

Informal Learning in a Museum Setting: A Case Study with Language Science

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By

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ABSTRACT

Informal science learning experiences (ISE) – including activities and demonstrations in science museums – offer a promising opportunity for filling gaps in the public’s scientific understanding. ISE has typically been conducted using traditional science fields, however we propose that using a nontraditional area of science, such as language science, could uniquely appeal to broader audiences and facilitate learning for a wider range of individuals. This study explored family learning outcomes when interacting with an informal science activity based on language science. The project focused on understanding how participants interacted with the activity, the types of statements that were associated with understanding of the activity’s content, and on participants’ views of science. Twelve family groups, consisting of 20 adults and 19 children, were recorded as they engaged in with activity and answered interview questions about the activity. Sessions were transcribed and coded to reveal general themes of participant discussion. Overall, the activity was successful at conveying scientific information using language science. Sixty-seven percent of the groups demonstrated a full understanding of the content. Results of the study reveal an association between participants’ level of understanding and a focus on the sensation of engaging with the activity. A process-based view of science was also positively correlated with understanding of the content. In addition, several discussion patterns were revealed that may help inform future activity design. The results of this research reveal potential benefits of using language science in ISE activities and broadens the current understanding of how families interact with these activities.

INTRODUCTION

In the modern world, the general public is increasingly faced with decisions that require scientific understanding, such as whether or not they should vaccinate their children or consume genetically modified foods. Despite the fact that scientific knowledge has an ever-increasing relevance in day-to-day experiences, overall science understanding is noticeably low in the United States (Funk & Goo, 2015). As an example, in a 2004 study, only 20% of American respondents could describe what a scientific study is (Miller, 2004). To address this growing educational need, it is important to explore ways to increase the general science knowledge of the public.

Formal education alone may not be enough to meet the science-related needs of the public. As children progress through their formal education, their interest in science tends to decrease and they increasingly find their science courses both unengaging and impractical (Barmby et al., 2008). Additionally, a number of students leave their primary education with major gaps in their scientific understanding due to roadblocks that occur during their education (Harlen, 2001). Although many Americans have negative experiences with science in school, they will often have an interest in science as adults. Studies show the majority of adult Americans express a high degree of interest in learning more about science (Falk et al., 2007). Despite being interested in science, most adults do not list their formal education as the primary source of the science knowledge they have learned. Instead, it seems that the main long-term benefit of formal science education is to serve to provide a framework for adults to pursue more information on their own (Miller, 2001). Formal education is a crucial part of fostering science learning but in addressing the current needs of the public, we need to explore additional means of helping individuals become more aware of, and engaged with, scientific pursuits.

Currently, one could view the American public as a group with major gaps in their engagement with, and knowledge about, science. These gaps should be addressed in a way that reaches a broad audience in terms of age and background and fits with the needs of a busy and diverse population. Informal Science Education (ISE) is an effective way to fill the public's educational gaps. Informal Science Education refers to science learning that occurs outside of a formal classroom environment. Informal educational environments, such as museums or hobbyist organizations, can have a major impact on society, and are already widely established throughout the country (Bell et al., 2009). Current research suggests that ISE plays an important role in increasing public understanding of science, as well as the amount of interest and engagement individuals have with science. ISE can also help individuals become more interested in pursuing science-related activities and careers. This makes informal science learning an area well-suited for use as a tool to fill the gaps in the public's current understanding of science.

One major benefit of informal learning environments is that they are especially suited to foster interest in science among children (Sentürk & Özdemir, 2014). Engaging with science outside of school is an important factor associated with continued participation in science. Additionally, science centers have been shown to increase visitors' understanding of, and interest in, careers within science, suggesting that informal science learning serves an important role in inspiring future scientists—an increasingly important role in society (Bell et al., 2009). On the other end of the age-spectrum, ISE can reach the adult population as well. In terms of lifelong learning, informal opportunities to learn (such as studying a topic on one's own or visiting science museums) seem to have a greater impact on an individual's science understanding than school (Falk et al., 2007).

Beyond establishing an interest in science, ISE can also have a substantial effect on individuals' understanding of science information. Miller (2004) found that whether or not an individual actively consumes informal science material is the next best predictor of science knowledge after taking college-level science courses. Informal science environments are effective educational tools, with studies showing that individuals often retain specific science information after just one visit to a science museum (Sentürk & Özdemir, 2014). Importantly, these benefits are accessible to individuals of all ages, allowing a wide range of adults who have finished their formal education to continue to learn scientific information. If we wish to create a science literate society, it is important to note that adults will have to do the majority of their learning outside of the formal educational system.

ISE can also help improve attitudes towards science. Part of the reason children often do not learn and retain knowledge about science is because they find their science classes to be boring and unengaging (Barmby et al., 2008). Individuals rarely learn and retain new information effectively if they do not feel a desire to learn the information in the first place (Csikszentmihalyi, 1990). One of the most fundamental goals of ISE is to spark interest and excitement towards science (Bell et al., 2009). Sentürk and Özdemir (2014) found that visits to informal science environments (e.g. science and technology museums, zoos, and libraries) lead to more positive attitudes towards science. Having a more positive relationship with science will allow learners to be more likely to identify with and try to understand science. Learning is influenced by the preexisting views of individuals. For example, being able to identify with academic pursuits predicts how cognitively engaged a learner will be when trying to understand new information (Walker et al., 2006). With this in mind, ISE serves an important role in helping individuals have a positive view of science, which can inspire future independent learning.

ISE can also change how individuals relate to science. There is evidence that science museums can help shift visitors' understanding of science from viewing it as a static body of facts to viewing science as a process for using evidence to generate testable ideas which can then grow into broader theories (Bell et al., 2009). Having this understanding of the core nature of science has been shown to improve understanding of science content (Lombrozo et al., 2008). Realizing that science is not a fixed body of facts generated by researchers, but rather a process used to gain knowledge, seems to help individuals engage with science in more meaningful ways, thus making informal science learning an important way to help the public develop a more effective way of interacting with science.

Beyond the general loss of interest in science during formal education, current science education often fails to take into account important factors such as the differences between various groups of the population. For example, the vast majority of research on ISE has come from educational programs focused on traditional science, technology, engineering and medicine (STEM) fields, such as physics or mechanical engineering. This focus may limit the educational benefits of ISE, by restricting both the types of information taught and the potential audience reached by the ISE programs. For example, research has long shown that women typically pursue careers that are related to humanities and social sciences as opposed to men who are more likely to enter STEM fields (Aud et al., 2010). Although men and women are equal in aptitude for STEM fields, they diverge in what careers they enter and in what topics they explore during college. Buccheri et al. (2011) found that across several countries, gender-related differences in interest seem to play a major role in the gender disparities in fields such as physics. This is relevant to the discussion of ISE because if educators focus solely on STEM-related informal

education they risk missing opportunities for expanding and broadening interest in science by failing to meet the needs of a large portion of the public.

Recognizing that many individuals do not have an interest in traditional science forces us to explore alternative avenues for engaging the public in science. ISE conducted using less traditional areas of science such as psychology and language, may offer unique benefits. One of the most important revelations from research on informal learning is the extent to which visitors' characteristics influence learning (Falk et al., 2007). Individuals who are not as interested in fields such as chemistry or physics are less likely benefit from ISE activities in these areas. To broaden the public's engagement with science, outreach based on more traditional sciences should be complemented with educational programs based on other fields that appeal to different individual interests. This helps create engagement and interest in science among individuals whose attention would not be captivated by other by more traditional subjects. Our study proposes that language science is a nontraditional science field that is ideally suited for use in informal science education.

Language science as an educational medium offers unique benefits. For one, language science is a good way to foster intrinsic motivation in a museum setting. Research by Deci and Ryan (2000) reveals several factors that promote intrinsic motivation, such as feelings of autonomy and competence. Informal science activities are good tools for promoting these aspects of intrinsic motivation (Henderson & Atencio, 2007). Autonomy is fostered by allowing individuals to self-direct much their learning experience within an informal science environment. Additionally, competence is promoted the personalized feedback and challenges that are typically a part of ISE activities. For example, many museum activities guide learners to figuring out the message of the activity for themselves. When learners are able to do this, they feel an

increased sense of personal competency. Language science may be even more effective than other fields in terms of fostering intrinsic motivation for a few reasons. Language science utilizes the pre-existing skills and knowledge of participants, which may help promote feelings of autonomy and competence. An additional benefit is that while many individuals lose interest in the science content covered in school (Barmby et al., 2008), language science is not a field that individuals have taken classes in, and thus may be more interesting to museum visitors.

Another major advantage of language science-based ISE is that language information is well-suited to be taught using juxtaposition. Juxtaposition involves contrasting a learner's current knowledge about a topic with new information that reveals some additional aspect of that topic. This effect serves to challenge learners to both rethink their previous assumptions and to tie new information to their previous experiences (Fenichel & Schweingruber, 2010). Language is a fundamental part of human life and is closely involved in the day to day experiences of every person (Wagner et al., 2015). Because of this, each person already has a rich personal background with language which will allow them to more easily form connections between new information and their previous knowledge—a process which is known to contribute to higher cognitive engagement (Walker et al., 2006). Thus, informal learning related to language science has unique features that can enhance learning. Language science concepts relate to the rich personal experiences of learners, making them an important method for engaging individuals with little to no previous experience with science (Wagner et al., 2015). Visitors with little scientific knowledge can quickly relate to language science information. Because of this, it is likely that learners will grasp scientific information about language more easily than in many other areas.

ISE environments offer several advantages for learning which language science is well suited to capitalize on. One major advantage of science museum activities is that they are designed as free choice learning environments—settings where visitors voluntarily choose to engage in learning activities. This type of voluntary learning design has been associated with a number of positive learning outcomes (Falk et al., 2007). Language science is a highly accessible topic for a wide range of visitors, due the rich connections with everyday experiences that language provides. This is especially appealing to family groups, which research shows are often primarily focused on finding experiences that their entire family can effectively engage with (Falk & Storksdieck, 2009). The fact that museum visitors usually already have a desire to learn information about science when they are visiting a museum is beneficial for educators who work in these environments. On the other hand, individuals have few incentives to engage in science learning activities that do not engage them or appeal to their interests. This is another reason to view language science as a way to reach more audiences. Such a field serves to bridge the gap between science and individuals who do not view themselves as interested in science. In many cases, it may be that the individual simply had not been exposed to an area of the scientific endeavor that interested them, in which case, language science may be the ideal tool to engage them with science.

One of the most effective ways to teaching new information is to provide learners with the opportunity to engage in open inquiry (Harlen, 2001). Open-inquiry experiences require learners to formulate, test, and reevaluate their own ideas about a phenomenon. This approach to learning often yields great results but is hard to achieve in the classroom because the level of support a learner needs in order to explore a topic varies greatly from person to person. These issues are less pronounced in museum activities, where the activity can be more individualized

based on who is engaging with it. Language science topics may be easier for participants to engage in inquiry with, because they can easily reference their personal experience to formulate questions to explore within the context of language. Allen and Gutwell (2009) found that activities designed around helping learners develop science inquiry skills were effective at teaching families new information and also in helping them learn to scientifically explore a topic. Inquiry skills such as these are crucial in equipping learners with the necessary skills to continue to pursue scientific information on their own. These types of inquiry-based experiences should be incorporated into language science activities to help foster ideal learning outcomes.

Conducting research on informal language science learning could yield important information about how to most effectively use non-traditional science fields to engage the public with scientific knowledge and processes. It could be used to engage a wider audience in learning science information by helping more people identify scientific pursuits. Museum activities based in language science have the potential to be a highly effective way to teach learners about science. As discussed above, language science fits well with established techniques for conducting informal science education, such as teaching using juxtaposition. Using a universally experienced phenomenon such as language to teach science may be especially effective since learners already have a rich history of experiences with language (Wagner et al., 2015). Thus, it is likely that informal science activities based in language will not only engage a broader audience but will also be highly effective ways to teach new science information to learners. This project seeks to shed light on some of these issues by examining language science-based activities at a science museum. The study focused on exploring how museum visitors interacted with one language science activity. Specifically, this work examined the content of family

discussions about the activity to reveal the main themes surrounding how participants engaged with the activity.

Three primary research questions drove this study. One area of focus was to examine which elements of the educational activity participants were most focused on, with the goal of understanding factors related to high engagement with the activity. A second research question examined factors relating to understanding of the scientific content presented within a language-based learning activity. This was done to evaluate what aspects of the activity served to either help or hinder museum visitors' understanding of language science. Lastly, the study explored museum visitor's views of science. This line of inquiry served to both help reveal the views of science held by museum visitors, and how those views may influence the way visitors interact with learning activities.

METHOD

Participants

Study participants consisted of family groups visiting the science museum. Families were defined as at least one parent (or legal guardian) accompanied by one or more child or adolescent below the age of 18. Other adults (such as older siblings or extended family) were also included in the family groups. A total of 13 family groups were interviewed, however data from the first group was not recorded due to interviewer error. The remaining 12 groups consisted of a total of 39 individuals, with a mean group size of 3.25 individuals. Fourteen participants were first-time visitors to the museum, while the remaining 25 had visited the museum at least once in the past. Five percent of study participants were black/African American, 13% were multiracial, and 82% were white.

Table 1. Demographics

	Female	Male	Mean Age
Adult	11	9	39.85
Child	11	8	9.86
Total	22	17	

Setting

This study took place in The Language Sciences Research Lab in Columbus, Ohio. The Language Sciences Research Lab is a state-of-the-art research lab embedded in Center of Science and Industry (COSI) run by personnel from a variety of departments within The Ohio State University (Wagner et al., 2015). The lab's main purpose is to conduct research, perform educational outreach for the public, and train new language science researchers. To fulfill its research goals, the lab recruits museum visitors of a variety of ages to participate in ongoing research projects overseen by affiliated lab faculty. These projects cover a diverse range of interests, but all broadly fall within the realm of language science. Outreach is accomplished through over a dozen short interactive activities designed to teach various aspects of language. These lab demonstrations are designed with the goal of both generating interest in science and educating people about the nature and study of language. The current study focused on analyzing one of these demonstrations.

Design and Procedure

This exploratory study was designed to examine factors related to learning from the language lab's demonstrations using an emergent design. Previous studies have shown that museum visitors typically visit as a multi-generational group that explore exhibits together (Falk & Dierking, 1992). Thus, the current study focused on family groups to more accurately represent an average museum experience. In addition, research shows that families collectively

work together to construct an understanding of the information they are learning (Ellenbogen et al., 2004). Family dynamics play a large role in how visitors learn information, and failure to account for this can lead to activities that do not work effectively (Shine & Acosta, 2000).

While recruiting for this study, the researchers approached the first family group that they encountered within the exhibit beside the language lab. As the lab's activities are performed in this area, the sampling process helped ensure that the study participants were representative of the overall population that visits the lab throughout the year. After agreeing to participate, participants entered the lab.

At this point, participants were recorded while engaging with the lab's Stroop Effect activity. This activity was selected because it is one of the lab's most popular demonstrations and is representative of game-based museum activities. The Stroop Effect refers to interference produced by incongruent stimuli (Macleod, 1991). For instance, when asked to name the font color of a word (i.e., the color of the letters), people are significantly slower and more error-prone when the word they are reading is the name of a color different than the font color. As an example, if a word is spelled out in yellow font, people will on average be slower to correctly name the color of a word as 'yellow' if the word spells out 'red', while they would not experience this effect if the word had been unrelated to color, such as 'monkey'. This effect demonstrates the fact that reading is an automatic mental process. After an individual learns how to read, they will be unable to look at words without reading them. This creates interference for individuals when they attempt to perform a task that requires them to ignore the meaning of a word—because they are automatically processing the meaning of the words that they see.

The Stroop effect activity is based around a mobile app designed by Coral Technology and is presented to participants on an iPad. Participants are presented with a word that spells the name of a color but is written in a color other than what it spells.



Figure 1. Image of gameplay from the Coral Technology Stroop Effect App

Six color buttons are located underneath the word and players must select the color that matches the color of the font which the word is written in—not the color that the word spells (see figure 1 for reference). The goal of the game is to correctly select as many colors as possible in a 30 second period. This game illustrates the Stroop Effect by demonstrating that reading occurs automatically, which makes the game somewhat difficult as participants must override their initial, automatic, reading of the color. After this, the demonstrator asks a series of questions designed to help participants reach the conclusion that reading is an automatic process on their own. Questions are worded to encourage participants to reflect on the activity and discuss it amongst themselves. For example, the first question the demonstrator asks is “what do you think makes that game so difficult?” in order to prompt players to recognize that they are automatically reading the word.

After the demonstration was complete, participants filled out a demographic survey and the modified Science Fascination Scale (Chung et al., 2016, see appendix). After finishing the

survey, the experimenter conducted a short interview with the participants, consisting of open-ended questions about their experience with the game, their perceptions of science, and what they may have learned from the demonstration. The full experiment was designed to take no more than 20 minutes to complete.

Conversation Coding

Video recordings of the family interactions were transcribed for each individual utterance. Participant statements were then coded using emergent coding. In emergent coding, coders review participant statements to find common themes, rather than approaching the data with a pre-existing set of coding categories (Stemler, 2001). Types of statements that are found to recur frequently within the transcripts form the coding categories for the study.

The majority of statements in this project were found to be generally related either to the take-home message of the activity, science in general, or to gameplay of the activity. Distinctive types of statements were then found within each of these three broader categories. These categories are discussed below.

Take-home Message

The core content message of the Stroop Effect demonstration is that reading is an automatic process. Throughout both the demonstration and the interview, participants are asked to reflect on what they learned from the activity. Responses to these questions, as well as spontaneous reflections on reading or the game's message were coded as related to the game's critical take-home message (CTM). These statements primarily fell into one of four types:

- *Reading:* These statements include general statements about reading in relation to the activity. Two main types of readings statements emerged from the data.

- (1) *Age-related reading statements*: These usually focused on reading as a learned skill (e.g. “kids that don’t read would be good at this game”).
- (2) *Process-related reading statements*: Statements in this category focus on the process of reading (e.g. “I read whatever I see”).
- *Sensation*: This category includes statements about what it feels like to experience the Stroop Effect during the activity (e.g. “when I saw the color, I immediately started thinking about it”).
- *Guesses*: Guess statements are participant’s attempts to explain the message of the activity that are unrelated to the actual content message of the activity (e.g. “it’s harder to make connections the more you learn”).
- *Automaticity*: Statements in this category demonstrate a full understanding of the game’s take-home message (e.g. “we’re so used to reading we do it without thinking about it”).

Science-Related

During the interview, participants were directly asked to describe how they think about science, as well as if they thought anything could be learned about science from activities such as the one they just participated in. Responses to these questions and any other statements about science made during the experiment were coded as being science related. Four main types of statements were predominant within this category:

- *Science Attitudes*: These statements reflect the speaker’s attitude about science in some way. This often took the form of attitudes towards science (e.g. “I feel that science is very important”) or descriptions of the speaker’s experiences with science (e.g. “I never found it very interesting during school”).

- *Science Information:* These statements reference scientific information (e.g. “I think we could learn about literacy rates from this”) or some activity related to science (e.g. “I always think science is just experiments”).
- *Science Process:* These statements describe science in a way that reflects an understanding of science as a process that people use to learn new things (e.g. “it’s the process of challenging the unknown”)
- *Unsure:* Statements in this category reflect an uncertainty about the nature of science or how it could be applied to the context of the game.

Gameplay

Participant statements related to the experience of playing the activity were centered around four main themes:

- *Competition:* Statements reflecting a focus on the competitive side of the game, such as one’s score or statements about winning/losing the game.
- *Enjoyment:* Statements reflecting either a positive view of the activity itself.
- *Difficulty:* Statements focusing on the relative difficulty of the game.
- *Banter:* Statements intended to help the speaker or someone else in the group understand the game’s instructions, or to encourage/facilitate the game-play of others (e.g. “Keep going, you just need to tap the color”)

Connections

In addition to these codes, a general code was developed for statements demonstrating a participant making a connection between some aspect of science or the take-home message and another concept with which the participant is already familiar. These connections generally took one of three forms:

- *Connections to School:* These statements connected something about the demonstration to an experience during one’s education.
- *Connections to Life:* These connections focused on ties between the demonstration and experiences at work or in persona life.
- *Connections to Culture:* This category covered connections to cultural knowledge, such as TV shows or games that a participant connected to the demonstration.

RESULTS

General Conversation Differences

Although the number of adults and children were nearly equal (20 adults, 19 children), adults talked more. Of 1196 total statements, 813 of the statements fell into relevant categories, with adults contributing significantly more statements than the children, $t(38) = 4.16, p < 0.001$. Adults made roughly 71% of the relevant statements and children made 29%.

Around two-thirds of participant utterances fell into one of the three main categories (Gameplay, Take-home Message, Science-related) with the remaining statements containing connections and non-relevant utterances such as agreement statements (e.g. “Oh okay”).

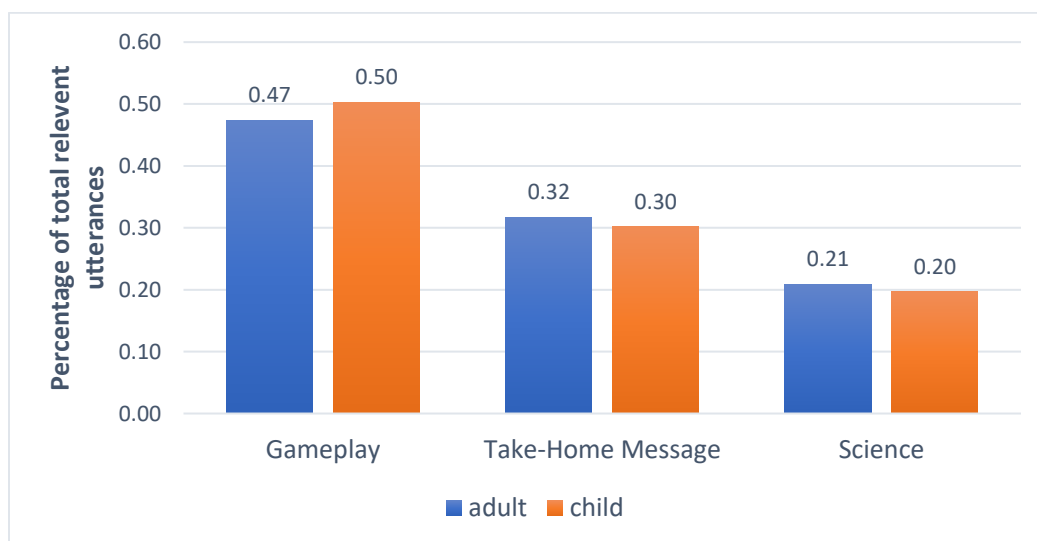


Figure 2. Percent of utterances in each relevant category by age.

Adults made more relevant statements overall (Adults made 542 statements in these categories, while children made 219). Participants made significantly more gameplay statements than take-home statements, $t(78) = 5.28, p < 0.001$ or science statements, $t(78) = 6.68, p < 0.001$ (see figure 2). The amount of take home statements and science statements were not significantly different $t(78) = 1.65, p = 0.103$. A chi square analysis revealed that adults and children did not significantly differ in their patterns of responses, $X^2(2, N = 39) = .50, p = .78$.

Additionally, children made 15 connection statements and adults made 37. Children made no connections to cultural information, and the majority of connections fell into the *Connections to Life Experiences* category. Results related to each research question are presented below.

Research Question 1: Which Elements of the Activity are Most Engaging to Learners?

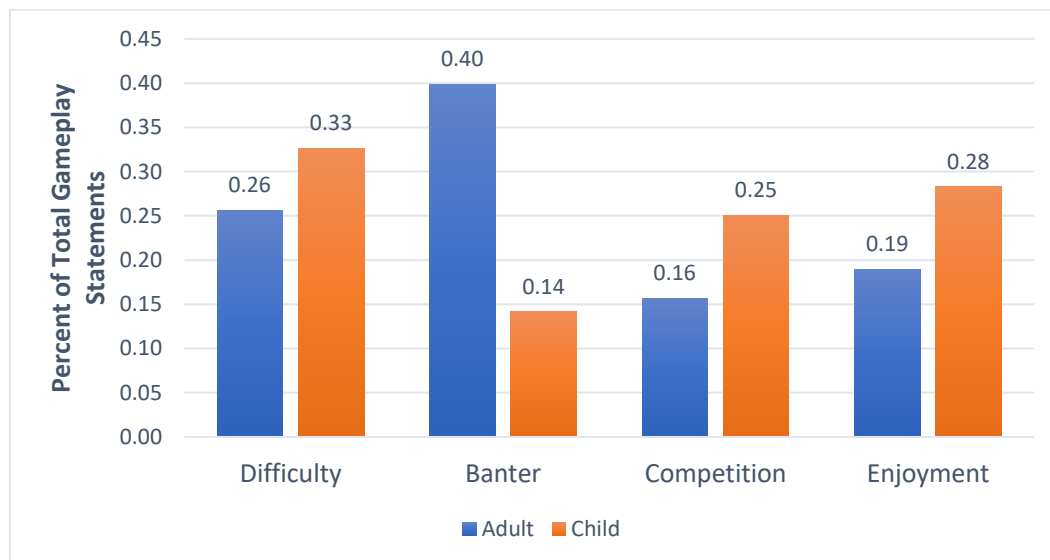


Figure 3. Percent of gameplay statements in each subcategory by age.

The gameplay category contains statements focused on aspects related to playing the demonstration itself. Within this category, 83% of the statements fell into either the *Competition*, *Banter*, *Enjoyment*, or *Difficulty* subcategories. Adults made the majority of gameplay

statements (211 for adults and 92 for children). Adults and children had significantly different response patterns overall, $X^2(3, N = 39) = 19.92, p < .001$ (see figure 3). Subsequent post hoc analyses were conducted that revealed that adults made significantly more *Banter* statements than children did. A Bonferroni correction was performed to adjust for the post hoc analyses, making the new threshold for significance $p < .05/6(.0083)$.

Research Question 2: What Factors Promote Understanding of the Activity's Content?

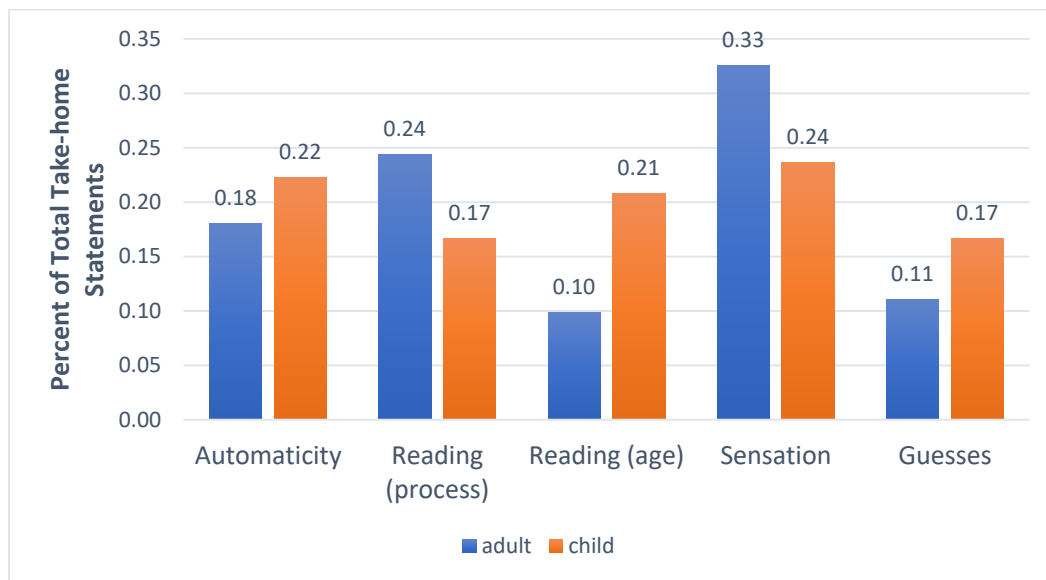


Figure 4. Percent of take-home statements for each subcategory by age.

Statements related to the activity's core content message were first grouped by type to reveal to what extent participants understood the idea that reading is an automatic process. Among the take-home-related statements, 99% fell into one of the 5 main categories. Children made 72 Take-home related statements, while adults made 172. A chi-square test of independence revealed that there was no significant association between age group and response type, $X^2(4, N = 39) = 8.87, p = .06$ (see figure 4).

Eight out of the 12 groups made statements that fell into the *Automaticity* category. These statements reflect a complete understanding of the activity's main content message. A

number of associations were explored to examine factors related to the percent of *Automaticity* statements that the groups made.

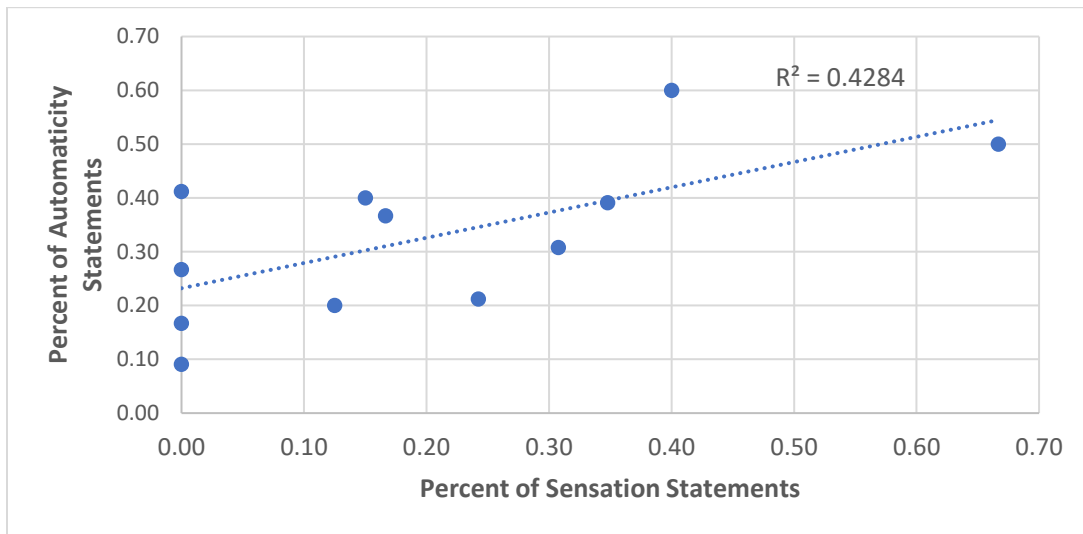


Figure 5. Percent of *Automaticity* Statements by the percent of *Sensation* Statements.

The percent of take-home related statements made by a group that fell into the *Sensation* category was positively correlated with the percent of *Automaticity* statements made by a group ($R^2 = 0.43$, see figure 5). This indicates that there is a positive relationship between discussion of the sensation of playing the game and making statements reflecting full understanding of the activity.

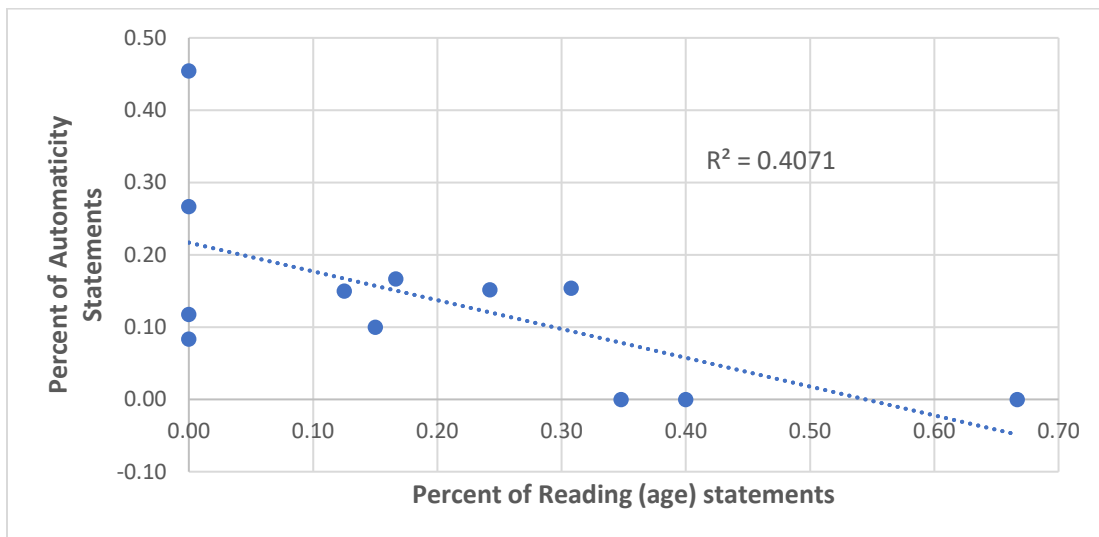


Figure 6. Percent of *Automaticity* Statements by the percent of Sensation Statements

The percent of take-home related statements made by a group in the *Reading (age)* category was negatively correlated with the percent of *Automaticity* statements made by a group ($R^2=0.41$, as seen in figure 6). Discussion of age-based reading differences is negatively related to how many statements a family makes reflecting a full understanding of the game's content.

In contrast, the percent of *Reading (process)* and *Guess* statements made by a group were not particularly associated with the percent of *Automaticity* statements that a group made ($R^2=0.01$ for reading process and $R^2=0.17$ for guesses).

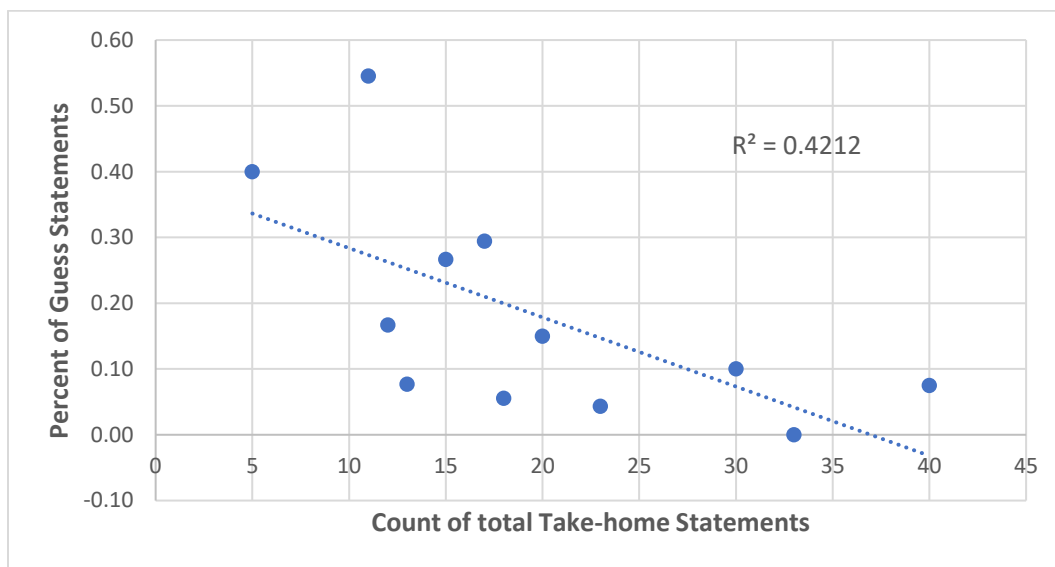


Figure 7. Percent of *Guess* Statements by total number of take-home statements

The percentage of *Guess* statements made by a group was negatively associated with the total number of take-home statements that a group made ($R^2=0.442$, as seen in figure 7), whereas *Automaticity* percentages were not correlated with total statements ($R^2=0.005$). Thus, level of discussion seems to be inversely related to making inaccurate guesses, but is unrelated to fully understanding the game's content.

The level of child participation in the group's discussion of the take home message was not associated with the percentage of *Automaticity* statements made by the group ($R^2=0.0149$). The total number of connections made by a group was not associated with the percent of *Automaticity* statements made by the group ($R^2=0.008$), nor were any subcategories of the connection statements.

Research Question 3: What Role do Participants' Views of Science Play in the Activity?

Science statements were first grouped by type to examine general themes of statements related to participants' views of science (see figure 8). Science statements were then analyzed to examine associations between science views and participants' understanding of the take-home message of the activity.

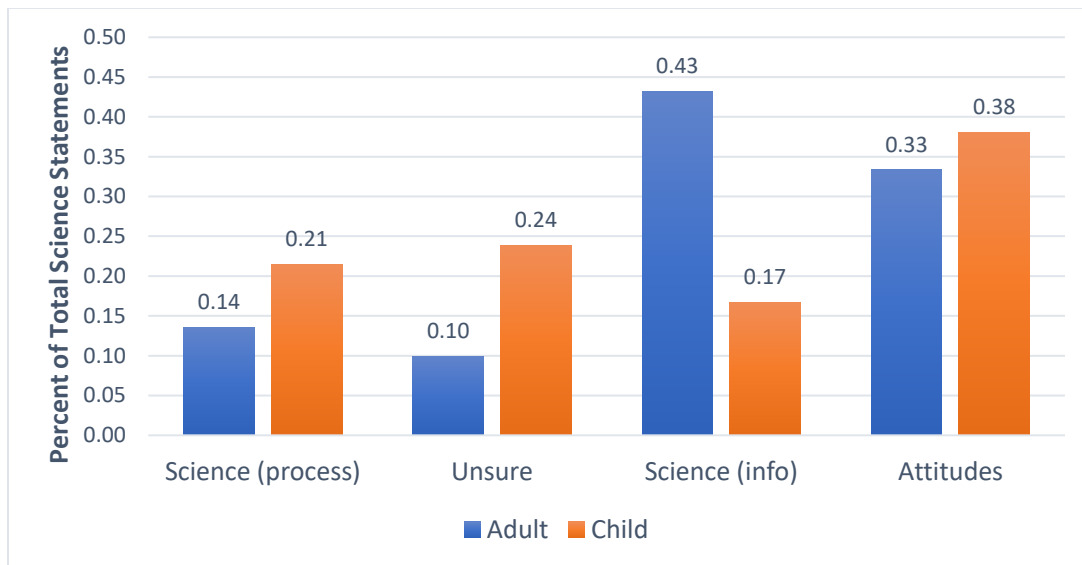


Figure 8. Percent of science statement in each subcategory by age.

Eighty percent of science statements fell into one of the 4 subcategories, with the remaining 20% containing clarifying statements or connections. Child and adult responses were statistically different overall, $X^2(3, N = 39) = 10.60, p < .05$ (see figure 4). After performing a Bonferroni correction to adjust for post hoc analyses ($p < .05/6(.0083)$), adults were found to

make significantly more *Science Info* statements than children while children made more *Unsure* statements.

The percent of science statements made by participants that fell into the *Unsure* category did not vary with the percent of take-home *Automaticity* statements ($R^2=0.07$). Additionally, the percent of science-relevant statements that were in the *Attitudes* category was negatively correlated with the percent of group statements that were in the *Process* category ($R^2=0.256$).

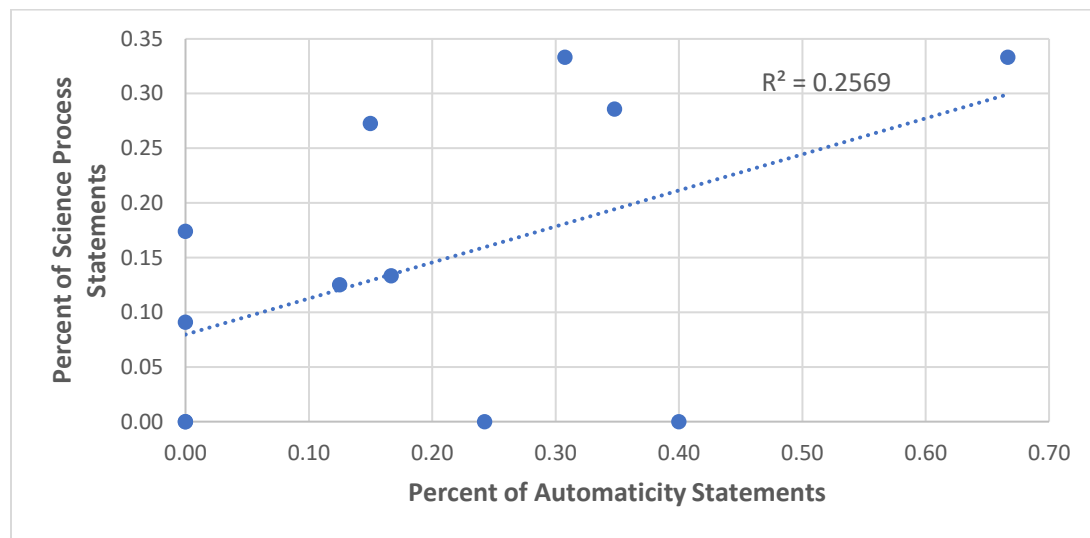


Figure 9. Percent of *Science Process* Statements by *Automaticity* Statements

The percent of science statements made by a group that fell into the process category *Process* was positively associated with the percent of *Automaticity* statements that a group made ($R^2=0.257$, see figure 9). Statements reflecting an understanding of science as a process are associated with increased discussion demonstrating full understanding of the game's content.

The overall science fascination scale scores for language items and traditional science items were 2.18 and 2.05 respectively (on a 1-4 scale, where low numbers are more positive), and were not significantly different. There were also no significant differences in interest between adults or children for language or science.

DISCUSSION

The overarching goal of this study was to explore the effectiveness of an informal science activity based on language science. The study was focused around three main research questions. First, this project explored what aspects of the language activity were most engaging to participants. Second, the study examined factors relating to how well participants understood the language science content presented by the activity. Lastly, this project explored the way in which participants view science and how those views affect the way participants interact with the demonstration.

Overall, the study did find that the demonstration was a successful tool for conveying language science information. The majority of family groups made statements demonstrating a full understanding of the core content message and all groups made statements that demonstrated at least a partial understanding of the core take home message. Although not all groups made *Automaticity* statements, each group made numerous sensation statements or reading statements. These statements reflect some understanding of the role of reading or automatic processes in the activity. Additionally, all family groups were able to practice engaging in open inquiry. Activities that prompt learners to explore a topic and form hypotheses about the nature of that topic generate more effective learning outcomes (Allen & Gutwell, 2009). In this activity, family members worked as group to arrive at explanations of the game. Even in the minority of groups that didn't demonstrate a full understanding of language automaticity, the group was able to practice their ability to engage in inquiry about scientific topics.

Relating to the first main research question, the study yielded several findings about how participants engage with the activity. In general, it appears that the demonstration was successful at presenting language science information in a way that both excited and engaged participants, meeting one of the fundamental goals of informal science education (Bell et al., 2009). Every

group made multiple statements expressing their enjoyment of the activity and the experiment itself. This is especially important given the free-choice nature of informal science activities. When an individual freely chooses to engage in an educational activity, they typically have better learning outcomes (Falk et al., 2007). However, because they can stop the learning activity at any time, it is imperative to design enjoyable and engaging activities. Furthermore, the fact that groups often focused on sensation statements (which can be thought of as connections between subjective experience and the activity) and more general connections, suggests high cognitive engagement with the game. Walker et al. (2006) found that connections between personal experiences and new information were tied to deeper processing of the new information and greater cognitive engagement. This information suggests that the activity was effective at generating a positive and effective learning experience.

Gameplay statements were the most common for both children and adults. The fact that participants focused heavily on discussing the game with one another, suggests that the activity was successful at eliciting family interaction. Activities that help individuals feel a sense of relatedness to those around them have been found to increase the amount of intrinsic motivation the individual feels towards an activity (Deci & Ryan, 2000). In other words, people are more likely to want to continue an activity if they feel related to one another. By providing opportunities to both understand and compete over the activity together, the activity becomes more engaging and enhances social interaction. In general, social interaction significantly improves the ability of participants to learn new information (Blud, 1990). In families, especially those with young children, parents serve a critical role in facilitating and mediating the learning of their children (Ellenbogen et al., 2004). Thus, the fact that the activity stimulates a great deal

of interpersonal discussion within the family groups is a positive factor in helping visitors learn more effectively.

The differing patterns between adult and child responses shed light on both visitor motivation and family dynamics. Learning in museum settings should take family dynamics into account (Ellenbogen et al., 2004). Visitors are influenced by the group that they come to the museum with and interpret new information within the context of their social group. Together, family groups construct shared meaning out of the experiences they share as they converse and interact in museum settings.

Adults make significantly more *Banter* types statements than children do. These statements are facilitative in nature, either clarifying instructions or trying to help another individual understand the game (e.g. “what you have to do is press red here”). One likely explanation for this finding is that adults are facilitating the experience of the children during gameplay. When interacting with a learning experience, adults enhance their child’s learning by making supporting statements (Blud, 1990). Activities that fail to account for adult-child interaction often do not work effectively and lead to reduced understanding (Shine & Acosta, 2000). The activity design currently allows for unstructured interaction between participants during gameplay, which seems to serve as an important opportunity for facilitative family interaction.

Linked to the second research question of the study, several factors were found to be related to how likely participants were to make statements that reflected a full understanding of the activity’s content. The association between the percent of sensation statements that a group made with the percent of automaticity statements suggests that a focus on the sensation of the Stroop Effect is involved with a greater likelihood of fully understanding the activity’s content.

This finding suggests that the activity encouraged interactivity. Being able to directly interact with an exhibit or activity seems to be especially valuable for enhancing learning (Fenichel & Schweingruber, 2010). In this case, participants were able to interact with language science information using their own physical sensations. The Stroop-Effect produced a mental sensation that learners were able to connect to novel information as they interacted with the exhibit.

Not all demonstrator approaches appear to be equally effective at conveying the content message of the game. Part of the standard delivery of the Stroop Effect is to mention the age-related differences involved in the effect (due to the fact that reading is a learned skill and is not automatic for young children). The percentage of group discussion focused on the role of age in relation to reading ability, was negatively associated with the percentage of automaticity statements made by that group. Although statements related to differences in reading ability by age imply an understanding that reading is learned process, it is possible that focusing on this area serves as a distractor from the automaticity message of the activity. *Reading Age* statements often took on the nature of comparing the abilities of adults to children (e.g. “I bet (younger child) would be good at this, she can’t read yet!”). These statements shift the focus from the nature of reading to more of a focus on age-related skill differences, which may distract learners from understanding the process of reading.

The sensation-automaticity association also provides support for the utility of juxtaposition in learning, one of the key benefits theorized to occur when using language science during informal learning. Being able to contrast new information with current knowledge is beneficial when learning something new (Fenichel & Schweingruber, 2010). Since language is something everyone has some knowledge about, it is likely that learning in this area allows juxtaposition to more easily occur (Wagner et al., 2015). The connection between the percentage

of *Sensation* statements made by a group and the percentage of *Automaticity* statements they make provides evidence for this claim. Participants of various ages made equal percentages of *Automaticity* statements, and all groups were able to make statements related to the activity's take home message. Given the fact that participants were of varying ages and educational backgrounds, these results suggest that language science may be an effective tool for helping a wide range of participants understand science more clearly. Additionally, the fact that language science generates juxtaposition so easily helps facilitate family learning. For example, research has shown that family members facilitate the learning of one another by helping one another understand connections between ideas (Ellenbogen et al., 2004). Using language science to teach information makes this process easier because each family member has language knowledge which they can contribute to the discussion.

Discussion within the family group seems to play an important role in the way in which participants understand the activity. The percent of *Guess* statements that a family made had a strong negative correlation with the amount of take-home related statements they made in general. In contrast, the percent of *Automaticity* statements made by a group was not associated with the number of total statements made by that group. One possible reason for this finding is that groups who discuss the activity more are less likely to make inaccurate statements about the meaning of the activity's content. However, simply having a lively discussion of the activity is not sufficient to reach a full understanding of the activity's content. Instead, conservation factors such as a focus on physical sensations related to the game and process statements about science appear to be more strongly linked to content understanding.

The analyses relating to the third research questions revealed several distinct ways in which participants view science as well as how those views relate to participants' ability to

understand the content of the activity. First, adults made significantly more *Information* statements regarding science than children, while children made significantly more *Unsure* statements. Given the different levels of experience between adults and children, it is logical that adults would make factual statements about science than children. This conversation characteristic does potentially offer several benefits. Research shows that family members often help each other understand new information by connecting it to mutually shared experiences (Ellenbogen et al., 2004). During family discussions of science, adults make statements that help their children learn new information and map it on to their current knowledge. For instance, an adult might connect a science definition to an experience at school (e.g. “it’s like what you did at the science fair”) or simply provide the child information about science (e.g. “scientists do a lot of experiments). When given the chance to discuss scientific information as a family, learning is facilitated, especially for children.

When discussing science, participants often responded with *Attitude* statements. These responses ranged from positive to negative, but all described science in an attitude-related way (e.g. “science is boring” or “science is everything, it’s really fun”). The percentage of *Attitude* statements a group made was negatively correlated with the percentage of *Process* statements made by that group. The exact relationship between attitudes towards science and understanding science as a process is unclear. Shifting attitudes regarding science to be more positive is one of the benefits of informal science learning (Sentürk & Özdemir, 2014), however it is uncertain how attitude-based views of science relate to understanding the process-based nature of science. It is possible that overly focusing on feelings about science distracts participants from understanding the nature of science. Future work could explore the different influences of

positive vs negative attitudes towards science, in relation to participants' understanding of the nature of scientific inquiry.

The percentage of *Process* science statements was correlated with the percentage of *Automaticity* statements made by participants. There is evidence that viewing science as a process leads to better understanding of scientific content (Lombrozo et al., 2008). Fitting with these findings, it appears from our data that group discussion about science as a process is connected to a group's understanding of the core take home message of the activity. One of the fundamental mental goals of informal science environments is to shift visitor perceptions of science from that of a stable body of facts to understanding science as a process for learning (Bell et al., 2009). The findings in the current study are exciting because they indicate that one of the main functions of ISE also serves to help learners see science in a way that broadly makes it easier for them to learn new information about science in general.

The modified science fascination scale did not reveal any differences in fascination between adults and children or between science and language items. One possible reason for this result is that the scale was administered directly after the participants engaged with a language-based learning activity, which could feasibly have altered their levels of fascination with language. Given that prior research has shown that science museum experiences can alter visitors' attitudes to be more positive towards science in general (Sentürk & Özdemir, 2014), it is likely that participants may show increased fascination directly after participating in the activity. Future work in this area should explore science fascination both before and after engaging with informal science activities.

Implications for Activity Design

The research findings present a number of possible methods of improving activity design. The association between sensation and automaticity suggests that focusing on one's subjective experience of playing the game may be an effective way to facilitate learning. One way to incorporate this finding would be to reformat parts of the demonstrator discussion to prompt participants to connect the activity to their personal experiences and knowledge. Additionally, some discussion topics such as the relationship between age and reading ability, appear to conflict with participants' understanding of the activity's message. Such discussion topics should be presented more carefully or not discussed at all to ensure that learning goals are met.

Family discussion appears to be beneficial to informal learning (Ellenbogen et al., 2004), so it is important to emphasize those elements of the activity. For instance, adults tend to make a substantial number of facilitative statements while interacting with the game, which likely serves to facilitate the experience for younger family members. One possible way to enhance this aspect of the activity would be to more explicitly incorporate demonstrator statements that encourage family members to try to help another understand the content, rather than just asking individuals to each make their own guesses about the activity's message.

More broadly, several ideas for general informal learning activity design flow from the findings of this study. For one, language science topics appear to be an effective way of engaging participants with scientific content, regardless of their current understanding. Second, it is important to design activities that make it easy for learners to form connections between their personal experiences and knowledge, and the content that they are learning. One way to achieve this is to focus participants on the relationship between the content they are learning and personal sensations they are experiencing. Language science makes this easier to achieve than most other fields, because many elements of language science can be tied to sensations that learners have

personally experienced. Lastly, creating an activity that several people can interact with, and discuss, at the same time, allows for participants to facilitate one another's learning.

Limitations and Future Directions

This study was exploratory in nature and intended to provide directions for future work examining the use of language science in informal science education activities. Due to this fact, the study has several limitations. Most notably, the study lacks a comparison group. Examining groups using a pre/post-test that examined participants' views before and after they interacted with the demonstration could allow for stronger conclusions to be drawn about the study. Another method of achieving more conclusive results would be to compare study groups to control groups which did not engage with the activity or who engaged with the activity in different ways.

Additionally, the study is limited in terms of the conclusions that can be drawn about the benefits of language science. It would be helpful to compare aspects of language science learning activities to ones conducted in more traditional science fields. Future work should also more explicitly examine factors such as gender and ethnicity to provide a better understanding of the benefits offered by conducting informal science education using language science.

Future work should compare different approaches to conducting activities. For example, a demonstration that focuses heavily on encouraging connections between a language effect and personal sensation could be compared to a more typical approach. This would help us understand how to effectively utilize the potential benefits offered from encouraging participants to focus on sensation. Other work could continue to explore the link between participants' understanding of science and how that influences their ability to understand new scientific information. Doing this

would help us understand to what extent participants' ability to learn is influenced by their ideas about science.

Lastly, family dynamics could be explored more thoroughly in future research. The current study only examined family discussion in a descriptive way. This limits our ability to draw any connections regarding the benefits of family engagement. Future research could more explicitly assess levels of family engagement and explore how that impacts understanding of language science.

Conclusion

This study provides evidence that language science is an effective way to conduct informal science education. The activity was enjoyable for learners and engaged them cognitively. Connections to personal sensation and knowledge, may have contributed to successful learning of the language science content. The association between *Sensation* statements and *Automaticity* statements illustrates that language information provides an easy opportunity for the juxtaposition of learners' current knowledge with new scientific information. It also appears that the way in which learners understand the fundamental nature of science can play a role in their ability to learn new scientific information. A process-oriented view of science is tied to one's ability to understand the core automaticity message of the game.

The study also revealed aspects of family-activity interactions that may facilitate or hamper the understanding of the scientific content. Focusing on one's attitudes towards science was negatively associated with a process view of science, which as discussed above may be linked to one's understanding of the automaticity message. Additionally, focusing on age-related differences in ability is also negatively associated with an understanding of automaticity. It is possible that the way in which families engage with the activity influences the success of their

learning as well. Given that families collectively arrive at an understanding of an experience (Ellenbogen et al., 2004), it is important to focus on emphasizing elements of the activity that encourage family discussion.

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Appendix: Modified Science Fascination Scale

Who is this survey about? ME MY CHILD

1. On a scale on of 1-5, I would rate my reading ability as:
 (Can't read on my own yet) 1 2 3 4 5 (Fluent reader)
2. I wonder about how nature works:
 Every day Once a week Once a month Never
3. I wonder about how language works:
 Every day Once a week Once a month Never
4. In general, I find science:
 Very interesting Interesting Boring Very boring
5. In general, I find language:
 Very interesting Interesting Boring Very boring
6. I am curious about how language works.
 YES! Yes No NO!
7. I want to read everything I can find about science.
 YES! Yes No NO!
8. I want to know everything about language.
 YES! Yes No NO!
9. I find information about science exciting.
 YES! Yes No NO!
10. I want to know how to do everything that scientists do.
 YES! Yes No NO!
11. I want to know how to do everything that language scientists do.
 YES! Yes No NO!
12. I like to play language games, like scrabble and boggle.
 YES! Yes No NO!