card answers by either holding a stray finger across their Plicker's® card or hesitating too long in holding up their card (perhaps due to indecision) or arriving too late. These missing data skewed data distributions. Since the under-12 crowd was the largest audience demographic, the missing data helped even out the age ranges, and isn't seen as a major impediment to the study.

This study investigated six main research questions; therefore, the reporting of the results is framed around those six research questions. Several similar questions are grouped together for clarity. First, I describe the results for both content-based research questions (RQ1 and RQ3) and then I report on the attitude research questions (RQ2 and RQ4). Next, I report on how audience members interpret the engagements (RQ5) and finally the research on eliminating misconceptions through redesign (RQ6). Research sometimes yields other information as well so that information is presented here as well under the section incidental results. The results section is therefore organized into five remaining sections:

1) Science Content Gains (RQ1, RQ2)
2) Science Attitudes and Beliefs (RQ3, RQ4)
3) Audience's interpretation of engagements (RQ5)

4) Redesigning to eliminate misconceptions (RQ6)
5) Incidental Understandings

Science Content Gains (RQ1, RQ2)

This section reports results for the following two questions:

RQ1: How does a presenter's mental engagements of the audience affect an audience member's resulting science content knowledge gained from a presentation?

RQ2: How does a presenter's physical engagements of the audience affect an audience member's resulting science content knowledge gained from a presentation?

Science Content Gains: Quantitative Evidence (RQ1, RQ2)

An examination of paired T-tests gives insight into whether presentations increase science content knowledge. Since this research study was expanded to include RQ6 (which examines whether this presentation could be redesigned to stop causing a misconception), additional variables existed in the trials. RQ6 required changing the order of the demonstrations. Table 18 presents paired T-test analysis among all variant groups including those with original demonstrations (pre-RQ6), those that took place when experimenting with the order of demonstrations (transition-RQ6) and those that took place after the new demonstration order was set (post-RQ6). All presentations yielded a mean a mean gain in content knowledge for audience members, and all but one were statistically significant increases. The data in Table 18 includes all scores, including those that topped out in the pretest (getting perfect content scores). If you exclude perfect pretests, the effect size rises, as can be seen in Appendix J. The mean change across all groups indicates that audience members generally learned content from the presentation no matter the engagement mechanism used.

Table 18. Pre/post–test content change by presentation format

Group	Mean Change (out of 100)	Standard Deviation	N	Sig. (p)	Cohen's D Effect Size
Control (all data)	19.8	21.3	58	<0.001*	0.930
Control (pre—RQ6)	23.3	17.6	15	<0.001*	1.325
Control (transition-RQ6)	25.0	15.8	11	<0.001*	1.582
Control (post-RQ6)	16.4	24.3	32	0.001*	0.676
Mental Only (pre—RQ6)	25.9	27.6	28	<0.001*	0.938
Physical Only (pre—RQ6)	20.8	25.5	30	<0.001*	0.817
Mental & Physical (all data)	20.6	28.4	80	<0.001*	0.728
Mental & Physical (pre—RQ6)	26.6	28.8	47	<0.001*	0.925
Mental & Physical (transition-RQ6)	2.8	23.2	9	0.729	0.120
Mental & Physical (post-RQ6)	15.6	26.4	24	0.008*	0.592

* indicates a statistically significant result

RQ1 and RQ2 question whether mental and physical engagements affect the knowledge gains. While Table 18 looks at all situations, the analysis doesn't specifically answer the research questions. To better address the research questions, we can look at the effect sizes across the four groups we are interested in re-categorized by engagement. There were differences in the effect size for the different engagements as seen in Table 19. Effect size (also known as *Cohen's D*) is the mean gain divided by the standard deviation (Cohen, 1962). All the results were statistically significant and were similarly large.

Table 19. Effect size of engagements in content

	No Mental Engagement	Mental Engagement
No Physical Engagements	.930 (p< 0.001)*	.938 (p<0.001)*
Physical Engagements	.817 (p< 0.001)*	.728 (p<0.001)*

p indicates statistically significance of result
* indicates statistical significance of result

The effect size data in Table 19 suggests that the presence of a physical engagements yielded smaller effect sizes than the absence of physical engagements. Although all the results in Table 19 indicate statistically significant gains in the chart, the difference between groups was not analyzed for statistical significance, thus the difference in effect size could be a random effect. One possible random effect is simply the difference in audience members' starting knowledge. For example, some people "topped out" getting perfect content scores prior to seeing the demonstrations—meaning the test was too easy for their starting knowledge. When individuals top out, the effect size for those individuals would be zero when their scores remained the same (which was typical). Removing individuals who start with perfect scores is one rudimentary control for the differences in starting knowledge. When these perfect scores were removed, and the effect sizes recalculated the scores shifted as seen in Table 20.

After removing the perfect scores, all the presentations have what Sawilowsky (2009) would define as 'large' to 'very large' effect sizes. Sawilowksy's work expands upon Cohen's (1962, 1992) work. Cohen (1962) developed the effect size measurement and gave the guidelines that effects sizes greater than .8 would be considered large. Looking at the effect

Table 20. Effect size of engagements in content—perfect pre-tests removed

	No Mental Engagement	Mental Engagement
No Physical Engagements	1.077 (p<0.001)*	1.28 (p<0.001)*
Physical Engagements	1.19 (p<0.001)*	.982 (p<0.001)*

p indicates statistically significance of result
* indicates statistical significance of result

sizes between tests with and without mental engagement, and those with and without physical engagements does not reveal any obvious differences.

To test for significant differences between the different groups, I ran an ANCOVA. The ANCOVA reveals that the presence of an engagement yielded a statistically insignificant difference as seen in Table 21. For the ANCOVA, homogeneity of variance was not an issue, but normality was, and attempts at normalizing the data failed which means the test itself is suspect.

Since the data were not normal, making the ANCOVA's results suspect, a Kruskal-Wallis

Table 21. ANCOVA content results

	Mean Difference (out of 100) (With engagement- without engagement)	Significance
Physical Engagement	3.68	.332 (not significant)
Mental Engagement	3.18	.395 (not significant)

ANOVA Test (1952) was conducted against the four types of presentations. The non-parametric Kruskal Wallis ANOVA test does not require normality, but it cannot deal with covariant factors. The Kruskal Wallis ANOVA test came out as insignificant as well (p = .406) indicating that no particular engagements were more likely to produce content increases than any other. The

statistical analysis results indicates if there is any effect on content gained from the engagements, then the effects are undetectable by the current tests.

Science Content Gains and Personal Context: Quantitative Evidence (RQ1, RQ2)

Analysis of personal context variables (age, grouping and whether the participant saw the presentation previously) were only analyzed as it might affect the research questions. Since age was viewed as a possible factor affecting learning gains, that was analyzed, and the results can be seen in Table 22. The data reveals no obvious affects in learning due to age groups, although

Table 22. Pre/post–test content change by age

age	Mean Change (out of 100)	Standard Deviation	N	Sig. (p)	Cohen's D Effect Size
Age 0-12 years old	20.6	25.4	51	<0.001*	0.811
Age 13-17 years	34.2	27.9	19	<0.001*	1.226
Age 18-25 years	21.9	20.9	8	0.021	1.048
Age 25+ years	19.3	25.8	109	0.001*	0.748

* indicates a statistically significant result

those who were between 13-17 years old showed a larger increase in content gain than any other age. A Kruskal-Wallis ANOVA revealed the change to be insignificant ($p = 0.391$).

Due to the difference in content gain for the middle age range (13-25), the relatively smaller sample size (n) the data was re-analyzed including only those who were <12 years old or over 25 years old and attending the presentation with family members. The resulting data in Table 23 grouped by presentation format and age range shows similar changes with some variation. Although the physical only effect size was smaller for adults experiencing the physical presentation, the group size was small, and the standard deviation was large, therefore

Table 23. Pre/post–test content change by age and presentation format (families)

Group	Mean Change (out of 100)	Standard Deviation	N	Sig. (p)	Cohen's D Effect Size
Control, age<12 & age >25 years	17.1	19.4	38	<0.001*	0.88
Control, age < 12 years	20.8	18.0	12	0.002*	1.15
Control, age > 25 years	15.4	20.1	26	0.001*	0.76
Mental Only, age<12 & age >25 years	24.0	27.5	25	<0.001*	0.87
Mental Only, age < 12 years	21.4	30.4	7	0.111	0.70
Mental Only, age > 25 years	25.0	27.1	18	0.001*	0.92
Physical Only, age<12 & age >25 years	15.8	27.9	19	0.024*	0.57
Physical Only, age < 12 years	16.7	20.4	6	0.102	0.82
Physical Only, age > 25 years	15.4	31.5	13	0.104	0.49
Mental & Physical, age<12 & age >25 years	17.1	25.6	54	<0.001*	0.67
Mental & Physical, age < 12 years	22.1	31.7	17	0.011*	0.728
Mental & Physical, age > 25 years	15.9	22.4	37	<0.001*	0.925

* indicates a statistically significant result

concluding that physical only engagement has less content impact on adults would be premature. When the mean change is examined the adult mean change for physical engagements is identical to the mean change for the control group, the difference comes in the standard deviation of the group. Furthermore, a Kruskal-Wallis of this reduced data set comes out as insignificant across

each format of presentation (p=0.678 or greater). The data in Table 23 supports the earlier conclusions that generally participants learn regardless of the presentation format. These results do not preclude differences in content gain due to presentation format and age range interaction, but nor do they substantially support the conclusion that there are differences in content gain due to presentation format and age interaction.

Science Content Gains: Qualitative Evidence (RQ1, RQ2)

The quantitative evidence for learning science content was supported by the 24 semi-structured group interviews of audience member who mentioned specific science content they felt they had learned during the presentations. Content mentioned varied, for example, one young boy stated, “I learned something new.” He continued, “Like, when a wheel is moving, it just keeps going straight, but if it’s not moving then it just leans to a certain direction,” which refers the tire on ground demonstration. In the tire on ground demonstration a rolling wheel stays upright and moves forward, while a wheel that isn’t rolling, or is rolling slowly leans to one side and falls over. The citing of specific instances went beyond gender lines, as a young girl mentioned “I learned that if you pull the tablecloth up, objects will come with it, but if you pull it straight, it will—it will just stay there.” Both child and adult interviewees stated things they learned in the presentations that gave insight into how the world works. One adult woman expressed surprise at what happened: “Like when I would have thought when you dropped your wallet [referring to a Plickers question that is addressed by the ball on turntable demonstration], it would’ve just went straight down,” instead of flying straight outwards in a tangential trajectory.

Science Content Gains: Connections to Formal Education Concepts

Adults and children who were interviewed connected content knowledge in the presentation to formal education concepts they had learned previously such as Newton's laws. For example, one woman said:

> I like that it explained concepts that you hear—you're talking about Newton like we have been reading. We read a quote about Newton this week. And so, you know you read something about you know a little tidbit about the guy, and then this fits in to a picture of illustrations or picture of some of the big concepts and breaks them down in something you can see in a small way.

Another man similarly stated:

> So, what it reminded me of was when I took my first physics class, and we learned the different laws of physics that I was taking those, and I was applying them to everything I saw. But now I've forgotten a lot of it.

Adults who were interviewed did this more often than children. Even when children connected learning to formally learned laws, they often dropped the conventional Newton nomenclature. For example, one young girl who attended the control presentation stated: "I learned more about the laws of motion themselves, because before I walked in the room. I didn't know very much about the laws of motion."

The presentations mentioned (but did not stress) vocabulary such as *Newton's laws of motion*, so interviewees could have been using language they remembered from the presentations instead of formal educational settings. Further, using vocabulary does not guarantee understanding of concepts the vocabulary represents.

Science Content Gains: Causal Reasoning

Unprompted, a few children even showed some causal reasoning skills—explaining their knowledge by providing reasons for why something happened as they explained how they understood phenomena. As one young boy explained: "When the wooden vehicle. I'm going to

say, um starts moving. The ball starts moving with it, too. But when it stops the ball can still move, so it still moves on to the wooden platform." He noted what had happened (the ball started moving and continued to move on the platform), and then gave an explanation (the ball can still move). Sometimes, these basic causal explanations by interviewees were incorrect, like the young boy who said he had gotten one [?] wrong because he misinterpreted a demonstration as relating to another situation: "If you're on a spinning platform and you stick… if you… and you're just straight in the middle and you stick your arms out, so it would be like your arms out. So, they're outside from your body. They…they make you go slower." The young boy refers to the person on turntable demonstration, where a person spinning around on a turntable sticks his/her arms out. He continued, "But when you bring them back in and [it] makes you go faster, and I thought it was the same on the carousel." So, he reasoned that horses on the outside would naturally go slower since if you are freely spinning and you stick your arms out your body spins at a slower rate.

This causal reasoning was not limited by gender or age, although young boys were more likely to explain the causal reasoning during an interview: four out of the six causal explainers were young (children), and five out of the six causal explainers were males. These causal chains of reasoning by interviewees occurred in all four forms of presentations.

Science Content Gains and Reasoning Effects of Multiple Presentations

One case of more advanced causal reasoning was exhibited by a young boy (my son) who had attended three different presentation forms. He attended the first presentation six months before the second and third presentations (which he attended on the same day). After his third show, he explained to me how he knew something, forgot it, then was able to reason again why his final answer was correct.

> Oh, also I relearned…I learned this before, but I forgot it…about the carousel. One of the carousel questions. It was: "which one is faster? The outside or the inside?" I was thinking the inside goes faster, but the outside makes a little more sense. Since if you think about the inside and the outside, they have to travel a different amount, but they have to meet, like it's around the same point. Um, if it was like lines, they have to meet in the same line at the same time. So, the middle, the center, has to go slower to get there; or the outside, it has to go faster, to get there.

Here the child says that "they have to travel a different amount," meaning different distances, because those points closer to the center of rotation travel in smaller circular tracks than those points farther from the center. He continued: "They have to meet in the same line at the same time" (because they are attached to the shared carousel platform). So, he finally adds in the resulting claim: "The center has to go slower to get there, or the outside has to go faster." This concept, taught in high school physics, was being grasped by a ten-year-old child. The child seems to have learned this by attending the presentation multiple times, supporting the idea that iterative exposures to knowledge may help people understand and retain that knowledge. The iterative nature of this learning seems to support the formal education concept of a spiral curriculum where topics are iteratively revisited.

Other attendees of multiple shows demonstrated an increased understanding of the content as well. A mother and her child attended a control presentation, then one month later attended a mental and physical engagement presentation. When asked the same question: "What did you think the presentation was about?" these were the responses:

> I think it was about mostly like motion and gravity (young boy, control presentation)
> It's about how speed—different speeds and different positions of objects can change. How you move and rotate. (young boy, attending mental and physical presentation one month later)

The first response was good—talking about motion, but it also talked about gravity—which many audience members erroneously state the presentation is about. The concept of gravity is conflated with

forces in general and particularly with circular motion, but the concept of gravity isn't explored in these presentations. The second response is much more detailed, going into specific concepts of motion.

Even adults, change their answers. One woman attended a presentation one month after her first time attending, and she gave these responses:

> Centrifugal force. (woman attending control presentation)
> Newton's laws of motion. (same woman, mental and physical presentation one month later)

Both answers seem good, though not detailed. The first answer uses a term specifically avoided throughout the presentation: centrifugal force. During the presentation, the terms centrifugal and centripetal force are avoided, since these terms can contribute to the belief that mystical forces arise when an item is spun around. As someone trained in physics, whenever I hear the words centrifugal force, I get the sense that someone is trying to sound intelligent—naming something they do not fully understand. They also seem to be attempting to connect items to terms they have previously heard. Generally, when people say "centrifugal force" they are referring to the idea that you are pinned to an object due to rotation—which is a factor of inertia, not a special force due to rotation. More specifically, a person is thrown outward on a spinning ride due to inertia, not due to centrifugal force. Meanwhile, the second answer of "Newton's Law's" utilizes something mentioned in the presentation: Newton's Laws of motion that can explain linear and rotational motion because of inertia.

Since there was a small sample size, I can't conclude that repetition yields larger science content understanding, but the conclusion seems probable. In the case of this research, repeat attendance led to interviewees revealing a more detailed understanding of content learned at the presentations.

Science Attitudes and Beliefs (RQ3, RQ4)

RQ3: How does a presenter's mental engagements of the audience affect an audience member's resulting attitudes towards science?

RQ4: How does a presenter's physical engagements of the audience affect an audience member's resulting attitudes towards science?

Science attitudes encompasses a wide range of beliefs about and feelings towards science. This research specifically looked at evidence of the audience members' perception of educational value, evidence of the enjoyment of science, and evidence of the desire to participate in science.

Beliefs About Science Learning in the Presentation (RQ3, RQ4)

Audience members across all types of engagement believed the presentations were enjoyable, and educational. For example, a man attending a both mental and physical presentation form concisely summarized what many interviewees mentioned: "Very good presentation, lots of fun, lots of laughs, and very informational." Sometimes audience members grouped the enjoyment and educational terms with a "but" as if enjoyment and education rarely go together, such as an adult woman attending a control presentation form who said: "It was really entertaining, but also informative." In general, the concepts of enjoyment and learning were intertwined when interviewees talked about the educational value of the presentation. For instance, one young girl attending a physical only presentation said: "I think it was fun to learn more about science." One man attending a both mental and physical presentation form summarized his thoughts by saying that the presentation provided for "very, very effective learning."

Surprising Real World Connections

The audience members expressed that the presentation demonstrations related to everyday things in the world that they would not have thought about otherwise. This included demonstrations that surprised them. The idea of surprises within these every day phenomena was well framed by one woman attending a control presentation: "Some things you never think about. Like when I would have thought when you dropped your wallet it would've just went straight down. I never thought about it like in cars and such – it just makes you think." Another woman specifically mentioned a demonstration that surprised her, "Like I didn't know the water wouldn't move side to side when you moved it. That was crazy." The woman was talking about the cup on platform demonstration, where not only does the water stay in the cup, and the cup stay on the platform, but the water level in the cup stays level with the platform. Being surprised by demonstration outcomes wasn't limited by age or gender, as one young boy attending a both mental and physical presentation commented on the same demonstration:

> When it was swinging around. That was like I did not know how those could, like, spin the cup was spinning around but it was not falling and none of it was spilling. That was so weird. I did not even know that those cups could do that.

Another young boy attending a control presentation stated that he enjoyed the presentation mainly because he liked "learning about how these things work, like this stuff that I never think about if I didn't come here." Here the child states explicitly states that the presentation focused his attention on items he would not have considered in the world.

Adults appreciated that real-world awareness, relating it to their past experiences, like the woman attending a control presentation who said: "I liked the explanations that were given because those were all things that I did as a kid. Experiments that I didn't really realize were experiments. You know and formal school and presentations reinforced that it is science."

Essentially the presentations framed science principles in a manner that allowed people to connect the science beyond the classroom, to the world they live in. For example, one woman attending a mental and physical form presentation related this to the exercise equipment at her workplace: “It made me think of other things throughout the day that just relate more to science. There’s some exercise stuff, and some equipment that we do…”

Multiple children appreciated the real world awareness as well. A young boy attending a control presentation explicitly made this connection: “I thought it was interesting to learn more about science and how stuff in the regular world works.” Here he seems to associate the presentation as taking place in the regular world instead of some classroom textbook, or experimental lab. A young girl attending a different control suggests a similar thing: “I think I learned something from it. I mean science is in everyday life—more than I already thought that it was.”

Some adults wanted to help their children make the connections between science and everyday life. These adults appreciated the use of everyday items in the demonstrations because they thought it would allow them to connect with their children around science at home. One man attending a control presentation said he specifically liked the presentation because “it was something that we could do again at home to get a better grasp of the different experiments.” One woman attending a control presentation framed this as an important element for her and other parents:

> I think that we, as parents are often looking for the reasons to explain why things work. And I…so it has something we can use that shows the scientific principle behind it. But then…So we’re often taking these concepts and trying to find them and say, “oh this is illustrating what we’re talking about.” So, I guess helping to make those connections.

This woman talked about how she would try to connect objects in the world to the science for her children, she continued stating that she liked connecting science principles to the phenomena

they encounter in the world. In her own words she generally wants "to know how this is relevant to…the world around us."

Quantitative Evidence: Desire to Participate in Science (RQ3, RQ4)

A paired-samples analysis of the pre/posttest Likert science participation question reveals no statistically significant increases in the desire to participate in science (see Table 24), but

Table 24. Effect size of engagements in desire to participate

	No Mental Engagement	Mental Engagement
No Physical Engagement	.117 (p= .300)	. 313 (p = .086)
Physical Engagement	-.076 (p =.691)	.042 (p = .661)

p indicates statistical significance of result.

there seems to be a non-statistically-significant but noticeable difference in effect size when there is mental engagement without physical engagement. In particular mental engagement without physical engagement is the engagement that is close to statistical significance. With this preliminary analysis, physical engagement seems to suppress the increase in desire to participate in science, although the effect is not statistically significant. However, this paired samples analysis does not look at the difference between audience groups' initial desire to participate in science, nor does it look at whether any differences seen are statistically significant.

To compare the effects of the different engagements, a non-parametric Kruskal-Wallis ANOVA Test (1952) was conducted to compare the four forms of presentations. An ANCOVA was not an option due to the non-normal nature of the data and unequal error variances. The Kruskal Wallis test came out as insignificant ($p = .610$) when all four engagement techniques were tested, indicating that no particular engagements were significantly more likely to produce desire for physical engagement beyond any other engagement.

The data on desire revealed “ceiling effect” issues—60% of the audience members ranked the desire to participate in science at the highest level prior to engaging in the presentation. A small minority of those rankings decreased from pretest to posttest, but most of the rankings stayed at the highest ranking. When those scores that “top-out” are eliminated from the analysis, then the sample is biased towards those that can be positively influenced, and a paired analysis shows that almost all groups show statistically significant increases in the desire to participate in science (see Table 25). This statistical measurement indicates that those who

Table 25. Effect size of engagements in desire to participate—perfect pre-tests removed

	No Mental Engagement	Mental Engagement
No Physical Engagement	.508 (p= .008)*	. 528 (p = .052)
Physical Engagement	2.041 (p =.004)*	.683 (p<0.001)*

p indicates statistically significance of result
* indicates statistical significance of result

have room to increase their interest are likely to become more interested in participating in science after attending a presentation. Although the presence of a physical-only engagement does show a significant increase in effect size, this effect size increase is likely a random effect due to the small group size (6). When a Kruskal Wallis ANOVA (1952) test is run on the data after removing scores that top-out, there are no statistically significant (p = .651) differences between the different presentation forms.

In summary, the statistical evidence suggests that people who can grow in the desire to participate in science do increase their desire to participate in science. The differences in engagements used by the various presentation forms did not substantially alter this effect.

Quantitative Evidence: Desire to Participate in Science and Personal Context (RQ3, RQ4)

Desire to participate in science increases were looked at as a function of age using paired samples analysis, as seen in Table 26. However, a Kruskal Wallis ANOVA (1952) test did not show significance (p = .076), although the Kruskal-Wallis ANOVA was close to significance. Once the perfect pre-test scores were removed the differences became much smaller as seen in Table 27, and the Kruskal-Wallis ANOVA was insignificant (p = 0.618). These results suggest that the personal context does matter, but elements such as age are relatively insignificant when compared with someone's prior desires and tendencies.

Table 26. Pre/post–test desire to participate change by age

age	Mean Change (out of 4)	Standard Deviation	N	Sig. (p)	Cohen's D Effect Size
Age 0-12 years old	-0.085	1.080	82	0.476	-0.021
Age 13-17 years	0.300	0.657	20	0.055	0.457
Age 18-25 years	-0.083	0.289	12	0.339	0.287
Age 25+ years	0.159	0.686	126	0.011*	0.232

* indicates a statistically significant result

Interpretation of Engagement (RQ5)

RQ5: How do audience members interpret and value presentations differently if the presentations have physical and mental engagements?

Table 27. Pre/post–test desire to participate change by age—perfect pre-tests removed

age	Mean Change (out of 4)	Standard Deviation	N	Sig. (p)	Cohen's D Effect Size
Age 0-12 years old	0.583	1.213	23	0.027*	0.481
Age 13-17 years	0.539	0.660	12	0.012*	0.817
Age 18-25 years	No Data, All	Pretests		Topped	Out
Age 25+ years	0.667	0.739	44	<0.001*	0.903

* indicates a statistically significant result

Quantized Interview Data: Enjoyment, Entertainment and Mental Engagements (RQ5)

Audience members generally reported thinking that the presentation was "fun," "cool," "educational," and enjoyed the "interactivity," no matter the type of engagement. The word used the most in every interview was "like," as in "I liked the presentation. It was nice. It was fun. It was interesting." (a woman attending a control presentation). This was the majority use of the term "like", but sometimes "like" was used to mean "similar to," or as a "placeholder." For example, a conversation between a mother and her daughter during an interview went like this: Mother: "What was neat about that?" Daughter: "Like it stayed on." When I analyzed all the words used and removed the word "like" as well as removing typical common words (of, the, etc.). I was able to see some differentiation in word usage between people attending the different engagements, as shown in the word clouds in Figure 11.

Figure 11. Word cloud of interviews grouped by form. Top Left: Control; Top Right: Mental Only Engagement; Bottom Left: Physical Only Engagement; Bottom Right: Both Mental & Physical Engagement

Word clouds use font size to show the relative use of commonly used words across the interviews (usage lists for the top words in each presentation are contained in Appendix K). Larger fonts indicate higher word usage. All presentations used demonstrations, yet the word demonstration was used more frequently by audience members interviewed following the control presentation (sixth most used word in the control), and the physical only presentation (tenth most

used word in the physical only), and less frequently by attendees of the both physical and mental presentations (nineteenth most used) and much less frequently (thirty-sixth most used) with mental-only presentations.

The demonstration word usage parallels the theme of *entertainment*. Although the word "entertainment" was not used much, it is interesting to note that it never came up following mental-only or both mental and physical presentations. The word "entertainment" came up four times following control presentations, and twice following physical only presentations. Interviewees used the term to describe how they felt about the presentation, such as the young girl who, after attending a control presentation, said: "I just liked it. I thought it was very *entertaining*," (emphasis added). Often an interviewee would put the word near terms such as fun, like a woman who stated: "I thought it was fun. I really liked it. It was interactive with the questions first, and then the demonstrations of those questions without giving it away. It was really *entertaining* but also informative," (control presentation, emphasis added). Sometimes the word entertainment would accompany the word "see" like when a young boy said "It was fun to see. It's *entertaining*—it was fun to see," (control presentation, emphasis added).

The word "see" was used extensively following the control presentations, such when a young boy who said: "I thought it was neat to *see* the demonstration" (control, emphasis added). The effect wasn't limited by gender, for example a young girl expressed a similar sentiment: "It made learning fun. It was interesting to *watch* and *see* it actually in action (control, emphasis added). Another young boy, while avoiding the word see, expressed similar sentiments after attending a control presentation: "It was a fun way to *show*—like *show…show*.. to learn a fun way to learn science," (control, emphasis added). See was tied with demonstrations for the sixth most commonly used word following the control presentation.

While in the presentations with any mental engagement, entertainment was never mentioned and "seeing" the demonstrations was only mentioned three times out of the twenty-nine 'enjoyment' coded sections. Even when audience members attending the mental engagement used the word see, it was often in context of other elements: "I think all of it was good. Yeah, doing it and seeing it and then asking questions," (woman, mental and physical).

The interviews were recoded to include an entertainment code to indicate that the presentation emphasized seeing a show. After the recoding, there were eight instances of the entertainment code within the control group (across four different interviews), three instances in the physical engagement group (in a single interview), one instance in a mental engagement group, and no instances in the mental and physical engagement group.

The use of the word "entertainment" in interviews, or the code *entertainment* does not indicate that the control presentations were more fun, as the theme of *fun* came up throughout all of the presentations. The difference was primarily the word choice that accompanied the theme *fun*. Across all presentations *fun* had considerable overlap—such as saying it was "cool" (young girl, mental-only and control; woman, mental-only; man, both mental and physical), or that the audience member "liked everything" (young girl, control), or "it was fun" (young boy, control). However, when mental engagements were present either in the mental only presentation form, or the Both mental and physical presentation form, the comments were often about the interviewees' general feelings towards the presentation, or what they specifically enjoyed. For example, one woman said: "It was more interactive instead of just being talked to. And it was upbeat. It was fun," (mental and physical), while a young girl just stated: "I loved everything," (mental). Enjoyment during mental only presentations was gender specific, as one young boy explained: "I didn't think I would like it at first. But I really did like it" (Mental and Physical).

Thus, the word usage and subsequent coding indicates that the interviewees viewed the control presentations (and to a lesser extent physical only presentations) more as entertaining demonstrations, and less as a series of scientific investigations.

Prediction as a Practice of Science: Mental Engagements (RQ5)

In the aforementioned Figure 12, the word "science" showed up prominently, being the first most common word used by interviewees following mental only presentations. Other engagements yielded lower usage of the word "science." "Science" was the fourth most used word by interviewees who attended a both mental and physical presentation, and it was the fifth most used word by interviewees who attended a physical only presentation. Audience members attending the control presentation had the lowest use of the word "science" (sixteenth most used).

The limited use of the word "science" within the control presentation and the increased use of words like "entertainment" and "see" may indicate that the audience interprets the presentations differently. More specifically control presentation audience members interviewed seem to see the presentation as more of a show and less of a scientific investigation. An analysis of the thematic content of the interviews reinforces this interpretation.

Although the word "science" was not used much by interviewees attending the control presentations, the theme of science was prevalent during all the engagements. A closer look at the theme of science revealed that there was a sub-theme, and only during the presentations that had mental engagements (either mental only or mental and physical and physical) did any audience members connect forms of questioning or prediction to the theme of science. For example, one young boy specifically called out the science practice of questioning: I "liked how you did the quest... How you did predictions like real scientists or hypothesis before" (mental-

only). The mental engagements seem to have connected the act of prediction with scientific practice. The connection between the act of prediction and science was encouraged at the beginning of the presentation as the presenter says: "As scientists we ask questions and make predictions."

Although the aforementioned child's initial comment explicitly referenced the mental engagement of predictions, the child continued, "Then you did what we think after, after which probably most people got it correct—I did not," which may reference the pre/posttest. Since audience members did not tend to differentiate between questions asked at the beginning of the presentation with those asked during the presentation it was difficult to disentangle whether interviewees whether interviewees were talking about the act of predicting what will happen in a demonstration, or the pre/posttest act of answering related hypothetical questions. Which element interviewees were specifically discussing at any moment may not be critical, since only interviewees who attended presentations with mental engagements (either mental only or both mental and physical presentations) made those connections.

In some presentations that used mental engagements (either mental only or both mental and physical presentations) the audience took to yelling out their predictions prior to each demonstration, which allowed easier differentiation. Children in particular seemed to "liked doing it" (young girl, mental only presentation). Most mental engagement audience members "really liked it was interactive with the questions first" (woman mental-only presentation). As one woman explained, the mental engagement of questioning and eliciting predictions was universally enjoyed because "It made you start thinking about what was gonna happen before it happened. So, when you did the experiment or the presentation, you were able to know if what you originally thought was right," (mental-only presentation). The act of thinking about an

experiment then conducting the experiment reflects scientific practice, which interviewees expressed an appreciation for: “I liked the scientific approach of… of making the prediction, and then doing the experiment, and then interpreting the results,” (man, both mental and physical presentation).

The act of predictions made one young girl reflect on the scientific practice from a diversity perspective: “And that’s the cool thing about science. That everyone has different predictions,” (mental-only presentation). This child seems to value the idea that people can come to science with their own thoughts and predictions.

Interestingly one audience member attending a control presentation suggested that we move the Plickers® pre/posttest questions to just before each demonstration, making it more like the mental engagement predictions conducted in the mental-only and the both-mental and physical presentations:

> Have you ever done the presentation where instead of putting it…front loading all of the questions doing all the experiments and then doing that…doing like one concept kind of at a time and building it? Like question, demonstration, demonstration concept and then revisiting the…the question? I think yeah, it would have added a different component. Having the actual interaction during the presentation. I think that would have been a nice touch. (woman, control presentation)

This particularly thoughtful audience member began the process of connecting the pre/posttest to the scientific practices, yet she never explicitly connected the questioning with scientific practice. This audience member’s suggestion lends credence to the value of using mental engagements where audience members predict what would happen immediately prior to the demonstration.

Realization of Presentation Techniques from Multiple Presentation Attendees (RQ5)

One audience member (my son) attended a mental-only presentation, then six months later attended a control presentation and almost immediately afterwards attended a presentation using mental and physical engagements immediately afterwards and could tell that the engagements were different. According to him, "The main difference is the volunteering. But the third one [both mental-and-physical presentation] I also noticed how you ask questions not at the beginning and end, but in the middle a lot more, and like it was a little different." If he is typical of other attendees, then audience members would also notice differences if they saw presentations with different engagements, back to back.

Another set of audience members saw different presentations separated by a month long time. A mother and her child saw a control presentation then saw a both mental and physical presentation. When asked how the presentations were different, their comments tended to concentrate on the specific demonstrations. For example, a young boy said "I liked how, since only certain people are chosen at a time. We actually had like a mini version of the table with the cloth except it was just with a flash card and a penny" (both mental and physical presentation one month after seeing a control presentation). His guardian responded:

> Yeah, that was different. So, where everybody got to do their own. So maybe the people who weren't as outgoing and not willing to go up one stage had the opportunity to do it right there. It's like their own private experiments. (woman, both mental and physical presentation one month after seeing a control presentation).

There seems to be recognition of other differences between the two engagements. For example, the same two people were asked what they thought of the new Mental and Physical engagement approach and the boy responded: "I liked how we could actually get up and do it instead of having to sit there the entire time," (both mental and physical presentation one month after seeing a control presentation). His guardian agreed: "Yeah, I think changing it up keeps

you engaged," (woman, both mental and physical presentation one month after seeing a control presentation).

When the interviewees had more than a month in between presentations they did not recall the differences as completely. One audience member who was interviewed revealed that he had seen this presentation earlier within the year. Unfortunately, I could not determine which presentation he attended, because he didn't recall when he attended the presentation. When asked about differences between the presentations, he responded

> I noticed that… I think as far as I remember, last time when I was here you don't put a penny and a paper. So, I think that this is also somehow very helpful. It's like, it's something. It's like an audience can just do this by themselves. (man, both mental and physical presentation)

This audience member seems to recognize the addition of the penny on the card demonstration. All presentations with physical engagements (physical only and both mental and physical presentations) use this demonstration. Despite this, he never mentioned that the physical engagement presentation was different because audience members were brought up onto stage as volunteers; therefore, there are three reasonable conclusions for this lapse of recall:

1) The audience member saw the penny demonstration and forgot he had seen it.
2) The audience member came in over fifteen minutes late during the last time he attended the presentation, and therefore he missed the penny demonstration. He did not mention missing part of the prior presentation, however.
3) The audience member attended a presentation without a physical engagement. This is quite likely as half of the presentations did use any physical engagements. He didn't mention anything about the use of volunteers on stage—which occurred during all presentations with physical engagements (either the physical-only or both mental and physical presentations).

When audience members see the same style presentation, they start recalling differences that weren't present, if asked "What, if any, differences did you notice between presentations?" Individual audience members assumed that demonstrations had been added when they hadn't. Essentially the question about differences seems to elicit the response in the audience member to look for differences, even though they might not exist.

Quantitative Sample and Physical Engagement (RQ5)

A forced-choice sample question asked all the audience members taking the pre/posttest to finish the following statement:

This presentation made me think

A) Science is more useful than I thought.

B) Science is more fun than I thought.

C) Science is something I would like to do more of.

D) Scientists are smarter than I thought.

An answer of A was classified as *utility* because the presentation made the audience member think about science being more useful. An answer of B was classified as fun because the presentation made the audience member think that science was more fun. An answer of C was classified as interest because the presentation made the audience member more interested in doing science. An answer of D was classified as respect because the presentation made the audience member increase in the respect for a scientists' intelligence.

The responses distributed as percentage of response for each type of presentation are shown in Figure 12. We can compare the results for each multiple choice answer directly by

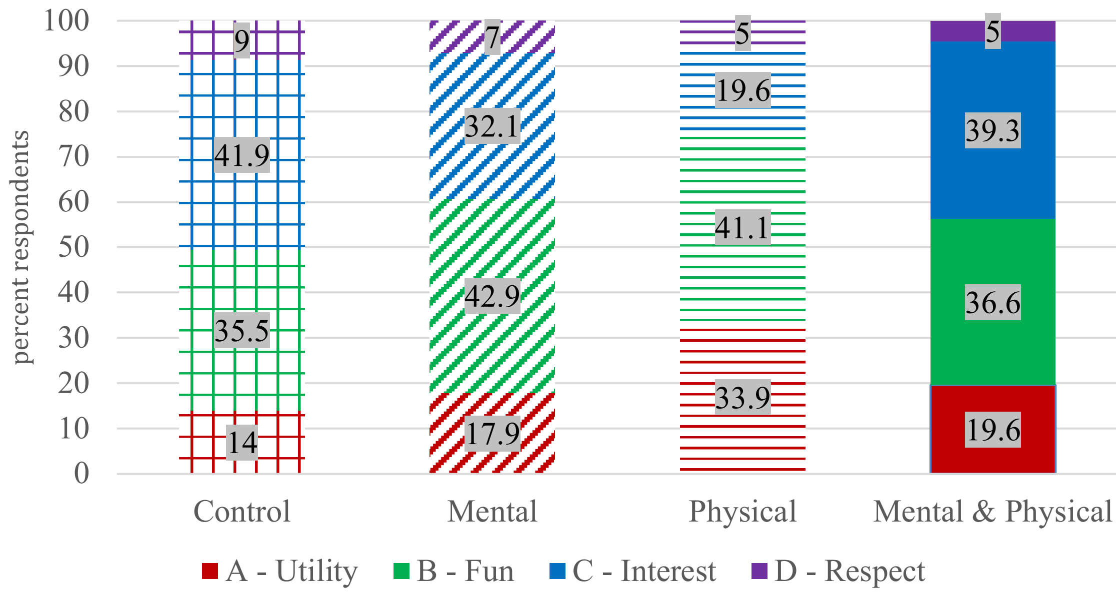


Figure 12. Response grouped by presentation format

lining up the A, B, C, D answers side-by-side. The charts then look like Figure 13 and suggest a correlation between the physical engagement and increases in A (the idea that science is useful) at the expense of C (the idea that one would want to do science). A Pearson Chi-Square test comparing the presentation forms against the distribution of answers yielded a p value of 0.088, under what would be considered statistically significant ($p<0.05$ is considered significant), but larger than any effects due to age ($p=0.30$). The p value indicates there are no generalizable results; however, this p value means that there is roughly a 9% chance a distribution could occur in a random group of people. A 9% chance means an unlikely (less than 1 in 10) result, which could indicate that there is a difference in how people interpret the different engagements—

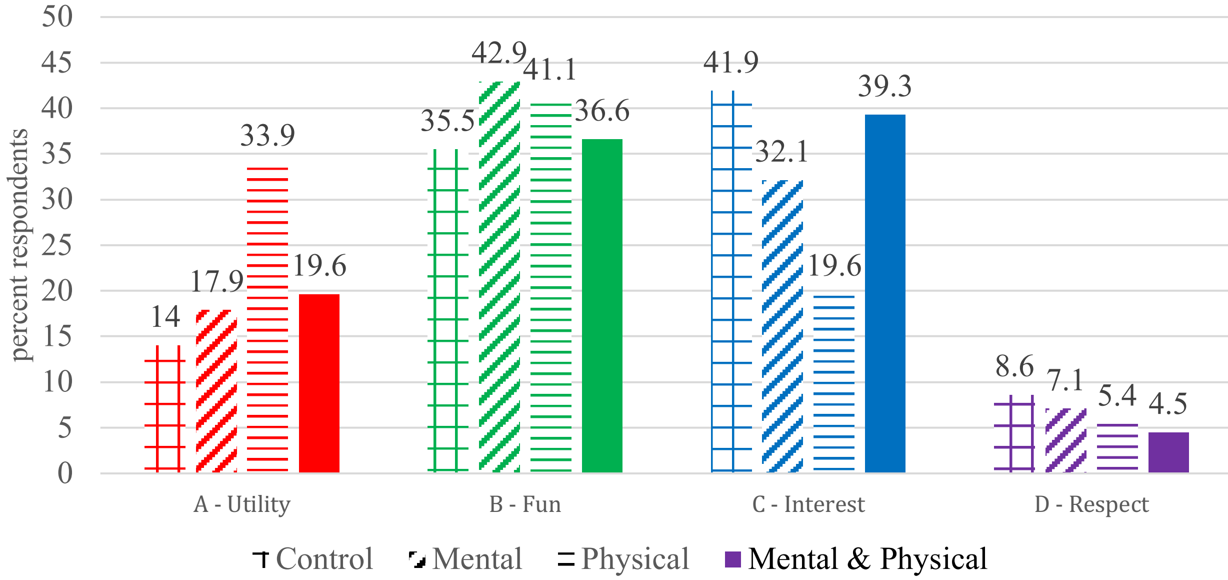


Figure 13. Response grouped by answer

particularly the physical engagement—but that this question doesn't quite capture that difference.

Merging Quantitative and Qualitative Data: Interpretation of Engagement (RQ5)

The evidence laid out suggests that interviewees attending control presentations described them as if they were entertaining shows, while interviewees attending presentations with mental engagements were more likely to describe the shows in terms that emphasized their scientific aspects. By integrating the quantitative aspects of word clouds, and the post survey with the qualitative coding, I was able to synthesize the research into a plausible understanding of how audiences interpreted the different presentation formats. This synthesis of results limits the final direct implications of the research and parallels step three (delimiting the theory) of Glaser's (1965) constant comparative method. Having combed through the qualitative and quantitative data to determine the differences between the presentation forms, I now merged those results together in one illustrative diagram contained in Figure 14.

In Figure 14 each separately colored quadrant signifies a presentation format. The black quadrant is the control—utilizing neither mental nor physical engagements. I symbolically chose black because in color theory black indicates the absence of light, paralleling the absence of mental and physical engagements. The blue quadrant indicates mental engagement. The red quadrant indicates physical engagement. The magenta quadrant indicates both mental (blue) and physical (red) engagements are present, because blue and red light combine to form magenta. In each quadrant, near the middle of Figure 14, the engagements used are listed, along with the actions expected of the audience members based upon the engagements used: observing, doing, and predicting. Between the upper and lower quadrant, is a double arrow indicating the general science communication strategy that is emphasized. In the black (Control) quadrant, the primary strategy used is one of sharing information, which requires the user to observe the demonstrations that the presenter is sharing. The control presentation grows out of the idea that the presenter has knowledge that (s)he wants to inform the audience member of. The control presentation uses a *deficit* model of science communication, since the presenter assumes the audience member has a deficit of knowledge, and the presenter can fill in that deficit, leaving the audience member full of information (Bucchi, 2008; Fogg-Rogers et al., 2015; Ko, 2016). In the magenta quadrant, the audience member is asked to be more of a directed cocreator of content, actively predicting the results and doing certain tasks. Co-creation of content parallels the science reform efforts embodied in the Next Generation Science Standards (National Research Council, 2013), 5-E (Bybee, R. (2002), and modelling approaches (Hestenes, 1997) which attempt to displace lectures with hands–on, minds–on experimentation and discussion.

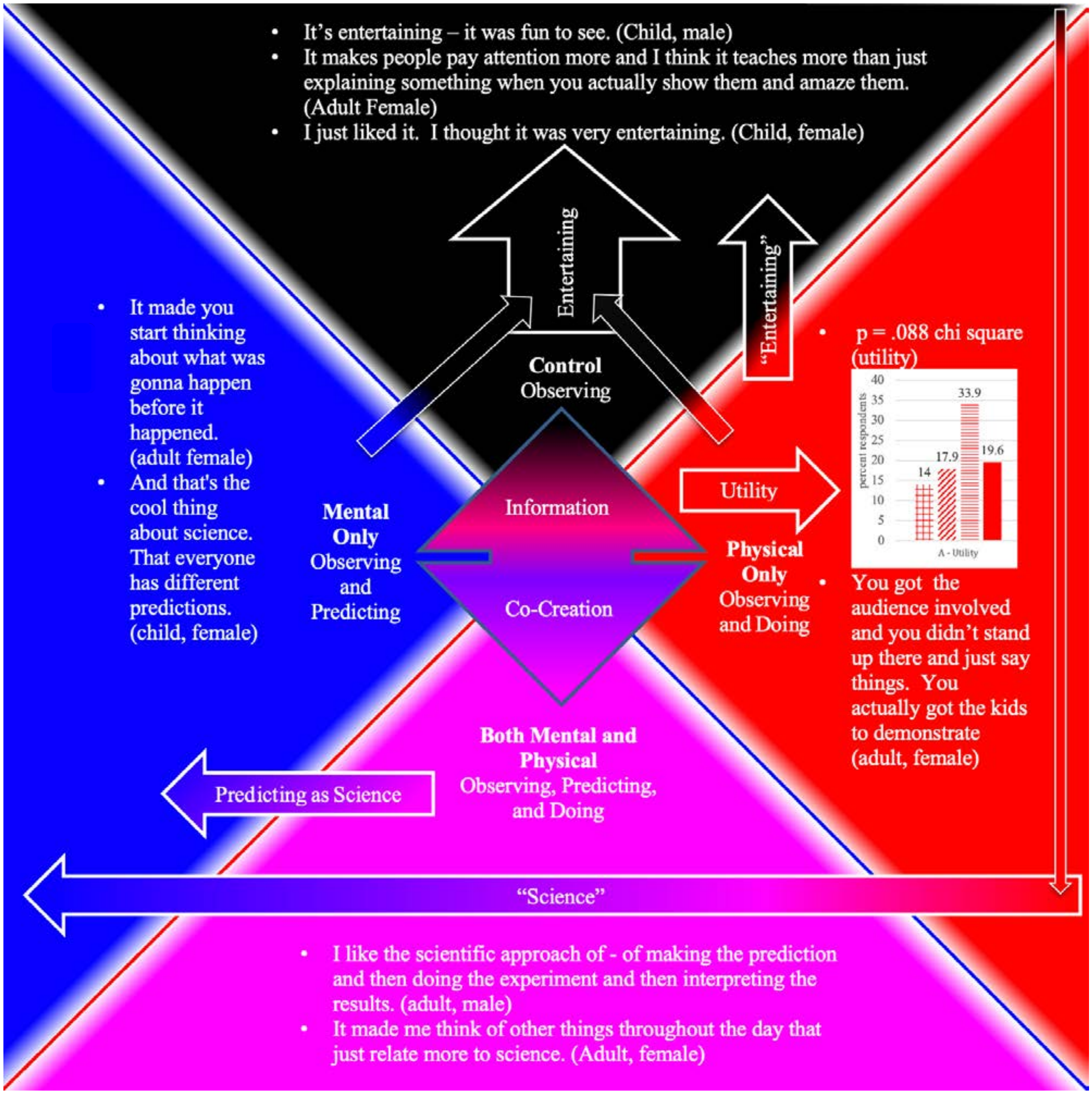


Figure 14. Engagement data synthesis

Within each quadrant are white-bordered arrows indicating the research results that are specific for those quadrants. The arrows cross the quadrants in which the research results pertain, but they also point to the quadrant for which the research results were the strongest. For example, the word "entertaining" resides in both the physical engagement presentation and the

control presentation because “entertaining” was used to describe both presentations. The control presentation was called “entertaining” more often, thus the arrow primarily resides in and points to the control presentation. Meanwhile the other two quadrants showed no evidence of being called “entertaining,” therefore the arrow avoids those quadrants. Similarly, the theme of entertainment mainly resides in the control, but had small overlaps into both the mental-only and physical-only presentation forms, therefore, small arrows go from the mental-only and physical-only presentations to the control presentation.

For the science aspect the research demonstrates that the word “science” was mentioned more by people attending the mental-only presentations, than the then the both mental and physical presentations, or the physical-only presentations with the word science falling dramatically in word usage by those attending the control presentation. Therefore, a small arrow emanates from the control presentation leading to a larger arrow that emanates from the physical-only to the mental-only quadrant, spanning the both mental and physical quadrant.

The predicting as science arrow refers to the theme expressed by audience members in the mental-only and both mental and physical quadrants, though more utilized in the mental-only quadrant. The final arrow is the utility arrow, which comes from quantitative assessments and fell only in the physical engagement quadrant.

Some examples of quantitative and qualitative data are listed in each relevant quadrant. For example, the control quadrant contains a quote from an interviewee: “It’s entertaining, it was fun to see” supporting the “entertaining” and entertaining research results in the control quadrant.

Redesigning to Eliminate Misconceptions (RQ6)

RQ6: For this particular presentation, can the presentation engagements of audience members be redesigned and reordered to prevent the presentation from causing misconceptions that were found? If so, how?

The misconceptions question data were analyzed for the three categories of redesigned formats (original, during the change and post-change) to see if the presentation was generating a misconception. A pairwise comparison showed that the pre-intervention presentation caused a misconception ($p < .001$, mean difference .22) as seen in Table 28, while the Post-Intervention and Intervention Transition did not. A Kruskal Wallis ANOVA test on the effect of the pre-intervention, intervention-transition and post-intervention presentations yielded a statistically significant result ($p = .009$). The statistical analysis indicates that the difference between the pre-intervention, the intervention-transition and the post-intervention was statistically significant and generalizable. The intervention had worked to stop causing, or at least reduce the creation of the misconception!

Table 28. Cause of misconception and intervention

Group	Mean Change (out of 1)	Standard Deviation	N	Sig. (p)	Cohen's D Effect Size
Pre-intervention	.219	0.497	160	<.001*	0.44
Intervention Transition	.037	0.518	27	.713	0.07
Post-Intervention	.022	0.515	91	.685	0.04

* indicates a statistically significant result

Surprisingly though, the Intervention-Transition category showed no significant generation of misconceptions in Table 28, suggesting that the full redesign may not have been necessary. The first intervention transition involved changing the order of the demonstrations. Perhaps simply changing the order of the demonstrations, may have been enough to eliminate the cause of the misconceptions the presentation generated.

The Pre and Post intervention results did not seem to significantly interact with the presentation format as seen in Table 29. Table 29 shows that all the presentations in the pre-intervention group seemed to cause the misconception (they were all statistically significant effects). Table 29 also shows that none of the intervention transition or post-intervention groups had statistically significant effects—therefore they do not cause the misconception in a statistically generalizable manner, indicating that the creation of a misconception was relatively independent of the engagement used in the presentation.

Redesigning to Eliminate Misconceptions and Personal Context (RQ6)

The data were analyzed to see if misconceptions were only generated in certain age groups. Table 30 shows the paired t-tests of all age groups in pre-intervention and post-intervention scenarios, resulting in similar mean gains. If the sample size was large enough (over 12), then the t-tests showed misconceptions were likely to be generated in the pre-intervention and but not likely to generate the misconception in the post-intervention group regardless of age

Although the post-intervention presentations no longer generated misconceptions in a statistically significant manner, a further analysis showed that post-intervention and the intervention-transition presentations did not generate the correct conceptions in a statistically.

Table 29. Cause of misconception—all variants

Group	Mean Change (out of 1)	Gain Std Dev.	N	Sig.	Cohen's D Effect Size
All Pre-Intervention	0.219	49.7	160	<.001*	0.44
Pre-Intervention Control	0.412	50.7	17	.004*	0.81
Pre-Intervention Mental Only	0.196	54.2	46	.018*	0.36
Pre-Intervention Physical Only	0.186	50.0	43	.019*	0.37
Pre-Intervention Both Mental and Physical	0.193	44.1	57	.002*	0.44
All Intervention Transition	0.037	51.8	27	.713	0.07
Intervention Transition Control	0.077	64.1	13	.673	0.12
Intervention Transition Both Mental and Physical	0.0	39.2	14	1.000	0.0
All Post-Intervention	0.022	51.5	91	.685	0.04
Post-Intervention Control	-0.018	59.3	55	.821	0.03
Post-Intervention Both Mental and Physical	0.083	36.8	36	.183	0.22

* indicates a statistically significant result

significant manner. The statistical results indicate that the intervention moves the presentation in the correct direction, as the presentation no longer causes a significant misconception that would need to be corrected. Unfortunately, the intervention did not significantly cause audience members to correctly answer this question.

Table 30. Cause of misconception and intervention by age

Group	Age Range	Mean Change (out of 1)	Standard Deviation	N	Sig. (p)	Cohen's D Effect Size
Pre-intervention	0-12 years old	0.184	0.378	49	0.011*	0.49
	13-17 years old	0.308	0.486	13	0.104	0.63
	18-25 years old	0.250	0.630	8	0.170	0.40
	25+ years old	0.229	0.463	83	<0.001	0.49
Post-Intervention	0-12 years old	0.033	0.895	30	.712	0.04
	13-17 years old	0.143	0.895	7	0.356	0.16
	18-25 years old	-	-	0	-	-
	25+ years old	0.000	0.571	44	1.000	0.00

* indicates a statistically significant result

Incidental Understandings

Interactivity and Pre/Posttest Activity Boundaries:

Although Research Question 6 asks about differences between presentations, some of the items that they had in common were surprising. Audience members found all the presentations interactive, no matter the engagement used. For example, what audience members called "interactive" varied. Audience members identified the Plickers pre-/post-test cards, the use of demonstrations, the use of volunteers, and the ability to come up to the stage and to do the experiments as "interactive" elements. Some of the interviewees who attended the control presentation gave answers that could be expected such as the young girl attending a control session who said, "I would like to do-do it—do the stuff, do what you did." Meanwhile a young boy attending the control presentation said, "It was fun to see and to play

around," indicating he meant that he enjoyed "playing" with the items after the presentation was over. Another young boy attending the control presentation mentioned, "We actually got to try out all of the different experiments," and a young girl attending the control presentation said,

> I just liked that it was very interactive, and you gave us an opportunity to actually try it ourselves. And that made it to where you could see it for yourself and not just somebody else doing it. You can experience it. (young girl, control)

Each of these interviewees' statements seem to imply that the audience members were able to physically participate in the experiments during the presentation, but no audience members were asked to participate during any control presentation. These comments reveal that audience members did not differentiate between what happened just before the presentation, during the presentation, and after the presentation. These audience members were talking about the ability to come up after the presentation to try out a few of the demonstrations. Thus, to the audience members in these control presentations, the ability to come up after the presentation and try out an activity for themselves was viewed by them as a part of the presentation they chose to take part in.

Pre/Posttest Plickers® Cards

Across all presentation formats except the strictly physical only presentation, audience members specifically mentioned using the pre/posttest Plickers® cards as one source of interaction. When mentioning this aspect, audience members frequently commented on enjoying the pre/posttest Plickers® cards. Audience members said things like, "I liked being quizzed. I liked the interactivity of it. I liked being able to hold up the cards and to see that our answers were being tallied. It was fun," (woman, control), "I really liked it was interactive with the questions first" (woman, control) and "I liked that the double quiz. The quiz at the beginning then the presentation, then the quiz at the end," (man, both mental and physical).

Audience members they liked the pre/posttest Plickers® cards for a few reasons, some enjoyed the novelty of the technology. For example, a young boy who attended the mental-only presentation stated, "(I liked) how you—all the technology—and how we had to hold up the thing. The paper thing with the answer. Instead of just writing it down or saying it like most people do. A man commented "One thing that that I also found interesting was, the…the cards – what kind of cards were those? (Interviewer answers: "They're called Plickers®") Plickers®—those were very interesting I've never seen those before those were very interesting."

A more sizable set of audience members (mostly adults) saw the pre/posttest as a source of learning. One woman attending the control presentation stated, "Yeah, and it was a good mix of things. You know with the questions and the cards first…And then going back to the same questions cause I could see them being demonstrated." Another man attending a both mental and physical presentation seemed pleased that people could track their learning: "They was able to actually learn throughout because they was able to see the beginning. What they thought they knew. But answering their questions, at the end they knew the answers." Another man attending a control presentation saw the test as a way to ensure people learned: "Cause of the presentation, the presentation actually taught them the answers to the questions. You could see that they were paying attention or not. Helps them remember the information to so probably they won't forget those concepts." The pre/posttest created a sense of desire to check on one's own learning in some audience members. One woman who attended a both mental and physical presentation said "I want to know did I get it right. Whenever they're like can we go—I'm like, no I want to know the answers."

Although adults were the main audience members praising the pre/posttest as an element of learning, some children mentioned it when talking of elements of the presentations that they

liked. For example, a young girl who attended a both mental and physical presentation said, "All the questions—like all the questions—he like let us choose." Then her mother responded, "So you like having the trivia? That's pretty cool huh?" The child nodded yes in response.

When directly asked about the pre/posttests and what people thought of them, only one person responded negatively, responding that he didn't care for them. The vast majority of interviewees saw the pre/posttest as a very positive interactive element of the experience.

Comparisons between this Presentation and School Classrooms

Younger interviewees sometimes volunteered information about how this presentation compared to classroom presentations. Sometimes younger interviewees spontaneously compared this presentation to their science presentations in their classrooms while at other times they compared the presentation to auditorium presentations in their school. One young boy attending a both mental and physical presentation volunteered that he learned something, and was subsequently asked the follow-up question by the interviewer, "What did you learn?" The young boy responded, "That science can be fun, instead of boring."

In response to the question "How is this different from other presentations you've seen and how is it similar to others," a young girl who attended a control presentation responded, "They are Powerpoints and boring. This one was fun!" When asked where she saw those Powerpoint presentations, she responded, "At school." Children that were interviewed primarily interpreted "presentations" as being associated with schools either as presentations in their auditoriums, or even associated with school classroom lectures by their teachers and not museum science presentations. When asked about seeing other presentations, one young girl who attended a control presentation responded, "Oh, yes, I have. They had, um…these type of presentations at some…at like school—at my school." The interviewer continued, "And how was this similar or different from those presentations?"

She responded “This one is like a lot more active, like they just...they didn’t show us. They didn't actually show us in person. They just showed us videos.” These comments referred to presentations at her school from both people who came to her school and teachers at the school. This child attended pre/posttest Plickers® cards were not used, yet according to her mother, she and her sister were: “really excited about what was gonna happen next.” The very act of doing a live demonstration seemed to make it exciting—yet the presentations at school were not utilizing live demonstrations, instead they used Powerpoint presentations and videos. Other children in different interviews confirmed that the presentation was different than presentations at their schools, as one young girl attending a physical-only presentation explained, “Our schools don’t experiment that much. They just teach us about it. They did more of telling us about it and not experimenting.”

Some adults reinforced this narrative that schools were boring and non-interactive. For example, a mother and her two children who attended a mental and physical engagement presentation said:

> Why was it fun? (Woman)
> I don’t know. (Young girl)
> I don’t know. (Young boy)
> (Woman laughs)
> You guys! (Woman)
> Because we got to learn science (Young boy)
> Because you liked what you learned, right? (Woman)
> Yeah. (Young girl)
> And you go to do stuff, right? (Woman)
> Yeah. (Young girl)
> Yeah. (Young boy)
> Instead of just sitting at your desk. (Woman)
> (Young girl and boy nod in agreement)

The adult reinforces the idea that schools have students sit at desks during science class without engaging in science experiments. The adult may be recalling her own experiences in school, but according to other students, schools don’t use many experiments or demonstrations.

My own son when interviewed after seeing after seeing the mental only presentation, revealed that often even simple experiments or demonstrations were not done in his science classes:

> The last science thing I remember doing was about the color—the spectrum of light. That white light is basically all of the colors—just you can't see with the naked eye like you need like a prism, which is—which separates white light into its colors to see it… Oh, that wasn't really presented. That was actually, like, class work… It told us an article and we had to start, and with the vocab words we had to do, and we had to answer the questions. (Young boy, Mental only)

Interviewees did not generally perceive their science classrooms as engaging in many memorable science demonstrations or experiments in contrast with the presentation.

Results Summary

General Effects of the Presentation

The audience members generally increased their understanding of content. Based upon interviews, repeat exposure to the presentations increased the depth of understanding the audience members came away with. For those audience members who weren't interested in participating in science, the presentation generally increased that interest.

Effects of the Presentation's Engagements

The difference in presentation formats did not significantly alter the content learned, nor did they significantly alter the audience members' desire to participate in science. The results suggest that engagements influenced the language the participants used to describe their experiences, which are largely encapsulated in Figure 14. In the discussion section Figure 14 is expanded upon to suggest a possible underlying theoretical substructure.

Misconceptions Caused by Presentations

The original presentation (pre-intervention) caused misconception in a statistically significant portion of the audience. After that misconception was identified, an intervention was implemented that re-ordered the demonstrations within the presentation. The intervention

restructured the order of the demonstrations so that the demonstration that primarily caused the misconception became the first demonstration done, as an anchoring phenomenon. The remaining demonstrations were ordered so that they helped explain how the first demonstration worked. The intervention eliminated the misconception from occurring in a statistically significant portion of the audience.

DISCUSSION

Introduction

This research examined altering the socio-cultural context (Falk & Dierking, 2000, 2016; Falk & Storksdieck, 2005) of a presentation by changing the engagements within a science museum presentation. The research initially examined three distinct categories of information about these presentations that could affect audience members: science content learned, attitudes toward participating in science, and presentation interpretation. I discuss each of these three categories in this chapter. As the research progressed, the research explored whether misconceptions caused by the presentation could be eliminated through presentation re-design; I discuss these re-design issues (misconceptions, design-build approaches, and anchoring phenomena) in the fourth part of this chapter. The research also suggested that audience members enjoyed the challenge of the pre/posttest Plickers®, which I discuss in the last section of this chapter: quizzing the audience.

Content Learned (RQ1, RQ2)

Situating within Past Research (RQ1, RQ2)

The science content research utilized Falk and colleagues' contextual model of learning (Falk, & Dierking, 2000, 2016; Falk & Storksdieck, 2005) and the findings from Crouch et al. (2004) that demonstrated that asking undergraduates to predict the results of a physics demonstration prior to presenting the physics demonstration led to larger science content gains. Crouch et al.'s (2004) research was corroborated by Zimrot's and Ashkenazi's (2007) research on chemistry demonstrations with undergraduates. Crouch et al.'s (2004) past research formed the basis of the approach to researching the mental engagements (questioning and prediction) within the informal setting of a science museum.

The research I performed utilized pre-/post-tests to account for the varying backgrounds of the heterogenous crowd that attends museums—ranging from young children to adults with degrees in the subject matter. Furthermore, Crouch et al. (2004) used questions about what specifically would happen in the demonstrations, I utilized questions with a similar idea, but in a novel situation. For example, one demonstration involved spinning around on a platform and letting go of a ball—the ball would fly straight out instead of curving as some might expect. The test question I asked was about letting go of an item while on a spinning carousel—a very similar, but not identical situation.

Crouch et al.'s (2004) research suggests that simply seeing a demonstration did change the outcomes to a $p = .03$ level with a Cohen's D of .19, while asking someone to predict raised the $p =.001$ with a Cohen's D of .35. This is a jump in significance and effect size. The research I present suggest that everyone had significant results, but the differences in effect size between those with mental engagements and those without weren't as dramatic. Perhaps a better comparison would be the ANCOVA (which is not entirely reliable due to the lack of normal data) which incorporated the audience's starting score. The ANCOVA found that mental engagements are associated with an increase of the mean of 3.7% over the control (observation) group, which is less than the 7% increase that Crouch et al. found, but the two results do not contradict each other.

Future Research: Testing Explanations

While my research results are in general agreement with Crouch et al.'s (2004) results, where Crouch et al. found more dramatic differences was in student explanations for why these observations occurred. As part of their research, Crouch et al. asked students to explain the causal reasons the demonstrations worked, then they used rubrics to grade those answers. A

further research study that looks specifically at this element would be interesting, but may require recruited audiences due to the time frame it would take to record audience member's explanations. This research would be interesting, but would no longer use a naturally occurring audience, ostensibly shifting the audiences' composition, affecting the personal socio-cultural contexts of the audience. Such a study would be interesting, even if it is not in keeping with some experts' insistence on using naturally occurring audiences within authentic contexts (Rennie et al., 2003; Tal & Dierking, 2014).

Future Research: Repeat Visitation

Another interesting avenue of exploration involves the increase in apparent complexity of reasoning exhibited by repeat visitors to the presentation. The qualitative evidence suggests that audience members who attended more than one presentation and were interviewed more than once grew in the complexity and accuracy of their answers. Repeat audience members showed evidence of more complex logical reasoning within their interviews, but with so few examples of repeat visitors in this research project, more research would need to be done. To investigate the increase in reasoning, research could be conducted where audience members are asked to provide explanations for their content-based answers, then invited back to future presentations with future opportunities to explain their content-based answers. Such research might determine reveal whether this is a real or illusory effect, or if it is attributable to another element such as an audience member's growing confidence in one's own understanding of the principles demonstrated.

Practitioner Recommendations

If audience members grow in their reasoning, after attending the same presentations more than once, then attending different, but reinforcing presentations could have the same effect—

elevating audience members' complex logical reasoning around the reinforced concepts. Alternatively, museum practitioners could work with selected schools so that the presentations that the museum staff provide for the schools specifically reinforces the school curricula; further, these local schools could work to reinforce and expand upon the museum presentations in subsequent classroom instruction. School-museum partnerships offer a wealth of growth opportunities. Interest in connecting such learning opportunities already exists, as evidenced by NSTA's (National Science Teaching Association) *Connected Science* journal started in March 2016. The *Connected Science* journal "highlights STEM education experiences that bridge the gap between in-school and out-of-school settings" (National Science Teaching Association, n.d.).

Attitudes: Desire for Participation (RQ3, RQ4)

Situating within Past Research (RQ3, RQ4)

The idea to test for a change in the desire to participate in science grew out of Price et al.'s (2015) work which saw the desire to participate in science grow significantly for school children exposed to a presentation and an exhibition. In their study they found that students who saw the presentation had a significantly larger increase in their desire to participate in science if they attended both the presentation and the exhibit than if they just attended the exhibit. Price et al. (2015) conjectured that the increase in desire to participate was due to the physically interactive nature of the presentation which shifted the socio-cultural context. My research does not support their conjecture, but my research had limited numbers, and my presentation audience was mostly a family-based audience that chose to go to a science center, instead of a science class that went to a science museum on a school field trip. Since the audience chose to go to a science center, my research demonstrated a ceiling effect—of those with pre-/post-test answers, 64% (159 of 250) started with the highest level of desire to participate in science prior to

attending a presentation. When the individuals who rated their desire the highest were removed from the sample, then my research suggests that Price et al.'s (2015) conjecture is plausible. Since the number of individuals who did not top out yet attended a physically interactive only presentation were so low (n= 8) I cannot draw any firm conclusions; however, I can state that this presentation increases people's desire to participate in science, if they don't already have that desire.

Future Research: Attitudes

A more thorough exploration of how transitive attitudes towards science change due to presentations would be a useful to conduct. This research project tried utilizing Szechter's (2009) attitude analysis and found this problematic due to the amount of time the attitude analysis took to fill out. Future research could utilize or adapt the Activation Lab's set of tools at http://activationlab.org/toolkit/. The Activation Lab's set of questions and answers were designed for use with ten to fourteen year-olds, and have been used for that audience to determine multiple elements of STEM attitudes. The Activation Lab tools have had previous testing and validation, so would likely encounter fewer problems when utilized as a part of future research on presentations.

One question that has not been settled when looking at the past research is: What is responsible for the increase in an audience member's desire to participate in science? Are certain presentation engagements more likely to change the desire to participate as Price et al. conjectured, presentation engagements irrelevant to the increase in desire to participate? Could specific presentation engagements correlate with specific attitudinal shifts? Research into what elements cause larger attitudes shifts and particularly in the desire to participate in science would be useful. Research into attitudinal shifts could help determine what elements should be

emphasized to create various attitudinal shifts. Attitude shifts due to presentations could be audience dependent, so one might expect that K-12 school field trip audiences react differently than free-choice museumgoers, opening another avenue ripe for research.

Practitioner Recommendations

Although researchers have not determined what elements within a presentation serve to increase the desire to participate in science, the research suggests that presentations increase the desire to participate in science in those who are less likely to engage with science. This research result suggests that science museums consider the implementing presentation programs if they have the staff capacity and they do not already have presentation programs in place. Price et al.'s (2015) study didn't suffer from a ceiling effect with desire to participate in science, while my own research did, suggesting greater increases in the desire to participate in science are achievable with school groups than with the general public that attends science museums. Therefore, science museums seeking to maximize their attitudinal impacts, should consider prioritizing presentations for school groups over presentations for the generally museum attending public.

Presentation Interpretation: Roles People Play (RQ5)

Situating within Past Research (RQ5)

The research results laid out in Figure 14 (p. 137) show that there were differences in the way people talked about the different presentation formats. These results suggest that altering the socio-cultural context by varying the engagements influences the way audience members view the presentation itself.

Prior research on presentations did not look at how people interpret changes in presentations, but research has looked at the language people use when describing their

motivations for visiting science centers and describing their reactions to exhibits. In 2006, Falk used interview evidence to establish that people's reasons for attending museums fall into one of seven categories, with the majority of people attending falling into combinations of just two roles: the role of explorer and the role of facilitator. An explorer is there to understand what the museum has to offer, to essentially browse through the museum for knowledge and things to do. A facilitator is there to help another person explore or get something out of the museum, such as a parent helping a child.

Famous theater and film director Peter Brook (1968/2019) noted that audiences took on roles based upon common cultural expectations that came with being an audience member. Brook noted that these culturally-based roles changed the way audiences reacted to a show (1968/2019) and later founded the International Centre for Theatre Research (Brook, 1968/2019). Falk's (2006) research, along with Brook's (1968/2019) observations, imply that roles and expectations impact the experience of an audience member attending a presentation.

Typically, audience members' take on observational roles. Audiences observe stage shows, presentations, and lectures. The audience member seems to exist outside the presentation, viewing the presenter(s) through an invisible fourth wall. Indeed, whenever stage performers in a play talk directly to the audience it is called "breaking the fourth wall" ("fourth wall," 2021). The convention of stage plays having a fourth wall allows the performers to act theoretically without regard to the audience, while the audience takes on roles of invisible, unobtrusive observers.

When science presenters break that fourth wall by asking the audience member to take part in a performance, that initial cultural division that makes audience members feel as outsiders starts to break down, which may be why audience members in interactive presentations were less

likely to call the presentation a "show" and were more likely use words like "science" in describing their experience. When engaging the audience directly, science presenters disrupt the idea of the audience member as unobtrusive observers attending an external show, since audience members have now become a part of the collective experience.

The interview evidence presents one fascinating element that stands out: Those who attended the control presentation far more likely to use terms like "entertaining" and "show," while those who went to the presentations with engagements were more likely to use words like "science." This dichotomy suggests that the presenter's engagements might encourage audience members to fall into one of two categories: that of a passive audience member watching a show for those viewing the control presentation, or that of an active science participant for those participating with any of the engagements. These roles should not be seen as absolute, but rather a continuum of role possibilities audience members might participate in.

As seen in Figure 14, audience members talk more about science when attending presentations that use acts of engagement, particularly mental engagement. When the presenter used engagements, the presenter would state how audience members were going to act as scientists. When mental engagements were used within presentations (in mental only and both mental and physical), audience members were told that they were going to ask questions and make predictions, like scientists. When physical engagements were used within presentations (in physical only and both mental and physical), audience members were told that they were going to act as experimental scientists physically conducting the experiments. Thus, the presenter told the audience members that they were participating in the act of science. The presenter's messaging may have helped audience members break away from the idea that the audience was seeing a show and instill the idea that the audience was engaged in acts of science. To clarify,

interviewees in this study did not talk about the idea of being scientists, but they did talk use the word "science" far more often in interviews, and they used the words "show" or "entertain" less often.

Future Research: Developing Underlying Theory

Above I have just begun to lay out an underlying theory to makes sense of the differences in how audience members interpret the different presentation styles (as shown in Figure 14). One perplexing element involves the difference in utility associated with physical-only presentations. This difference could be due to differences in starting audiences, a statistical aberration that will disappear with more research. Another possibility is that the question did not quite capture the differences that audience members saw with the physical engagement. If this difference exists then it seems that this difference should carry into all presentations that use physical engagements, not just the physical only presentation. However, it is also entirely conceivable that the mental engagement differences obscured any differences the physical engagements created or had an effect that nullified the physical engagement. These remaining questions suggest that research should be done to tease out what is happening, and to develop a theoretical model for how presenter's mental and physical engagements of the audience effect the audience's interpretation of the presentation.

I suggest a new possible theoretical model for what occurs when using engagements in Figure 15 based upon this current research. Figure 15 uses the same quadrant architecture that Figure 14 uses, but Figure 15 makes use of the two axes dividing the quadrants. The axes are tilted at forty-five degrees from the vertical. One axis represents the amount of physical engagement, transitioning from no physical engagement in the upper left to high physical

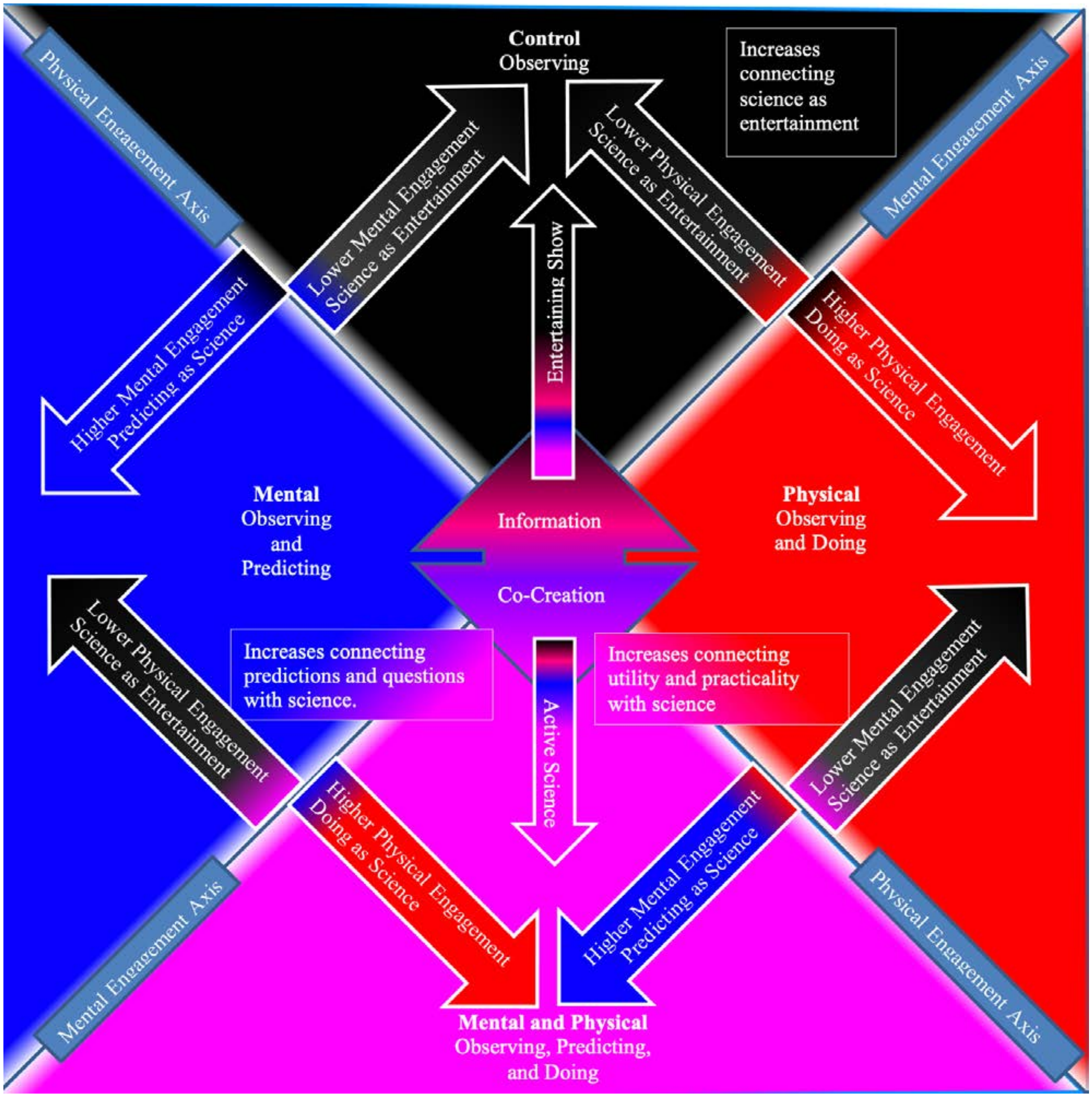


Figure 15. Proposed engagement model

engagement in the lower right. The other axis represents the amount of mental engagement transitioning from no mental engagement in the upper right to high mental engagement in the lower left. The large arrows coming off the axis indicate the direction of change in engagement (lower or higher), along with what such change in engagement is associated with (science as

entertainment, predicting as science or doing as science). Thus, as mental engagements increase, the scientific act of predicting based upon past data—a hallmark of theoretical science—becomes more prevalent. Meanwhile, as physical engagements increase, the act of physically manipulating materials to test out ideas—a hallmark of experimental science—becomes more prevalent.

Figure 15 notes three sets of correlated results (located in boxes) based upon this research project. Data encapsulated in Figure 14 suggests that participants associate presentations with either physical and/or mental engagements with science, as they spontaneously use the word science with a much higher frequency. Presentations that used mental engagements (mental only, and both mental and physical) meanwhile had a subset of participants actively talking about prediction as an act of science. Therefore, the theory suggests that increasing mental engagements should increase association between the predictions and questioning done in the presentation with the act of science, while physical engagements should increase association with utility or practicality of science. The past evidence for these correlated results is primarily qualitative in nature. Doing hands-on work is often associated with practical expertise and accomplishment, therefore, there is a compelling reason for hands-one science to seem more practical and utilitarian.

This research suggested that the control presentation, and therefore the lack of engagements is associated with the audience identifying the presentation as an entertaining show. Therefore, this theory predicts (or suggests) that lack of any engagement may slightly increase the association of the presentation as entertainment (as noted by the arrows pointing towards lower mental and physical engagements in the figure). Then, when neither engagement is used,

the associations of the presentation as entertainment would increase more dramatically while the association with science would drop, which is what the research suggests.

Further research would better flesh out this theoretical substructure about how people interpret different engagement mechanisms. Further research could expand on this initial work via a two-stage, mixed-methods approach. During the first stage, interviews of audience members would catalog the words or phrases they use to describe the experience they had at the presentation. Next the interviews would be analyzed for words that typify the presence or absence of an engagement. After this qualitative analysis, the research would utilize a quantitative approach, where audience members are asked a series of questions at the end of the presentation using Plickers® cards to answer. Each question could ask the audience members to choose between two competing words to describe the presentation. Based upon interview data collected so far, a question might pit words like “science or scientific” against words like “show” or “entertaining.” Comparing word usage more precisely could help differentiate how the engagement methods work to make people see the same presentations differently.

Another tact to further explore the effects of engagements, would be to examine whether an interaction exists between types of audiences and engagements. In particular, one could examine whether K-12 field trip audiences react differently than typical free-choice museum goers to different engagements. All the research I conducted examined free-choice audience participants primarily in social units consisting of at least one adult and one child. Family units that freely go to a museum likely have different reactions to presentation engagements than do K-12 field trips or groups of adults. This research has immediate practical applications since it would enable museums the ability to determine whether engagements should change based upon the groups arriving at the museum. While most science museums cater to family groups on

weekends, their typical morning weekday audience consists primarily of school groups. If certain engagements are more effective with K-12 school groups over and above family groups, then museums could schedule their programming more effectively. Since the socio-cultural context varies by group, this could yield some interesting insights.

Practitioner Recommendations

Museum staff should consider their goals when designing their presentations. If the goal is to associate the presentation experience as an entertaining show, then this research suggests staff should eliminate various attempts at mental or physical engagements altogether in future science museum presentations. If the goal is to associate the experience as a scientific endeavor, then this research suggests staff should increase mental and physical engagements. Although this research was performed with public participants, the data may hold for organized groups. Practitioners can consider the goals of the group when giving them presentations. For example, a school group coming from a theater and arts school might find engagement-free presentations more in line with their desires, while a STEM focused school might find science-oriented presentations (more engagements) more in line with their goals. To test whether this customization approach helps, research with carefully vetted groups would need to be done.

Misconceptions, Design–Build Approaches and Anchoring Phenomena (RQ6)

Situating within Past Research (RQ6)

This research identified a demonstration (cup on platform) that caused a statistically significant misconception within the presentation. The physical causes that underpinned the demonstration were not fully understood by the audience; therefore, audience members developed an alternative conception (commonly called a misconception) that rotational motion causes inward gravitational-like forces. Other alternative conceptions on motion have been

examined before, with various alternative conceptions about motion and rotation having been previously documented (Sahiner et al., 1987; Wandersee et al., 1994).

Past research about similar alternative conceptions was famously demonstrated by the video *A Private Universe* (Sahiner et al., 1987). In *A Private Universe*, one bright student named Heather demonstrates a few misconceptions, one of which includes a looping orbit of the earth going around the sun that was rooted in misinterpreting a diagram that she didn't fully understand in her textbook. While A Private Universe deals with an alternative conception that resists change, according to Wandersee et al. (1994) not all alternative conceptions are tenacious, and since the alternative conception was not significantly present in participants minds prior to seeing the presentation, this research assumed that the alternative conception would not be tenacious.

This research project found that changing the order of the demonstrations eliminated the creation of the common misconception even though it didn't significantly generate the correct conception. The initial presentation used a set of demonstrations that sought to start with simpler concepts and build them into more complex concepts. The new demonstration order started with the tougher, more puzzling demonstration. Demonstrations afterwards were positioned to explore possible understandings of why the original demonstration worked, successfully eliminating the alternative conception of "things that move fast stick together." Essentially the new conception that "things that move fast stick together" was posed prior to pulling a tablecloth out from under a plate and dishes. If things that move fast stick together, then pulling the tablecloth quickly should cause the plate to stick to it, while pulling a tablecloth slowly should leave the plate behind, but the opposite happens. By posing these experiments to test alternative

conceptions on why the water stayed in the glass and the glass on the platform, this particular alternative conception was defeated.

Puzzling phenomena that requires multiple experiments to understand are called anchoring phenomena within the formal K-12 system. Using anchoring phenomena to create investigative experiments around is one of the current approaches taken in science education. The approach is like the approach of science itself—that of finding a puzzling phenomenon and breaking it into smaller phenomena to study and understand. This approach shifts the socio-cultural context from the position of building up knowledge in discrete logical steps determined by the teacher, to one of exploring why something occurs from the position of the researcher who is guided by a more senior researcher (the teacher or presenter).

The anchoring phenomena approach parallels the approach taken by Cantor (2015). In Cantor's Fusion Science Theater project, they built their science museum presentation around solving a single scientific puzzle. Cantor's (2015) research along with the misconception research I conducted, both support the idea that concentrating a presentation around a single puzzling phenomenon results in a good approach to creating a presentation.

Viewing anchoring phenomena from Falk and colleagues' contextual model of learning (Falk, & Dierking, 2000, 2016; Falk & Storksdieck, 2005) perspective suggests two elements are changed when repositioning a misconception causing demonstration to the beginning of the demonstration. First, by beginning with a surprising, conceptually challenging anchoring phenomenon, the visitor's curiosity is more likely piqued, an essential element to supporting intellectual engagement (Falk & Dierking, 2016). Second, by positioning the phenomenon as an element to investigate and understand due to one's own curiosity, the role of the visitor changes from that of learner to that of curious, scientific investigator. In a traditional educational setting,

teachers start with basic concepts and build them up towards more complex concepts, and the role of the student often entails passive learning. The view of education as passive and boring seems embedded in the social fabric of those interviewed for this research, and probably beyond. By positioning the anchoring phenomenon first within the presentation and inviting the audience members to consider possible reasons for the anchoring phenomenon's occurrence, the audience member gets the opportunity to role switch from classic learner of basic phenomena, to investigator of complex phenomena. This socio-cultural adjustment eliminated the creation of at least one alternative conception.

Future Research: Misconceptions and Anchoring Phenomena

Although my research eliminated the common misconception, it did not cause a significant number of people to understand the correct conception well enough that they could apply it to unfamiliar circumstances. These results suggest that more work should be done to understand how to move to correct conceptions that can be applied to novel situations.

Further research investigating the anchoring phenomena approach as a way of reducing misconceptions could prove valuable when creating new presentations. Although my research suggests that demonstrations prone to cause misconceptions can benefit from use as anchoring phenomenon, this merely uses one such case. Whether or not other misconception causing presentations could be improved by reordering the demonstrations remains a compelling research topic. Such research would require a multi-stage approach. The first stage of research would involve finding the misconceptions that are being caused and isolating the key demonstrations that caused the misconceptions. The second stage involves revamping the order of the demonstrations so that the misconception causing demonstration becomes the anchoring phenomenon, with subsequent demonstrations seeking to investigate possible principles

underlying the phenomenon. The third stage of the research involves checking to see if the intervention works.

Practitioner Recommendations

This research suggests that after first testing out a presentation, practitioners should query audience members about common misconceptions that might result from the presentation. Staff that would like to reduce misconceptions caused by demonstrations could start by looking at books such as Keeley's Uncovering Student Ideas series (2021). The Uncovering Student Ideas book series has 'probes' that are useful for testing whether people hold misconceptions after seeing related demonstrations in a presentation. Then, if there are relevant misconceptions, museum staff can work on fixing the misconceptions via a series of demonstrations that explore and eliminate each possible misconception.

A more powerful method of eliminating misconceptions involves partnering with a school system to identify common misconceptions their students have. Then staff can look for a demonstration that might cause one of these misconceptions. The misconception generating demonstration could then form the anchoring phenomenon which staff can build a presentation around. Although this work might be daunting, the benefits promise to yield particularly powerful learning opportunities—particularly when paired with K-12 school lessons that explore these concepts further.

Quizzing the Audience

Situating within Past Research

As Falk and Dierking (2016) note, even changing the questions within an environment alters the socio-cultural context within the environment. By having the quiz at the beginning of the presentation the social context the audience members find themselves in changed into one

where they felt challenged. Recent research on exhibits in science museums suggests that people particularly like and remember challenging exhibits, including ones they feel they learn from. Research by Paneto et al. on productive struggle (2020) details an exhibit that uses a computer quiz to guide people in examining skulls. The exhibit used a computer-based, quiz-like structure with various cognitive supports to help people choose the right answer. As people give wrong answers, the computer guides participants to recognize that the shape of the skull's teeth may indicate what the creature may eat, which helps the participants to identify what type of animals the skulls belong to (carnivore, omnivore, herbivore). Participants felt a sense of accomplishment as they learned to identify an animal from clues obtained by examining a skull. Similarly, in the presentation research I conducted, many audience members interviewed noted that they enjoyed the pre/posttest because they felt a sense of accomplishment when their posttest answers were more correct than their pretest answers. This suggests that the act of quizzing audience members within a presentation may help induce the positive feelings created by establishing a sense of productive struggle similar to what researchers found within exhibits (May et al., 2018, 2022; Paneto et al., 2020).

Future Research: Quizzing the Audience

This research suggests that anonymously quizzing audience members in a pre/posttest format may increase the audience's satisfaction as they can track their science content growth. Audience satisfaction as related to the pre/posttest was not tested in this research but would be an interesting aspect to examine in future research.

Researchers could use a simple research set-up where some presentations used pre/posttest, while others did not. At the end of both sets of presentations, audience members could be asked a series of questions to determine how much they enjoyed the presentation and

how much they felt they learned. If the testing procedures connect each participating audience member's pre/posttest scores to their sense of satisfaction, correlations between content gain and satisfaction could be examined.

Practitioner Recommendations

Audience members generally enjoyed using the Plickers® cards for the pre/posttest. Several audience members were so interested in the Plickers® cards that they asked me specifically about them following my presentation. Some of the individuals curious about the Plickers® card system were teachers, while one who saw the Plickers® card system as a possible research tool was a university student studying social science.

As a method of obtaining data, Plickers® worked without requiring audience members to use clickers or cell phones. But as a method of obtaining data, Plickers® ® also had some problems. For example, even with training, people accidentally covered up the card symbol with their fingers, preventing accurate identification of the answer by the software. This problem may be preventable by framing the Plickers® cards with a holdable frame so that people's fingers are less likely to protrude onto the symbols. If the frame of each card were a different material (such as stiff foam or plastic) from the symbol on the card, then the tactile sensation produced by the material might be enough to help people realize when their fingers strayed onto the symbols. Although I thought of this approach too late to implement in my research, I recommend its use in future research.

Conclusions

The study suggests that the sociocultural context (Falk & Dierking, 2000, 2016; Falk & Storksdieck, 2005) influences the audience member's transitory personal context. As Falk (2006) noted, the personal context often involves transitory roles. During the presentation,

audience members transitory roles are influenced by the surrounding sociocultural context. The study suggests that the sociocultural context shifts depending upon the engagements that the presenter utilizes. These ideas are consistent with Falk and Dierking's (2016) arguments that "social interaction during the museum visit includes the questions and discussions generated" (p. 148). The attempt at adding engagements within a presentation represents an attempt "to create an environment in which the visitor becomes part of a seamless array of mutually reinforcing contexts that separately and collectively support visitors' needs and interests, while also helping the museum support its goals" (Falk & Dierking, 2016, p. 250) of positioning the visitor as the scientist. When combined with a museum's exhibits, shifting engagements further cements the position of the audience member, as one of co-creator as well as observer.

This research represents a first step in understanding the effects of different components of presentations that influence the sociocultural context within informal educational settings. Although research on presentations in informal settings has been done previously, such research looked at the effects of individual presentations, not how changes within the presentation affected the audience's sociocultural context, thereby influencing the understanding and interpretation of the presentation. This research looked at a small slice of the socio-cultural context: how engagements and demonstration order change the effect of a presentation on the audience. These changes alter socio-cultural context of the museum, with potentially interesting consequences.

This research had several conclusions, but whether these conclusions should be applied to presentations on different topics still needs investigation. This research concludes that engagements effect the audience members' interpretation of the presentation. When the presenter engaged the audience mentally and/or physically the audience was more likely to view

the presentation as science. Fewer engagements meant audience members were more likely to view the presentation as entertainment. The research concludes that demonstration order within a presentation can encourage or discourage the creation of new misconceptions. More specifically, misconception causing demonstrations are potential anchoring phenomena to build presentations around.

Readers of this work are encouraged to think through other means of socio-cultural shifting, and to apply these socio-cultural modifications to their own work. The suggestions given throughout this chapter are intended to yield starting locations for both researchers and practitioners. This research can serve as a starting point to investigate how conscious design decisions on socio-cultural aspects of the museum experience might yield more positive impacts for the audience member that align with the museum's goals.

APPENDIX A. PRESENTATION DATES AND TIMES

Table 31. Presentations and data collection by date

Date	**Free/Paid attendance**	**Type of presentation**	**Time (PM)**	**RQ6 Status (pre/Transit /post)**	**Types of data successfully collected**
11/4/18	Free	Mental & Physical	1	Pre-RQ6	Interview (2A,6,11,12)
11/4/18	Free	Control	3	Pre-RQ6	Interview (2A,12)
11/24/18	Paid	Mental Only	1:30	Pre-RQ6	Plickers®
12/2/18	Free	Physical Only	1	Pre-RQ6	Plickers®
12/2/18	Free	Mental & Physical	3	Pre-RQ6	Plickers® & Interview (2A,7, 11)
12/29/18	Paid	Mental Only	1	Pre-RQ6	Plickers®
12/29/18	Paid	Mental & Physical	3	Pre-RQ6	Plickers® & Interview-was lost
1/6/19	Free	Physical Only	1	Pre-RQ6	Plickers® & Interview (11)
1/6/19	Free	Control	3	Pre-RQ6	Plickers® & Interview (9,11)
2/2/19	Free	Control	1	Pre-RQ6	Interview (A,7,11)
2/2/19	Free	Mental & Physical	3	Pre-RQ6	Plickers® & Interview (A, 5,<5)
3/3/19	Free	Mental	1	Pre-RQ6	Plickers®
3/3/19	Free	Physical	3	Pre-RQ6	Plickers® & Interview (13)
3/23/19	Paid	Physical	1	Pre-RQ6	Plickers® & Interview (A,10)
3/23/19	Paid	Mental & Physical	2	Pre-RQ6	Plickers® & Interview (A, 7)
3/23/19	Paid	Mental	3	Pre-RQ6	Plickers® & Interview (A,11) / (9)
5/5/19	Free	Mental & Physical	1	Pre-RQ6	Plickers® & Interview(2A,6,9,<5)
5/5/19	Free	Mental	3	Pre-RQ6	Plickers® & Interview (5,8)
5/11/19	Paid	Physical	12	Pre-RQ6	Plickers®

(table cont’d)

Date	Free/Paid attendance	Type of presentation	Time (PM)	RQ6 Status (pre/Transit /post)	Types of data successfully collected
5/11/19	Paid	Control	2:30	Pre-RQ6	Plickers® & Interview (A,16,16)
8/4/19	Free	Mental & Physical	1	Transition	Plickers®
8/4/19	Free	Control	3	Transition	Plickers® & Interview (A,11)
9/1/19	Free	Control	1	Post RQ6	Plickers® & Interview (A,11)/(10)
9/1/19	Free	Mental & Physical	3	Post RQ6	Plickers® & Interview (A)/(10)
10/6/19	Free	Mental & Physical	1	Post RQ6	Plickers® & Interview (A,11)
10/6/19	Free	Control	3	Invalidated NGSS Post	Plickers® & Interview (2A,5,<5)
11/3/19	Free	Mental & Physical	1	Post RQ6	Plickers®
11/3/19	Free	Control	3	Post RQ6	Plickers® & Interview (2A,5,<4)
12/1/9	Free	Mental & Physical	3	Post RQ6	Plickers® & Interview (A, 7, 9)

APPENDIX B. FINAL PRE/POSTTESTS

Final Pretest

1) I am
    a. 12 years old or less
    b. Between 13- 17 years old
    c. Between 18- 25 years old
    d. Over 25 years old

2) I have
    a. Never seen this presentation before
    b. Seen this presentation before

3) Today I came here
    a. With a school or after-school group
    b. With my family
    c. With my friends
    d. By myself.

4) I like participating in science
    a. Strongly agree
    b. Somewhat agree
    c. Somewhat disagree
    d. Strongly disagree

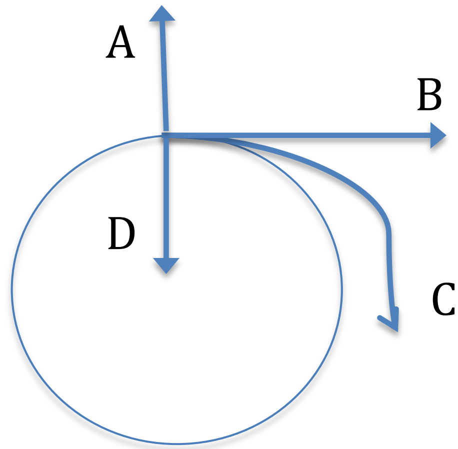
5) Knowing science means only knowing the facts and Figures
    a. Strongly agree
    b. Somewhat agree
    c. Somewhat disagree
    d. Strongly disagree

6) Thinking like a scientist is only useful when taking a test in science class
    a. Strongly agree
    b. Somewhat agree
    c. Somewhat disagree
    d. Strongly disagree

7) On a carousel amusement park ride:
    a. All of the horses go the same speed (in miles/hour or feet/second)
    b. The horse closest to the center goes the fastest in miles/hour or feet/second)
    c. The horse closest to the outside goes the fastest (in miles/hour or feet/second)

d. I have no clue

8) If the carousel was going really fast and I let go of my wallet it would fly (use the diagram to the right): Radially outward from the center□
    a. Tangentially outward
    b. Continuing to spin around the carousel.
    c. Inward to the center of the carousel
    d. I have no clue



9) If an ice skater is turning and brings her/his arms inwards he/she
    a. Starts spinning faster (more rotations per minute)
    b. Starts spinning slower (less rotations per minute)
    c. Doesn't experience any change in spinning (same rotation per minute)
    d. I have no clue

10) A tire is more likely to stay upright longer if
    a. It is not spinning
    b. It is spinning
    c. It doesn't matter if the tire spins or not—it falls over at the same rate.
    d. I have no clue.

11) If the earth spun fast enough
    a. We would feel be stuck on the ground unable to move.
    b. We would be flung off the earth's surface.
    c. Nothing would change (other than shorter days and nights).
    d. I have no clue.

Final Posttest

1) This presentation made me think
    a. Science is more useful than I thought
    b. Science is more fun than I thought
    c. Science is something I would like to do more of
    d. Scientists are smarter than I thought

2) Knowing science means only knowing the facts and Figures
    a. Strongly agree
    b. Somewhat agree
    c. Somewhat disagree
    d. Strongly disagree

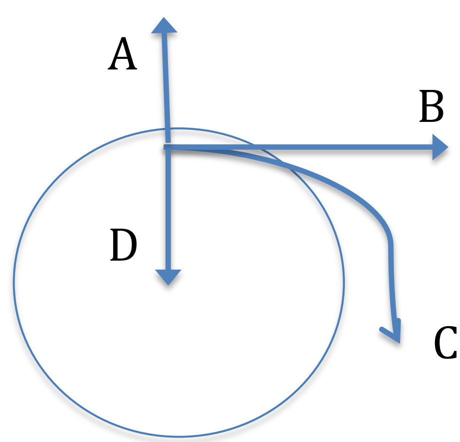
3) Thinking like a scientist is only useful when taking a test in science class
    a. Strongly agree
    b. Somewhat agree
    c. Somewhat disagree
    d. Strongly disagree

4) I like participating in science
    a. Strongly agree
    b. Somewhat agree
    c. Somewhat disagree
    d. Strongly disagree

5) If I wanted to know what happened when a ball is placed on a spinning surface, I would
    a. Ask someone
    b. Google it (or use another search engine)
    c. Try it out (experiment)

6) On a carousel amusement park ride:
    a. All of the horses go the same speed (in miles/hour or feet/second)
    b. The horse closest to the center goes the fastest in miles/hour or feet/second)
    c. The horse closest to the outside goes the fastest (in miles/hour or feet/second)
    d. I have no clue

7) If the carousel was going really fast and I let go of my wallet it would fly (use the diagram to the right):
   Radially outward from the center
    e. Tangentially outward
    f. Continuing to spin around the carousel.
    g. Inward to the center of the carousel
    h. I have no clue



8) If an ice skater is turning and brings her/his arms inwards he/she
    e. Starts spinning faster (more rotations per minute)
    f. Starts spinning slower (less rotations per minute)
    g. Doesn't experience any change in spinning (same rotation per minute)
    h. I have no clue

9) A tire is more likely to stay upright longer if
    e. It is not spinning
    f. It is spinning
    g. It doesn't matter if the tire spins or not—it falls over at the same rate.
    h. I have no clue.

10) If the earth spun fast enough
    e. We would feel be stuck on the ground unable to move.
    f. We would be flung off the earth's surface.
    g. Nothing would change (other than shorter days and nights).
    h. I have no clue.

APPENDIX C. ORIGINAL PRE/POSTTESTS

Original Pretest

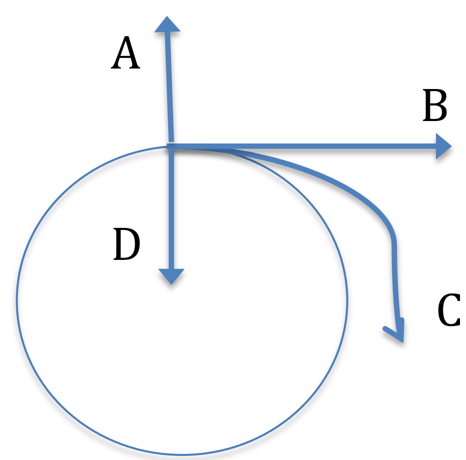
1) I am
    a. 12 years old or less
    b. Between 13- 17 years old
    c. Between 18- 25 years old
    d. Over 25 years old

2) I've
    a. Never seen this presentation before
    b. Seen this presentation before

3) I came here
    a. With a school or after-school group
    b. With my family
    c. With my friends
    d. By myself.

4) On a carousel amusement park ride:
    a. All of the horses go the same speed (in miles/hour or feet/second)
    b. The horse closest to the center goes the fastest in miles/hour or feet/second)
    c. The horse closest to the outside goes the fastest (in miles/hour or feet/second)
    d. I have no clue

5) If the carousel was going really fast and I let go of my wallet it would fly (use the diagram to the right): Radially outward from the center□
    a. Tangentially outward
    b. Continuing to spin around the carousel.
    c. Inward to the center of the carousel
    d. I have no clue



6) If an ice skater is turning and brings her/his arms inwards he/she
    a. Starts spinning faster (more rotations per minute)
    b. Starts spinning slower (less rotations per minute)
    c. Doesn't experience any change in spinning (same rotation per minute)
    d. I have no clue

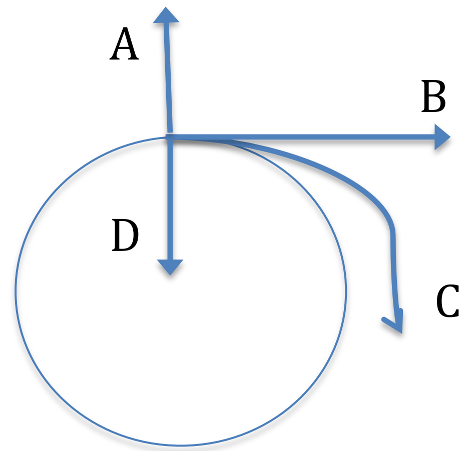
7) A tire is more likely to stay upright longer if
   a. It is not spinning
   b. It is spinning
   c. It doesn't matter if the tire spins or not—it falls over at the same rate.
   d. I have no clue.

8) If the earth spun fast enough
   a. We would feel be stuck on the ground unable to move.
   b. We would be flung off the earth's surface.
   c. Nothing would change (other than shorter days and nights).
   d. I have no clue.

Original Posttest

1) On a carousel amusement park ride:
    e. All of the horses go the same speed (in miles/hour or feet/second)
    f. The horse closest to the center goes the fastest in miles/hour or feet/second)
    g. The horse closest to the outside goes the fastest (in miles/hour or feet/second)
    h. I have no clue

2) If the carousel was going really fast and I let go of my wallet it would fly (use the diagram to the right):
Radially outward from the center
    e. Tangentially outward
    f. Continuing to spin around the carousel.
    g. Inward to the center of the carousel
    h. I have no clue



3) If an ice skater is turning and brings her/his arms inwards he/she
    e. Starts spinning faster (more rotations per minute)
    f. Starts spinning slower (less rotations per minute)
    g. Doesn't experience any change in spinning (same rotation per minute)
    h. I have no clue

4) A tire is more likely to stay upright longer if
    e. It is not spinning
    f. It is spinning
    g. It doesn't matter if the tire spins or not—it falls over at the same rate.
    h. I have no clue.

5) If the earth spun fast enough
    a. We would feel be stuck on the ground unable to move.
    b. We would be temporarily flung off the earth's surface.
    c. Nothing would change (other than shorter days and nights).
    d. I have no clue.

6) If I wanted to know what happens with a ball when placed on a spinning surface, I would:
    a. Ask someone.
    b. Google it (or use another search engine).
    c. Try it out (experiment).

APPENDIX D. ORIGINAL ATTITUDE SURVEY

Original Survey Attitude Pre-Test (discarded)

Please fill in the box to show how much you agree with each of the following statements. Fill in
a “7” if you “mostly agree,” fill in a “1” if you “mostly disagree” and fill in a box in between to show how much you partially agree or disagree with the statement.

	Mostly Disagree			Neither agree nor disagree			Mostly Agree
1. Scientists are among the most successful people.	1	2	3	4	5	6	7
2. Thinking like a scientist is only useful when taking test in science class.	1	2	3	4	5	6	7
3. Science is among the most useful school subjects.	1	2	3	4	5	6	7
4. There is no point to learning about science because everything we know will be wrong in 20 years.	1	2	3	4	5	6	7
5. I would enjoy a being a scientist.	1	2	3	4	5	6	7
6. Students who like science are the least popular in school.	1	2	3	4	5	6	7
7. Scientists are among the most honest people.	1	2	3	4	5	6	7
8. Science makes me feel like I am lost in a jumble of numbers and words.	1	2	3	4	5	6	7
9. I enjoy visiting science museums.	1	2	3	4	5	6	7
10. Science is fun when compared to other school subjects	1	2	3	4	5	6	7
11. If science shows that my belief is wrong, I consider changing my belief.	1	2	3	4	5	6	7
12. The world would be better off if people thought more like scientists.	1	2	3	4	5	6	7
13. Knowing science only means knowing facts and formulas.	1	2	3	4	5	6	7
14. I see myself becoming a scientist one day.	1	2	3	4	5	6	7
15. Scientists are among the smartest people.	1	2	3	4	5	6	7
16. I like participating in science.	1	2	3	4	5	6	7

Original Attitude Post-Test (discarded)

Please fill in the box to show how much you agree with each of the following statements. Fill in
a "7" if you "mostly agree," fill in a "1" if you "mostly disagree" and fill in a box in between to show how much you partially agree or disagree with the statement.

	Mostly Disagree			Neither agree nor disagree			Mostly Agree
1. Scientists are among the most successful people.	1	2	3	4	5	6	7
2. Thinking like a scientist is only useful when taking test in science class.	1	2	3	4	5	6	7
3. Science is among the most useful school subjects.	1	2	3	4	5	6	7
4. There is no point to learning about science because everything we know will be wrong in 20 years.	1	2	3	4	5	6	7
5. I would enjoy a being a scientist.	1	2	3	4	5	6	7
6. Students who like science are the least popular in school.	1	2	3	4	5	6	7
7. Scientists are among the most honest people.	1	2	3	4	5	6	7
8. Science makes me feel like I am lost in a jumble of numbers and words.	1	2	3	4	5	6	7
9. I enjoy visiting science museums.	1	2	3	4	5	6	7
10. Science is fun when compared to other school subjects	1	2	3	4	5	6	7
11. If science shows that my belief is wrong, I consider changing my belief.	1	2	3	4	5	6	7
12. I learned a lot from this presentation.	1	2	3	4	5	6	7
13. The world would be better off if people thought more like scientists.	1	2	3	4	5	6	7
14. Knowing science only means knowing facts and formulas.	1	2	3	4	5	6	7
15. This presentation was very entertaining.	1	2	3	4	5	6	7
16. This presentation was very educational.	1	2	3	4	5	6	7
17. I see myself becoming a scientist one day.	1	2	3	4	5	6	7
18. Scientists are among the smartest people.	1	2	3	4	5	6	7
19. I like participating in science.	1	2	3	4	5	6	7
20. This presentation was very boring.	1	2	3	4	5	6	7

APPENDIX E. PRESENTATION SCRIPTS

Circular Motion (Spin)

This presentation shows modifications with mental and physical engagements. Physical engagements begin with a “P:”, mental engagements begin with an “M:” and Mental and Physical engagements begin with an “P & M:”.

Presenter states:

As part of our efforts to improve presentations we are doing research on the effects of engagements within informal science presentations. The purpose of this research is to better understand how the elements within a presentation alters your attitudes and understanding. When you entered the presentation, you were given some voting cards with small A, B, C, and D on them as well as some large, strange codes (shows sample card). If you would like to participate in this research, simply answer the questions by holding up your voting card. If you hold it up so that an A is upright, then you’re voting for A. I will record your answers with my cell phone/tablet. We will start by seeing what you already might know, and at the end, we’ll check again to see if anything changed.

You don’t have to participate if you don’t want to. If you have any questions about this study, you can ask me now, or if you prefer you can call me up after the presentation at [redacted] or contact the LSU IRB board at 225-578-8692. These numbers will also be on the PowerPoint presentation you will see. Are there any questions?

In order to ensure the presentation meets our standards, we will be videotaping the presentation itself—not the audience, but the presentation. If you are incidentally caught on videotape as part of the presentation don’t worry, we are not planning on showing it to anyone. In any case we would not show video to anyone without your express written approval.

Presenter then reads each question on the quiz as these same questions come up on the overhead Plickers® presentation. The voting cards contain codes that are read by the cell phone (or a tablet) during the presentation. Although individual answers are recorded and traced, user information is not recorded (no pictures or data other than the code is taken by the cell phone).

After the pretest the presentation begins with the script detailed on the next page. When the presentation is over the Plickers® posttest is conducted.

Spin! Circular Motion Demonstrations

Presenter introduces himself and conducts the pre-test first. This involves mentioning that this project is part of a larger study on the impacts of presentation, and that at any time if audience members don't want to participate by holding up there voting cards, then they are under no obligation to.

Presenter: Hello, I'm William Katzman. Welcome! We will be talking about motion—in particular, circular motion—spinning! Now let's examine motion. Presenter goes to a set-up with a tablecloth on a table with a plate silverware and a cup of water.

DEMO 1: Tablecloth

Presenter: Somedays after a hard day at work I come home, I pour myself a nice glass of quality wine (pulls out jug) and pours it into the cup and I think: Science!

Control: Now science says if I pull this tablecloth out from under the dishes quickly then there won't be enough time for the **tablecloth** to pull on the dishes and yank them off the table.

M: As scientists we ask questions and make predictions. So, what do you think will happen if I pull this tablecloth out slowly? Will the dishes stay there, or come with the tablecloth? What if I pull it out quickly?

P: I could try pulling out the tablecloth from under these dishes, but I think you should do the experimental—just like an experimental scientist. Located at each of your seats is a penny and a card. Put the penny on the card. And put the card on your hand. Grab the card with

your spare hand. If you move the card slowly what happens to the penny. What if you move it quickly? Now let's go to a larger scale—with a tablecloth.

P & M: As scientists we ask questions and make predictions. So, what do you think will happen if I pull this tablecloth out slowly? Will the dishes stay there, or come with the tablecloth? What if I pull it out quickly? Are you curious about this? Are you ready to make a prediction and try the experiment? Located at each of your seats is a penny and a card. Put the penny on the card. And put the card on your hand. Grab the card with your spare hand. Try moving the card slowly or quickly to see what happens to the penny! Now let's go to a larger scale—with a tablecloth.

Presenter: Now remember before I do it…this could get very messy.

Performs Tablecloth demo, where the tablecloth is pulled quickly, and the dishes remain still.

P, P & M: Can I have a volunteer from the audience who would like to give this a try?

Presenter: The item stays still due to its inertia. As Newton said, an object in motion stays in motion while an object stays at rest. Now let's try it with an object in motion.

DEMO 2: Object on Car

Control: According to Newton, an object at rest stays at rest, and an object in motion stays in motion. So, for example if you're in car, and the car stops suddenly…you don't you keep going until you hit something. Just like this

M: What if an object was moving? Would it keep moving?

P: (To volunteer) Roll this right into that block.

P & M: What if an object was moving? Would it keep moving? (To volunteer) Roll this right into that block.

Performs in motion demo, where an object sits on a car, and the car is suddenly stopped by running into an object, but the object on the car keeps going.

DEMO 3: Linear Speed vs. Rotational rate (twirling stick)

Control: I'm going to spin this object around, and I want you to take a look at the outside and the inside. Notice that the outside seems to move faster than the inside, and it blurs more. (Twirls stick). The outside goes quicker is because it travels around the whole big circle in the same amount of time that the center travels a really tiny circle.

M: I want you to predict what you will see when I twirl this stick around. Will the outside and inside look the same, or will one go faster than the other and blur more? Make a prediction.

P: I need 4 volunteers. Together we will line up along this long pipe and just twirl around the stage. Take a look at how much I move—at the center of this pipe, versus how much the people on the outside move. (Arranges people along pipe and says) let's begin rotating…. come on faster! Notice how the people on the outside had to run while I barely moved. The outside people needed to go quicker because they traveled around a whole big circle in the same amount of time that the inside traveled a really tiny circle, and I merely rotated. Just like on this stick (twirls stick).

P & M: I need 4 volunteers. Together we will line up along this long pipe and just twirl around the stage. We're all going to move around the stage, in a circle lined up along this

pipe, but pivoting around me. In order for us to do this, do you think everyone will need to move the same speed, or different speeds? If different speeds, who do you think will have to move the fastest? Make a prediction. (Arranges people along pipe and says) let's begin rotating…. come on faster! Who was running? Who barely moved? That's right, the outside people needed to go quicker because they traveled around a whole big circle in the same amount of time that the inside traveled a really tiny circle, and I merely rotated. Just like on this stick (twirls stick).

DEMO 4 (glass on platform) and 5 (ball let go on turntable):

Presenter: So rotating objects actually have different parts of the object moving at different speeds.

Control: But that's not the only surprising thing about rotating objects. Here I have an ordinary glass filled with water, on an ordinary platform. If I now swing this platform I can keep the glass on the platform, even though gravity wants to pull it down. Or at least I think I can. Anybody want me to try? *(performs demo)*

P: But that's not the only surprising thing about rotating objects. Here I have an ordinary glass filled with water, on an ordinary platform. If I now swing this platform I can keep the glass on the platform, even though gravity wants to pull it down. Or at least I think I can. Here I go: *(performs demo)* Anybody want to try it? We can start with a plastic cup filled with foam on the platform! *(Coaches volunteer to perform demo)*.

M: Have any of you seen or heard of things going so fast they can go upside down without falling? Do you think we could do the same with an ordinary glass of water on a platform? If I swing this around, do you think the glass will stay on the platform? How about the water—will it stay in the glass? Make a prediction on what would happen if I swung this around. Make a prediction on what would happen if I swung this around. Let's see if your prediction was right: *(performs demo)*

P & M: Have any of you seen or heard of things going so fast they can go upside down without falling? Do you think we could do the same with an ordinary glass of water on a platform? If I swing this around, do you think the glass will stay on the platform? How about the water—will it stay in the glass? Make a prediction on what would happen if I swung this around. Let's see if your prediction was right: *(performs demo)* Anybody want to try it? We can start with a plastic cup filled with foam on the platform! *(Coaches volunteer to perform demo)*.

Control: Now the truth is, gravity would have pulled the glass down, but the platform beat gravity—first the platform flung the glass to upwards then it pushed the glass down because it's attached to a string. People have proposed this motion for space stations to form a kind of apparent artificial gravity in space. But this gravity doesn't work like our gravity pulling things to the center. If the earth were to vanish you would fall downwards, while if this platform vanished the glass would fly outwards. What I'm really doing is flinging this wine sideways, and then it meets the platform which redirects it upwards, where it again meets the platform! Now I'll get on a spinning platform to prove this is the case. I'll spin myself

around, while holding this ball, and when I let go, the ball will fly out tangentially. So, I'll let go of the ball right, when it's between me and the audience, but the ball will fly out to the side of the stage. *(Performs demo 5)*. The same thing is happening with the water, but the glass is there to catch it, and the platform is there to catch the glass.

P: Now the truth is, gravity would have pulled the glass down, but the platform beat gravity—first the platform flung the glass to upwards then it pushed the glass down because it's attached to a string. People have proposed this motion for space stations to form a kind of apparent artificial gravity in space. But this gravity doesn't work like our gravity pulling things to the center. If the earth were to vanish you would fall downwards, while if this platform vanished the glass would fly outwards. What I'm really doing is flinging this wine sideways, and then it meets the platform which redirects it upwards, where it again meets the platform! Now I'll get on a spinning platform to prove this is the case. I'll need two volunteers—one to spin me around, and one to catch the ball when it flies out tangentially. So, I'll let go of the ball right, when it's between me and the audience, but the ball will fly out to the side of the stage. *(Performs demo 5 with assistance of volunteers)*. The same thing is happening with the water, but the glass is there to catch it, and the platform is there to catch the glass.

M: People have proposed this motion for space stations to form a kind of apparent artificial gravity in space. But is this artificial gravity working like our gravity pulling things to the center? If so, why doesn't this water fall out of the glass? Well before we answer that question, let's answer another question with another experiment. Let's not consider gravity.

Imagine we spun this sideways, and then we let go of the platform. Which way would the platform & the water go? If I let go of the platform so that it was right directly in front of me, where would it go? Would it go out into the audience? Would it go to the side of the stage? Would it circle around me? Would it come back towards me? Make a prediction. Now we aren't going to actually do this with the platform and water, instead we'll do it with a ball. I'll spin myself around, while holding this ball, and I'll let go when I face the audience. Make a prediction on which direction the ball will go. Let's see if you're right *(performs demo 5)*. The ball flew to the side. In a similar manner, the platform flung the glass and the water the side, the platform caught the glass, which caught the water, then the platform flung the glass and water upwards and caught it again, and this happened on a continuous basis, with the glass being flung sideways and caught. What I'm really doing is flinging this glass sideways, and then it meets the platform which redirects it upwards, where it again meets the platform! Everyone give the volunteers a round of applause.

P & M: People have proposed this motion for space stations to form a kind of apparent artificial gravity in space. But is this artificial gravity working like our gravity pulling things to the center? If so, why doesn't this water fall out of the glass? Well before we answer that question, let's answer another question with another experiment. Let's not consider gravity. Imagine we spun this sideways, and then we let go of the platform. Which way would the platform and the water go? If I let go of the platform so that it was right directly in front of me, where would it go? Would it go out into the audience? Would it go to the side of the stage? Would it circle around me? Would it come back towards me? Make a prediction. Now we aren't going to actually do this with the platform and water, instead we'll do it with

a ball. I'll spin myself around, while holding this ball, and I'll let go when I face the audience. I'll need three volunteers—one to protect the audience and catch the ball if it flies towards the audience, one to catch the ball when if it flies out tangentially of the stage, and one to catch the ball if it flies around to the back of the stage. So, I'll let go of the ball right when it's between me and the audience. Who do you think is going to catch the ball? *(Performs demo 5 with assistance of volunteers)*. The ball flew to the side. In a similar manner, the platform flung the glass and the water the side, the platform caught the glass, which caught the water, then the platform flung the glass and water upwards and caught it again, and this happened on a continuous basis, with the glass being flung sideways and caught. What I'm really doing is flinging this glass sideways, and then it meets the platform which redirects it upwards, where it again meets the platform! Everyone give the volunteers a round of applause.

DEMO 6: Rotational Inertia Spinning legs (legs in, legs out)

Control: Let's take spinning just a bit further. So far, we've let things that were spinning go, but what if we just moved them around? For example, imagine I was sitting down on the platform and spinning with my legs out, then I brought them in. If you recall the first demo, objects on the outside of a spinning object go faster, so my legs would be moving faster than my head, so if I brought my legs in, it should speed up my head and it would be like a ballerina bringing her arms in, causing me to spin faster. Let's try it *(performs demo)*.

P: Let's take spinning just a bit further. So far, we've let things that were spinning go, but what if we just moved them around. For example, imagine I was sitting down on the platform and spinning with my legs out, then I brought them in. If you recall the first demo, objects on the outside of a spinning object go faster, so my legs would be moving faster than my head, so if I brought my legs in, it should speed up my head and it would be like a ballerina bringing her arms in, causing me to spin faster. Let's try it. Can I have a volunteer who doesn't mind being spun around, or wouldn't mind spinning me? *(Gets volunteer to spin presenter, then to be the one spun around performing the demo.)*

M: Let's take spinning just a bit further. So far, we've let things that were spinning go, but what if we just moved them around? For example, imagine I was sitting down on the platform and spinning with my legs out, then I brought them in—what would happen? Make a prediction…would I just continue spinning at the same rate? Or would my rate of spinning change—speeding up or slowing down? Let's try it. *(performs demo)*. So, it is like a ballerina bringing her arms in—I speed up. Why do I speed up? If you recall the first demo, objects on the outside of a spinning object travel faster, so my legs would be moving faster than my head, so when I brought my legs in, that sped up my head, and it was like a ballerina bringing her arms in, causing me to spin faster.

P & M: Let's take spinning just a bit further. So far, we've let things that were spinning go, but what if we just moved them around? For example, imagine I was sitting down on the platform and spinning with my legs out, then I brought them in—what would happen? Make a prediction…would I just continue spinning at the same rate? Or would my rate of spinning

change—speeding up or slowing down? Can I have a volunteer who doesn't mind being spun around, or wouldn't mind spinning me? *(Gets volunteer to spin presenter, then to be the one spun around performing the demo.).* So, it is like a ballerina bringing her arms in—I speed up. Why do I speed up? If you recall the first demo, objects on the outside of a spinning object travel faster, so my legs would be moving faster than my head, so when I brought my legs in, that sped up my head, and it was like a ballerina bringing her arms in, causing me to spin faster.

DEMO 7: **Spinning things resist changes: bike tire on ground**

Presenter: We have said that objects that are still tend to remain still, and objects that are moving tend to remain moving. How about objects that are spinning?

Control: It turns out that objects that are spinning tend to remain spinning in the same direction. So, if this bike wheel isn't moving, it falls over (*demonstrates*). But if it is spinning it will tend to remain upright, spinning in the same direction (*demonstrates*). That's one reason it's easier to stay upright on a bike that's moving quickly rather than on a bike that's moving slowly. Scientists call this the conservation of angular momentum.

P: It turns out that objects that are spinning tend to remain spinning in the same direction. So, if this bike wheel isn't moving, it falls over (*demonstrates*). Now can I have a volunteer? Would you stand over there, because I'm going to send this bike wheel over to you. See if the bike wheel is spinning it will tend to remain upright, spinning in the same direction

(*demonstrates*) and arriving across the stage. That's one reason it's easier to stay upright on a bike that's moving quickly rather than on a bike that's moving slowly. Scientists call this the conservation of angular momentum.

M: What do you think will happen if I let go of this bike wheel? Go ahead—make your predictions. (Demonstrates). Yes, it fell over. The bigger question is what would happen if it were spinning, and I let go? Would it stay up right? Would it still fall over? Would it move a bit and fall over? Go ahead—think about it and make your prediction. Now let's test it: (*demonstrates*). It turns out that objects that are spinning tend to remain spinning in the same direction. See since the bike wheel was spinning it remained spinning upright. Think about whether it's easier to ride on a bike that's going fast or slow. Fast, right? Scientists call this the conservation of angular momentum.

P & M: What do you think will happen if I let go of this bike wheel? Go ahead—make your predictions. (Demonstrates). Yes, it fell over. The bigger question is what would happen if it were spinning, and I let go? Would it stay up right? Would it still fall over? Would it move a bit and fall over? Now can I have a volunteer? Would you stand over there, because I'm going to spin this bike wheel. If it moves and stays upright, I want you to stop it from hitting the wall. If it falls over, I'll get it and stand there twiddling your thumbs. Everyone, make your prediction. Now let's test it: (*demonstrates*). It turns out that objects that are spinning tend to remain spinning in the same direction. See? Since the bike wheel was spinning it remained spinning upright. Think about whether it's easier to ride on a bike that's going fast or slow. Fast, right? Scientists call this the conservation of angular momentum.

DEMO 8: **Bike tire on hand**

Presenter: Let's take this to a whole new level.

Control: If I let go of this bike wheel while the axle is on my hand, it falls, right? (*demonstrates*) However if the bike wheel is spinning, it tends to keep spinning as gravity tries to twist it off my hand, but that would change what direction it is spinning in, so (*demonstrates*) it remains upright. Again, this is called conservation of angular momentum.

P: Now**,** may I have my volunteer come over here. I want you to hold this and try turning it sideways. Easy, right? What happens if I spin it? Now try to turn it. What happened? Yes, it was much more difficult to move. In fact, if I let go of this bike wheel while the axle is on my hand, it falls, right? (*demonstrates*) However if the bike wheel is spinning, it tends to keep spinning as gravity tries to twist it off my hand, but that would change what direction it is spinning in, so (*demonstrates*) it remains upright. Again, this is called conservation of angular momentum.

M: If I let go of this while the axle is on my hand—what will happen? (*demonstrates*). Sure, it falls over off my hand. But what if it were spinning? Would it remain upright, with the axle on my hand, or would it fall over? Make your prediction. Let's try it (*demonstrates*). It remained upright! Again, this is called conservation of angular momentum.

P & M: Now, may I have my volunteer come over here. I want you to hold this and try turning it sideways. Easy, right? What happens if I spin it? Now try to turn it. What happened? Yes, it was much more difficult to move. In fact, if I let go of this bike wheel while the axle is on my hand, it falls, right? (*demonstrates*) However if the bike wheel is spinning, it tends to keep spinning as gravity tries to twist it off my hand, but that would change what direction it is spinning in, so (*demonstrates*) it remains upright. Again, this is called conservation of angular momentum.

DEMO 9: **Bike Tire on rotating platform**

Control: If you move a spinning wheel while you're on top of another free spinning platform you can even use the conservation of angular momentum to get yourself moving one or another, like so (*demonstration*).

P: If you move a spinning wheel while you're on top of another free spinning platform you can even use the conservation of angular momentum to get yourself moving one or another. May I have a volunteer to help out? (*demonstration with volunteer*).

M: What do you think would happen if you moved a spinning bike wheel while you were on a free spinning platform? Make a prediction, if I change the direction of the spinning bike wheel, what effect (if any) would it have on the big platform? (*demonstration*) Moving the small wheel caused the big one to rotate through that same process of conservation of angular momentum.

P & M: What do you think would happen if you moved a spinning bike wheel while you were on a free spinning platform? May I have a volunteer to help out?

Before we do this, I want you to make a prediction, if I change the direction of the spinning bike wheel, what effect (if any) would it have on the big platform? (*demonstration with volunteer*) Moving the small wheel caused the big one to rotate through that same process of conservation of angular momentum.

Presenter: Thank you for coming to this presentation. Now as part of the research, let's take a quick quiz, just like the beginning of the presentation. If you don't want to take part you don't need to, but at the end you will be welcome to come up and see some of the pieces I used. Thank you! Let's start:

Presenter then reads each question on the quiz (see attached PowerPoint).

APPENDIX F. INTERVIEWER SCRIPT

Questions for Social Group Interviews

Researcher Instruction: If the interviewee has agreed to video and audio recording, proceed as normal. If one or more interviewees has only agreed to audio recording, then put a lens cover over the camera portion of the video-tape. If videotape is not used, ask people to say their name prior to speaking.

Researcher Dialogue: Everyone thank you for agreeing to be a part of this recorded interview. As previously explained, this will be recorded for research on the presentation. At this point I would like each of you to state your name. If at any time you want to leave, feel free to do so.

We're going to try to have a bit of a conversation about the presentation.

Questions:

1) What did you think about the presentation?
2) What did you think the presentation was about?
3) What did you like about the presentation?
4) What did you dislike?
5) Was this presentation what you expected when you decided to see it, if not how was it different?
6) What did you get from this presentation? Was it fun? Did you learn anything?
7) How was this different from other presentations you've seen?

8) Item specific statement (see below). What did you think of this approach?

For item specific questions on presentation style and topic use the following statements:

For control condition of the ‘Circular Motion’ presentation

This presentation used demonstrations.

For experimental condition 1 (mental engagements) for ‘Circular Motion’

This presentation used demonstrations and asked you to predict what would happen prior to the demonstration.

For experimental condition 2 (physical engagements) for ‘Circular Motion’

This presentation used demonstrations and asked you to try an experiment in your seats and used volunteers on stage.

For experimental condition 3 (mental and physical engagements) for ‘Circular Motion’

This presentation used demonstrations and asked you to predict and to physically participate in experiments.

APPENDIX G. PARTICIPANT CONSENT FORMS

Participant consent forms (textually accurate reformatted for this dissertation)

A Non-Clinical Survey Study

Study Title: Effects of engagements within informal science presentations

Performance Site: Louisiana Arts & Science Museum

Investigator: The following investigator is available for questions about this study: Monday – Friday, 2 PM – 5 PM, William Katzman [redacted]

Purpose of the Study: The purpose of this research project is to improve presentations within science centers. Specifically, we ask how mental and physical engagements utilized by a presenter affects the visitor's experience of the presentation.

Inclusion Criteria: Children who have seen a presentation on circular motion at LASM with their parents or guardians.

Exclusion Criteria: Anyone who has not seen the presentation on circular motion is excluded.

Number of subjects: 50 individuals (10 social groups)

Study procedure: Complete a recorded interview after seeing a presentation on circular motion. Attendees will be invited to attend a second presentation and complete a second recorded interview.

Time Required: Each interview can vary in time but should take approximately 5 - 15 minutes.

Risks: The only risk is the inadvertent release of identity of someone who was interviewed causing potential embarrassment if they said something that they found to be embarrassing.

Benefits: Insights gleaned might be of use to other museums dealing with similar programs.

Financial information: By completing this interview the child's parent is entered into a raffle to earn a $40 amazon gift card awarded Dec. 31st or June 15th (whichever date is next). If a second interview is arranged for another day, and the participants can't enter LASM without paying admission, the researcher will arrange to pay admission in lieu of the child's parents paying for admission.

Privacy and Anonymity: The child's responses will be kept confidential and anonymous if so chosen on the assent form by either the parent or the child. Data will be kept confidential unless release is legally compelled.

Participation and withdrawal: Participation is completely voluntary and a child will become part of the study only if both the child and the parent or guardian agrees to the child's participation. At any time, the child may withdraw from the study, or the parent can pull the child from the study while still being entered in to the raffle for the $40 amazon gift card. If the child withdraws or is withdrawn from the study during the first interview, then there will not be a second interview.

To Contact the Researcher: If you have questions or concerns about this research please contact:

William Katzman
[redacted]
17177 Culps Bluff Ave.
Baton Rouge, 70817
wkatzm1@lsu.edu

You may also contact the faculty member supervising this work: Dr. Thomas Ricks, [redacted], Louisiana State University, Louisiana State University, Baton Rouge, LA 70803

Whom to contact about your rights in this research, for questions, concerns, suggestions, or complaints that are not being addressed by the researcher, or research-related harm: Committee on the Use of Human Subjects in Research at Louisiana State University, Dennis Landin, Institutional Review Board, (225) 578-8692, www.lsu.edu/irb.

In this interview process we like to use video and audio recording in order to capture verbal and nonverbal clues and to allow for easier identification of who is speaking.

Please initial which statement you agree to:

_________ You may use a video and audio recording of me within presentations (such as at a conference) on your research.

_________ Although you may video and audio record me, please do NOT show it to others. You can use my answers for research, but keep me anonymous, by using only transcripts without real names.

_________ You may record my audio, but please do NOT record video of me. You can use my answers for research, but keep me anonymous, by using only transcripts without real names.

Signatures:
The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. For injury or illness, call your physician, or the Student Health Center if you are an LSU student. If I have questions about subjects' rights or other concerns, I can contact Dennis Landin, Institutional Review Board, (225) 578-8692, irb@lsu.edu, www.lsu.edu/irb. I agree to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of this consent form if signed by me.

Full Name ____

Signature____ Date: _________________

Email:
____
(email is necessary to contact you if you win the raffle. Phone Number (optional)
____

Please initial here, if you are willing to be called for a follow-up phone interview: _____

If appropriate: the parent/guardian has indicated to me that he/she is unable to read. I certify that I have read this consent from to the parent/guardian and explained that by completing the signature line above he/she has given permission for the child to participate in the study.

Signature of Reader:________________________________ Date:____________________

A Non-Clinical Survey Study – Parental Permission

Study Title: Effects of engagements within informal science presentations

Performance Site: Louisiana Arts & Science Museum

Investigator: The following investigator is available for questions about this study:
Monday – Friday, 2 PM – 5 PM, William Katzman [redacted]

Purpose of the Study: The purpose of this research project is to improve presentations within science centers. Specifically, we ask how mental and physical engagements utilized by a presenter affects the visitor's experience of the presentation.

Inclusion Criteria: Children who have seen a presentation on circular motion at LASM with their parents or guardians.

Exclusion Criteria: Anyone who has not seen the presentation on circular motion is excluded.

Number of subjects: 50 individuals (10 social groups)

Study procedure: Complete a recorded interview after seeing a presentation on circular motion. Attendees will be invited to attend a second presentation and complete a second recorded interview.

Time Required: Each interview can vary in time but should take approximately 5 - 15 minutes.

Risks: The only risk is the inadvertent release of identity of someone who was interviewed causing potential embarrassment if they said something that they found to be embarrassing.

Benefits: Insights gleaned might be of use to other museums dealing with similar programs.

Financial information: By completing this interview the child's parent is entered into a raffle to earn a $40 amazon gift card awarded Dec. 31st or June 15th (whichever date is next). If a second interview is arranged for another day, and the participants can't enter LASM without paying admission, the researcher will arrange to pay admission in lieu of the child's parents paying for admission.

Privacy and Anonymity: The child's responses will be kept confidential and anonymous if so chosen on the assent form by either the parent or the child. Data will be kept confidential unless release is legally compelled.

Participation and withdrawal: Participation is completely voluntary and a child will become part of the study only if both the child and the parent or guardian agrees to the child's participation. At any time, the child may withdraw from the study, or the parent can pull the child from the study while still being entered in to the raffle for the $40 amazon gift card. If the child withdraws or is withdrawn from the study during the first interview, then there will not be a second interview.

To Contact the Researcher: If you have questions or concerns about this research please contact:

William Katzman
[redacted]
17177 Culps Bluff Ave.
Baton Rouge, 70817
wkatzm1@lsu.edu

You may also contact the faculty member supervising this work: Dr. Thomas Ricks, [redacted], Louisiana State University, Louisiana State University, Baton Rouge, LA 70803

Whom to contact about your rights in this research, for questions, concerns, suggestions, or complaints that are not being addressed by the researcher, or research-related harm: Committee on the Use of Human Subjects in Research at Louisiana State University, Dennis Landin, Institutional Review Board, (225) 578-8692, www.lsu.edu/irb.

In this interview process we like to use video and audio recording in order to capture verbal and nonverbal clues and to allow for easier identification of who is speaking.

Parental Permission Form

Please initial which statement you agree to:

_________ You may use a video and audio recording of my child/children within presentations (such as at a conference) on your research.

_________ Although you may video and audio record of my child/children, do NOT show it to others. You can use their answers for research, but keep them anonymous, by using only transcripts without real names.

_________ You may record audio of my child/children, but please do NOT record video of my child/children. You can use their answers for research, but keep them anonymous, by using only transcripts without real names.

My children who may participate are:
Children's full names: ____
____

Signatures:
The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. For injury or illness, call your physician, or the Student Health Center if you are an LSU student. If I have questions about subjects' rights or other concerns, I can contact Dennis Landin, Institutional Review Board, (225) 578-8692, irb@lsu.edu, www.lsu.edu/irb. I agree to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of this consent form if signed by me.

Full Name ____

Parent's Signature_______________________________________ Date: _______________

Email: ____

Phone Number (optional) _____________________

Please initial here, if you are willing to be called for a follow-up phone interview: ________

The parent/guardian has indicated to me that he/she is unable to read. I certify that I have read this consent from to the parent/guardian and explained that by completing the signature line above he/she has given permission for the child to participate in the study.

Signature of Reader:_____________________________ Date:__________________

Child assent form

I ____, agree to be interviewed on camera in order to help people create better presentations.

Put a check mark next to which instruction you agree to:

________You can take video of me and show it to others.

________You can take video of me, but do NOT show it to others.

________You can record my voice, but you can NOT take video of me.

I can stop being interviewed at any time without getting into trouble.

Child's
Signature:____

Age:__________ Date: _________________________

Witness*
____
* Witness must be present to witness the child's understanding of and agreement to participate in this research.

Date: _________________________

A Non-Clinical Survey Study

Study Title: Effects of engagements within informal science presentations
Performance Site: Louisiana Arts & Science Museum
Investigator: The following investigator is available for questions about this study: Monday – Friday, 2 PM – 5 PM, William Katzman [redacted]
Purpose of the Study: The purpose of this research project is to improve presentations within science centers. Specifically, we ask how mental and physical engagements utilized by a presenter affects the visitor's experience of the presentation.
Inclusion Criteria: People attending presentation on circular motion at LASM.
Exclusion Criteria: Anyone not attending the presentation is excluded.
Number of subjects: 150 individuals
Study procedure: You will complete a survey before and after the presentation.
Time Required: The surveys will take approximately 5 minutes to complete each for a total of 10 minutes. The demonstration you will watch will take approximately 30 minutes.
Risks: The only risk is the inadvertent release of identity of someone's answers to attitudinal and conceptual knowledge survey.
Benefits: By filling out these surveys you are entered into a raffle to earn a $25 amazon gift card awarded Dec. 31st or June 15th (whichever date is next). In order to win this you must give your email or phone number. Insights gleaned might be of use to other museums dealing with similar programs.
Confidentiality: Your responses will be kept confidential. When research results are reported, responses will be aggregated (added together and described in summary) and reported without attributing the results to specific identifiable individuals.
Participation and withdrawal: Your participation is completely voluntary and you may refuse to participate or withdraw from the study at any time without penalty.

To Contact the Researcher: If you have questions or concerns about this research please contact:

William Katzman
[redacted]
17177 Culps Bluff Ave.
Baton Rouge, 70817
wkatzm1@lsu.edu

You may also contact the faculty member supervising this work: Dr. Thomas Ricks, [redacted], [redacted], Louisiana State University, Louisiana State University, Baton Rouge, LA 70803

Whom to contact about your rights in this research, for questions, concerns, suggestions, or complaints that are not being addressed by the researcher, or research-related harm: Committee on the Use of Human Subjects in Research at Louisiana State University, Dennis Landin, Institutional Review Board, (225) 578-8692, www.lsu.edu/irb.

The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. For injury or illness, call your physician, or the Student Health Center if you are an LSU student. If I have questions about subjects' rights or other concerns, I can contact Dennis Landin, Institutional Review Board, (225) 578-8692, irb@lsu.edu, www.lsu.edu/irb. I agree to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of this consent form if signed by me.

Full Name ____

Signature____ Date: ________________

Email:
____
(email is necessary to contact you if you win the raffle).

Phone Number (optional) ______________________

Please initial here, if you are willing to be called for a follow-up phone interview: ________
Note: after matching the pre-post surveys, and collecting demographic data we will remove this information from the original surveys in order to keep the individual answers anonymous, UNLESS you initialed at the above line and provided your phone number.

APPENDIX H. DEMONSTRATIONS POST RQ6

Table 32. Demonstrations centering around the anchoring phenomenon

Demo	**Question being explored**	**Brief idea for exploring phenomena**
Cup on platform	Why does the water stay in the spinning cup and the cup on the platform?	Complex anchoring phenomenon. Transition to the next demo requires the presenter/audience observing that you must go fast to make this work.
Twirling Stick	Do rotating things move fast?	The middle barely moves, but the outside (where the cup is) moves fast, like the end of the stick.
Tablecloth	Maybe fast things stick together?	Presenter sets it up where if fast things stick together, then the dishes should stick to the tablecloth – but they don't.
Ball on Car	Do two moving things stick together or do moving things keep moving if the thing moving them stops?	Presenter sets up the idea of an item in motion staying in motion.
Ball on Turntable	What happens to a spinning thing that is moving if the thing spinning them lets go?	Presenter sets up the idea that items spinning, would continue moving outwards in a tangent straight direction…

(table cont'd)

Demo	**Question being explored**	**Brief idea for exploring phenomena**
Repeat cup on platform	How does the ball on turntable relate to the cup on platform?	…so, the water is "caught by the cup which is "caught" by the platform.
Item stuck to bottom of platform	What would an item do if it was stuck to the bottom of the platform and spun?	…so, items are flung outwards (tangentially), even if they are connected to the platform.
Person on turntable	What would happen if an item that was spinning changed where its parts were? Say items moving quickly on the outside came inwards?	Anchoring phenomenon exploration is over, now exploring other phenomena.
Tire on Ground	What would happen if a tire were spinning and let go on the ground?	Anchoring phenomenon exploration is over, now exploring other phenomena.
Tire on hand	What would happen if a tire were spinning and one side of it was let go?	Anchoring phenomenon exploration is over, now exploring other phenomena.
Tire and Turntable	What would happen if we put this spinning tire held by someone, on another turntable?	Anchoring phenomenon exploration is over, now exploring other phenomena.

APPENDIX I. QUALITATIVE CODES

Context Codes:

Age (Child or adult)

Gender (male / female)

Presentation (Control, Mental Only, Physical Only, Both Mental and Physical)

RQ6Status (Pre-RQ6, Transition-RQ6, Post-RQ6)

General Codes

Aud>Background: Interviewee refers to her/is background or interest

Aud>Difference: Interviewee notices a difference attributed to the audience between presentations

Aud>Spont: References an audience's spontaneous action

ClassCompare: Compares the demo to classroom activities

CompareFormats: A comparison of what the audience member thinks happens differently in presentation formats

CompareFormats>Demo: Interviewee noticed a difference in the demonstrations between presentations.

Confusion: Interviewee expresses the idea that (s)he is or was confused about something within the presentation

Connection: Interviewee connects the presentation to either something learned, something experienced, or mentions what it reminds the interviewee of.

DemoOrder: Interviewee expresses opinions on whether the demo order matters

EducationalL: References that the presentation was educational, or learning happened

Enjoyment: Expression of enjoyment like love, cool, enjoy

Entertainment: Indicates the presentation is seen as entertaining

Gravity: About or concerning gravity (often used when responding to what the person thought the presentation was about)

FormatImplication: Implies the style of presentation the attendee had previously went to.

Int>Cards: References interaction related to the use of question and answer cards before and after the presentation

Int>Demos: References interaction related to the use of demos within the presentation

Int>Physical: References interaction related to the use of physical interaction of the audience during the presentation

Int>Questions: References interaction related to the use of questions during the presentation

Interactive: Refers to the presentation or any part of it as interactive

Likes: Interviewee indicates liking a particular portion, concept, or structure

Likes>demo: Interviewee responds that (s)he like a particular demonstration

MultPresent: Interviewee attended multiple sessions

Phys>nonexp>better: The participant thinks it would have been better with physical participation, BUT the participant did not experience it.

Aud>Preconception: Interviewee reveals a preconception.

Presenter: References a presenter quality during presentation

Reason>advance: Individual shows advance reasoning that is clear and at least partially scientifically accurate

Reason>begin: Individual shows evidence of reasoning as the individual talks. Such as: I thought this, but that doesn’t make sense due to this demo. Reasoning does not need to be clear with accurate results.

Sci>world: References the world as it relates to what science is or what the show demonstrated

Science: Indicates belief it was about the general topic of science

Science>Process Indicates referring to a scientific process such as prediction or experimenting

Spinning; Related to spinning or motion

Suggestion: Interviewee offers a suggestion for improvement

Surprise: Expresses surprise at an element of the presentation

WantMoreInteract: participant thinks (s)he would prefer more interaction

APPENDIX J. CONTENT RESULTS WITH PERFECT PRETESTS REMOVED

Table 33. Pre-post content data with perfect pretests removed

Group	Pre-Test Mean	Mean Change	Std Dev.	Std. Error Mean	N	Sig.	Cohen's D Effect Size
Control (all data)	2.038	.887	.824	.113	53	<0.001*	1.076
Control (pre—RQ6)	1.923	1.077	.641	.178	13	<0.001*	1.680
Control (transition-RQ6)	2.000	1.000	.632	.191	11	<0.001*	1.582
Control (post-RQ6)	2.103	.759	.951	.177	29	<0.001*	0.798
Mental Only (pre—RQ6)	1.696	1.304	1.020	.213	23	<0.001*	1.278
Physical Only (pre—RQ6)	2.160	1.080	.909	.182	25	<0.001*	1.188
Mental & Physical (all data)	2.227	1.061	1.080	.133	66	<0.001*	0.982
Mental & Physical (pre—RQ6)	2.122	1.244	1.113	.174	41	<0.001*	1.118
Mental & Physical (transition-RQ6)	2.429	.286	.951	.360	7	.457	0.301
Mental & Physical (post-RQ6)	2.389	.944	.938	.221	18	.001*	1.006

* indicates a statistically significant result, highlight indicates directly comparable cases

APPENDIX K. WORDS USED IN INTERVIEWS

Table 34. Most common words used during interviews (excluding like)

Rank	Control	Mental Only	Physical Only	Both Mental & Physical
1	Think	Science	think	think
2	One	Thing	know	Know
3	Time	Think	Different	Thought
4	Know	Different, stuff	fun	science
5	Different		Lot, Stuff, Thought, Science	Different
6	See, Demonstrations	Cool, one, say		One, fun
7				
8	Thought			Actually
9	Going	Anything, see, things		Didn't, right
10	Fun		Get, Gravity, Presentations, Talking, Expected, Demonstration, Experiment/experimenting, Learn/learning	
11	Anything			Stuff

(table cont'd)

Rank	Control	Mental Only	Physical Only	Both Mental & Physical
12	Something	Gravity, move		Spinning
13	Really			Part, learn/learned
14	Cool, Things	Know		
15		Actually, answer, little, really		Can, get, question, time
16	Get, Good, Science			
17			Approach, Interaction, Learned, Much, Seats, Spinning, Things	
18				
19	Questions	Also, biochemist, can, mean, probably, thought, time, fun		Questions, demonstration
20+	20: Actually 21: Much, Way	27th Example. Going, kind, lot, much, outside, part, platform, wanted 36th demonstrations - tied with 15 other words)	23rd Going, Involved, Kids, See, Spin, Thank, Volunteers, Yes	21st see

APPENDIX L. IRB APPROVAL

Institutional review board action on exemption approval request

ACTION ON EXEMPTION APPROVAL REQUEST

Institutional Review Board
Dr. Dennis Landin, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu
lsu.edu/research

TO: William Katzman
Curriculum Studies

FROM: Dennis Landin
Chair, Institutional Review Board

DATE: October 19, 2018

RE: **IRB#** E11276

TITLE: Effects of engagements within informal science presentations

New Protocol/Modification/Continuation: New Protocol

Review Date: 10/19/2018

Approved X **Disapproved**__________

Approval Date: 10/19/2018 **Approval Expiration Date:** 10/18/2021

Exemption Category/Paragraph: 2b

Signed Consent Waived?: No

Re-review frequency: (three years unless otherwise stated)

LSU Proposal Number (if applicable):

By: Dennis Landin, Chairman DLandin

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –
Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. **SPECIAL NOTE: When emailing more than one recipient, make sure you use bcc. Approvals will automatically be closed by the IRB on the expiration date unless the PI requests a continuation.**

* *All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb*

APPENDIX M. PERMISSION

William Katzman <bill_the_kat@att.net>
To: permissions@exploratorium.edu

Tue, Feb 8 at 12:45 PM

2/8/2022

Exploratorium
3601 Lyon Street
San Francisco, CA 94123-1099

permissions@exploratorium.edu

Dear Dr. Thomas Humphrey and Dr. Joshua Gutwill:

I am completing a doctoral dissertation at Louisiana State University entitled "Effects of engagements and presentation order in informal science presentations." I would like your permission to reprint the following material from *Fostering Active Prolonged Engagement* in my dissertation, which is in preparation for my graduation in May 2022.

Text: According to Hein, as recounted by Humphrey and Gutwill, many early science center exhibits were "Exhibits of arresting phenomena, often counterintuitive" and "were designed to illustrate scientific purposes," (Humphrey and Gutwill, 2005, p. iii

At an early version of one exhibit Humphrey & Gutwill (2005) saw "wonderful investigatory behavior: people making predictions, generating and testing hypotheses and drawing conclusions" (p. 5). Investigation - was just one of the interactions visitors engaged in. In the end Humphrey & Gutwill (2005) saw four main styles of interactions in the prolonged engagements "Exploration, Investigation, Observation and Construction" (p. 7).

Knowing that multi-sided and multi-user exhibits encouraged family learning, the original Spinning Patterns table (see Figure 2) was a large sand table that spun around slow enough so as to not throw off the sand. When it was used on the exhibit floor it was quickly discovered that "visitor interference shut down engagement" (Humphrey & Gutwill, 2005, p.19).

Pictures: Pulley Table, on p. 18 upper left (reproduced at one-half page size); Single station version of Spinning Patterns on p. 19 upper right (reproduced at one-quarter page size); Multi-station version of Spinning Patterns on p. 19 lower section (reproduced at one-third page size).

All of the text and photos will be a part of the Literature review that talks about seminal works that look at interactivity in informal science centers.

Please contact me if you have any questions or need additional information.

Sincerely,

William Katzman

17177 Culps Bluff Ave.

Baton Rouge, LA 70817

wkatzm1@lsu.edu or bill_the_kat@att.net

Megan Bury <mbury@exploratorium.edu>
To: William Katzman

Wed, Feb 9 at 8:24 AM

Dear William,
Hello and thank you for your message. The Explaoratorium grants permission for you to use the text and images from our Fostering APE book for your paper. Thanks for including us in your work!

I am attaching high-res jpegs of the 3 images below--please credit them as follows:
© Exploratorium, www.exploratorium.edu

citation:
Gutwill, J. P., & Thogersen, E. (2005). Reflecting on APE. In T. Humphrey & J. Gutwill (Eds.), Fostering Active Prolonged Engagement: The Art of Creating APE Exhibits. Walnut Creek: Left Coast Press.

Thank you for your interest in our work.

Regards,
Meg

Megan Bury | Media Archiving and Permissions
permissions@exploratorium.edu
pronouns: she/her

exploratorium

Pier 15, San Francisco, CA 94111
Mailing: 17 Pier, Suite 100, San Francisco, CA 94111
www.exploratorium.edu

> Show original message

Download all attachments as a zip file


Spin Single.jpg
3.4MB


5 3 station 4.jpg
4.3MB


Pulley multi.jpg
6.4MB

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VITA

After graduating with a Bachelor's in Physics and Humanities from Worcester Polytechnic Institute, William Katzman went on to receive a Master's in Education from UMASS Amherst. William spent several years working as a middle school and high school teacher in Massachusetts, prior to transitioning over to the field of informal education. William began his informal education career, as the exhibits director at Catawba Science Center, in North Carolina, overseeing the museum's expansion and creating several nationally travelling exhibitions. When the opportunity arose, William began leading the science outreach efforts at LIGO, a National Science Foundation facility located in Livingston, Louisiana. During his tenure at LIGO, he decided to pursue his PhD in Curriculum and Instruction, at Louisiana State University, resulting in this dissertation.