

Math Attitudes and Interests of Adult Science Café Participants

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Abstract

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Negative attitudes toward math, characterized in part by dislike of, disinterest in, and low self-confidence in math, are so pervasive in the United States as to have become socially acceptable. Some science centers, as institutions dedicated to inspiring interest in STEM fields, have incorporated more opportunities for visitors to engage with math, but such exhibits and programs have been designed mainly for children and family groups. This mixed methods study examines the math-related attitudes and interests of participants in a popular form of science center-sponsored program for adults, the science café. Findings suggest that science café audiences may be receptive to the introduction of increased math content and math-related topics into the program format. Most participants indicated moderate to high self-confidence in math and high value of participating in math-based learning activities, particularly as a benefit to brain health. Moreover, the majority of participants indicated significant interest in hearing about applied mathematics topics in science cafés, with greatest interest in math as it relates to the arts. Participants preferred math-related topics that are relevant, unexpected and personally valuable, as well as those that provide a unique learning opportunity and are within their perceived level of math ability. These findings may be useful to science café organizers and science center professionals looking to incorporate more math-based content into their programs in a way that is enjoyable, relevant and interesting for adult audiences.

Dedication

I would like to dedicate this work to my parents and grandparents, who have given me the opportunity to complete my degree and have always supported the desire to learn entirely for its own sake.

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Chapter I: Introduction

Innumeracy, or the inability to use and engage confidently with math to meet the needs in one's life, is a widespread problem in the United States: a recent, multinational study found that American adults ranked third to last in numeracy among 23 participating countries (OECD, 2013b). Weak numeracy skills are linked to many disadvantages at an individual and national level, including lower earnings, reduced participation in the labor market and civic life, and poorer health and well-being. The Numeracy Network asserts “negative attitudes, rather than a lack of innate talent, are at the root of our numeracy crisis” (Numeracy Network, n.d.) and research suggests that negative attitudes toward math are linked to poor performance in math across formal and informal contexts. Negative math attitudes, characterized in part by dislike of, disinterest and low self-confidence in math, are so pervasive as to have become socially acceptable in the United States, contributing to our largely innumerate culture.

Negative math attitudes in adults are even more detrimental because negative math culture can be cyclical: adults with negative attitudes toward math can pass those attitudes along to younger generations. Parents' as well as teachers' own attitudes toward math have been demonstrated to be influential on the attitudes of children (Eccles & Jacobs, 1986; Gunderson, Ramirez, Levine & Beilock, 2011). Adults' attitudes toward math have been shown to be particularly influential on the math-related interests and values of young females (Amelink, 2012). Furthermore, adults' individual attitudes toward math can influence public policy on mathematics education. A 1989 report from the National Research Council on the future of mathematics education stated:

From the faulty premise that most students ‘can’t do math’ and the fact that many adults who never learned mathematics have succeeded without it, [adults] rationalize that official expectations should be limited to minimal basic levels. The result is a spiral of

lowered expectations in which poor performance in mathematics has become socially acceptable (p. 10).

Thus, efforts to cultivate more positive attitudes toward math in adults may help increase numeracy and benefit math education in the United States.

Informal science learning environments like science centers can spark visitors' interest in and enjoyment of science (National Research Council, 2009) and may be uniquely suited to serve the same goal for mathematics. Indeed, several science centers and science center professionals have already undergone efforts to this end. ASTC (the Association of Science and Technology Centers) and some member institutions have spearheaded initiatives to make math a more explicit focus in science centers. Several math-focused exhibits, many of which have been designed as traveling exhibitions, have also been developed by science centers in the past 15 years. Recent examples include Math Moves (developed by a partnership of 6 museums and educational organizations), Geometry Playground (developed by the Exploratorium), and Design Zone (developed by OMSI). Evaluations of these exhibits have shown that they have achieved numerous positive impacts for visitors (Selinda Research Associates, 2012).

However, although opportunities for visitors to engage with math are becoming more common in science center programs and exhibits, these efforts have been largely carried out to serve children and family groups. Math-related content remains harder to find in exhibits or programs designed for adults, even in science centers with explicit math initiatives or mission statements involving math. Several successful math-focused programs have been developed that target adults in their role as caregivers (as facilitators for children's learning) or teachers (as professional development); however, efforts to incorporate math-focused content for adults in their role *as adults* are largely absent. Because many adults, including those who already attend science center exhibits or programs, may not identify as teachers or caregivers, science centers

may be missing an opportunity and perhaps a need for providing math-focused content for this audience. In order to contribute to changing negative math culture and the cycle of negative attitudes, math-related programming should be incorporated for audiences of all ages.

Adult audiences have already proven themselves as interested participants in certain types of programs put on by science centers. One of the most common types of science-based adult programs in science centers, the science café, has been a successful and growing format of science program. Science café-type programs offer thematic science-based presentations, generally on current or controversial science, and facilitate dialogue between scientists and participants in casual environments like bars, restaurants or theaters. Such programs can be considered successful based on several different measurements including high attendance rates, high rates of retention and high participant satisfaction (Bitgood & Ahmann, 2008; Café Conference, 2007; Ong, 2012).

Because of the successes of the format, science cafés may provide a good opportunity to incorporate increased math into programs designed for a mainly adult audience with the goal of improving attitude and increasing interest. An emerging body of research has explored many characteristics of the science café-attending audience, such as demographic information, motivation for attending, and level of engagement with science. However, little is known of their perceptions of math, making the starting point for such an opportunity uncertain. The goal of this research is to describe the attitudes toward and interest in math of current science café participants. The specific research questions are:

1. How do science café participants define math and recognize math in the science café setting?
2. What are participants' attitudes toward math, including their self-confidence, value and

enjoyment of math?

3. To what extent are participants interested in hearing about math-related topics at science café-type events? Which types of math-related topics interest participants the most?

These findings provide baseline information on the math perceptions, attitudes and interests of adult program participants, which Education and Public Programs departments at science centers may use to design programs with math-focused content based on the needs and interests of their existing audiences. Incorporating math content into science center programming in a way that is enjoyable, relevant and interesting for adult audiences may help the field contribute to a positive math culture for all ages.

Chapter II: Literature Review

The affective challenge of math has long been considered to play an important role in math learning and performance. Positive attitudes towards math are viewed both as an indicator of one's relationship with math as well as their own outcome to be sought. Science centers, which focus on sparking interest and excitement, may be in a position to promote positive math attitudes in visitors and program attendees.

The first section of this literature review describes numeracy and outlines studies on the numeracy levels of adults in the United States. The next section examines math attitudes, why they are important to math education research, past research efforts to measure them and what those efforts have found. The final section explores the science museum's potential role by describing STEM in science centers and research on the science café format and its audience.

Numeracy

The term “numeracy” was first used in 1959 in the “Crowther Report” on the education of secondary school students in the U.K. (Madison & Steen, 2007). The report described numeracy as the ability to reason quantitatively and communicate it at a substantial level, especially in regard to “everyday” tasks and concerns. Since then, numeracy has evolved to include various terminology and definitions. Steen (1997) has described how differing terms, including “numeracy,” “quantitative literacy” and “quantitative reasoning” are used to describe similar, but not identical, concepts. Definitions even vary among a single term, but all tend to relate to the ability to use numerical information to meet the math-related needs in one's life.

Overall, definitions tend to agree that numeracy is closely related to mathematics but, unlike quantitative literacy or quantitative reasoning, they are not synonyms. Instead, numeracy relies on certain mathematical proficiencies, including but beyond arithmetic skills, with a focus

on a “real life” context. Ginsburg, Manly and Schmitt (2006), quoting Orill (2001), state, “pure mathematics is abstract and context-free, yet ‘unlike mathematics, numeracy does not so much lead upward in an ascending pursuit of abstraction as it moves outward toward an ever richer engagement with life’s diverse contexts and situations’” (p. 1). Definitions of numeracy often include an affective component, including confidence in ability and an “at-homeness” with numbers (Condelli, L., American Institutes for Research, & Office of Vocational and Adult Education, 2006).

Since the “Crowther Report,” focus on numeracy as an educational and national standard has grown around the world. Various U.S. reports have described the importance of numeracy for the country (Committee on the Mathematical Sciences in the Year 2000 & National Research Council (U.S.), 1989; Orill, 2001; Steen, 1997). The “Crowther Report” first introduced numeracy as it related to secondary school students, and many subsequent reports and research have focused on measuring numeracy skills of students in the formal school system. Although relevant, research on the numeracy skills of non-adult students is generally set in the context of mathematics education and falls outside of the scope of this study.

However, some studies have detailed the skill level of American adults in the past decade. In 2003, the National Assessment of Adult Literacy (NAAL) determined that 55% of adults surveyed ($N=19,000$) performed at or below basic levels, which, as defined by the assessment, indicates that they are unable to locate and use less familiar quantitative information to solve problems when the arithmetic operation needed is not easily determined (Kutner et al., 2005). Only 13% of the adults surveyed scored at the proficient level. Results found that certain demographic factors correlated with differences in skills, with males scoring higher than females,

high-income individuals scoring higher than low-income individuals, and more educated individuals scoring higher than less educated individuals.

More recently, the Organisation for Economic Development (OECD) conducted a Survey of Adult Skills on approximately 166,000 adults aged 16-65 in 23 countries and subnational regions (OECD, 2013a). The study found that the numeracy skills of adults in the United States are much lower than the cross-country average, with one in three Americans having weak numeracy skills (OECD, 2013b). Only one American adult in twelve scored at the highest numeracy level. The study found that factors influencing numeracy skills were socioeconomic background, migration status, ethnicity, age and level of education. However, although high level of education is a factor correlated to better numeracy skills, other studies have found that even highly educated individuals can be innumerate (Lipkus, Samsa, & Rimer, 2001).

Weak numeracy skills can be detrimental on an individual level as well as a national level. Individuals with poor numeracy skills earn lower wages, experience higher levels of unemployment, and report poorer health, lower civic engagement and less trust in governments and public institutions (OECD, 2013a). Numeracy plays an important role for adults in terms of giving an individual power in democracy and civic decision-making (Orill, 2001). Furthermore, numeracy skills are required for other essential literacies. Proficient numeracy skills are needed for adults to successfully manage the health of themselves and their children, including seeking out health information, making health-related decisions including maneuvering health insurance, and coping with chronic disease (Peters, Meilleur & Thompkins, 2014). Numeracy has also been determined to be linked to financial literacy, an essential literacy as “many governments and employers...are increasingly shifting the responsibility for saving, investing and borrowing onto individuals” (Lusardi, 2012, p. 9).

Math Attitudes

The Numeracy Network, an organization based in the U.K. (which also struggles with low adult numeracy) asserts, “negative attitudes, rather than a lack of innate talent, are at the root of our numeracy crisis” (Numeracy Network, n.d.). Changing attitudes has been viewed as a national priority in the United States as well; for example, the National Research Council’s 1989 report on the future of mathematics put considerable emphasis on the need to change the public’s beliefs and attitudes toward math. Indeed, the correlation between attitudes, as well as what defines a positive and negative attitude toward math, is generally accepted as “common knowledge.” However, scholars disagree on what “attitudes” toward math actually means.

Researchers have long attempted to define and redefine attitude toward mathematics, which affective dimensions it describes, and how specific dimensions ultimately affect math performance. Modern definitions are still ambiguous, affecting the ability to measure math attitude and potentially undermining the results of research in this field (Zan & Martino, 2007; Larsen, 2013). Much of this disagreement stems from the fact that “affect is much more difficult to describe and measure than cognition” (McLeod, 1992, p. 576). However, examining the evolution of math attitudes demonstrates the central elements of importance of this definition and the increasing complexity with which it has been considered.

Research on attitude in the field of math education “has been motivated by the belief that ‘something called “attitude” plays a crucial role in mathematics’” (Neale (1969), as quoted in Zan & Martino, 2007). The field of social psychology and its work on attitudes has heavily influenced the shaping and evolution of math attitudes research (Larsen, 2013). Early (and some subsequent) definitions of attitude as it relates to math have described it as a one-dimensional positive or negative response, referring solely to an individual’s emotional disposition (Larsen,

2013). McLeod (1992) has written an influential piece from this standpoint, arguing that “attitudes” is one of three components of affect related to mathematics learning. He defines attitudes as “affective responses that involve positive or negative feelings of moderate intensity and reasonable stability” (p. 581). He separates them from beliefs, which he describes as completely cognitive and stable, and emotions, which he describes as completely affective and unstable. Later definitions evolved to incorporate more than one of these three dimensions as a part of attitude toward math: a bi-dimensional definition involving a pattern of both beliefs and emotions, and a multidimensional definition of complex interaction of beliefs, emotions and behavior (Zan & Martino, 2007). Furthermore, Chamberlain (2010) argues that each component can have three characteristics within it that can be measured: “target” toward which the feeling is directed, “intensity” (degree or strength) of the feeling, and “direction,” or the positive or negative orientation of the feelings.

Further disagreement arises in classifying certain attitudes as “positive” or “negative.” Conventional wisdom suggests that all feelings we associate with negativity are undesirable in the context of math learning. However, some researchers have found that feelings of frustration and being challenged can lead to dramatically improved achievement in some students (Yeung, 2009). Furthermore, research described in Evans (2000) suggests that lower levels of anxiety up to a certain point actually *increase* math performance; only after an optimal level of anxiety is reached does performance decrease. Zan and Martino (2007) use findings like these to call for a shift away from describing attitudes as either “positive” or “negative.” They state that across various studies, researchers define what is “positive” or “negative” a priori, often defined as a result of the instrument used to measure the attitude instead of used to create the instrument itself. For example, “positive” may interchangeably refer to a feeling that is pleasurable, a

belief that is shared by the experts, or a behavior that results in success. Furthermore, they argue, in multidimensional definitions of math attitude, it is unclear whether “positive” or “negative” would describe only one dimension, each dimension individually, or an attempt to sum them altogether (Martino & Zan, 2009).

Instruments to measure math attitudes. The precise components, or indicators, of attitude vary by instrument. Many different instruments have been developed in the past fifty years to measure math attitudes and have generally evolved from measuring one area of affect to many (Chamberlain, 2010). Historically, instruments designed to measure attitude toward math have included components of enjoyment, value and interest; other instruments have included components such as motivation, emotion, self-efficacy, and anxiety (Larsen, 2013; Chamberlain, 2010). Although most researchers of math attitude have underlined the need for a more unanimous definition of attitude and the specific components it should describe (Larsen, 2013; McLeod, 1992), some have pointed out that attitude toward math may be most effective as a “working definition,” in which researchers can apply it to their own self-posed problems as needed and use proper instrument accordingly (Daskalogianni & Simpson, 2000, as quoted in Martino & Zan, 2009).

In addition to an evolution from measuring one area to many in a single instrument, methods to measure math-related attitudes have in general moved from quantitative to qualitative (Larsen, 2013). McLeod (1992) describes the quantitative approach, which mostly relies on the use of questionnaires and a variety of scales (most commonly a Likert-type scale), as the “traditional paradigm.” Although he critiques this type of quantitative approach as incomplete, lacking in a strong theoretical background, and often contradictory, he acknowledges, “most of

what we know about affective factors in mathematics education comes from work within this traditional paradigm” (p. 577).

Perhaps the most influential instrument developed as a part of this “traditional paradigm” is the Fennema-Sherman Mathematics Attitudes Scales (FSMAS), designed for secondary school students. The FSMAS is a series of scales, designed to be used as a whole or individually, which evaluate nine specific domains using Likert-type scales: attitude toward success, mathematics as a male domain, mother’s attitude, father’s attitude, teacher’s attitude, confidence in learning mathematics, mathematics anxiety, motivation and mathematics usefulness (Fennema & Sherman, 1976). The FSMAS has been widely used in the field of math education, with a particular focus on examining differences between genders, and many researchers have modeled other instruments after the design of the FSMAS to meet different needs and audience types. The Attitude Towards Mathematics Inventory (ATMI) was developed by Tapia and Marsh (2004) to fulfill the need of an updated and shorter version of the FSMAS. The ATMI measures four dimensions of attitude: confidence (including anxiety), value, enjoyment and motivation. This instrument has been tested and used with students of various ages, including college students (Tapia and Marsh, 2002).

Instruments such as the FSMAS and ATMI are widely used and valuable because of their extensive history of use and their ease of administration. However, as is noted by many researchers in the field of math education, quantitative, self-report instruments are subject to many inherent shortcomings that limit their ability to measure math attitude. Larsen (2013) and Chamberlain (2010) summarize many of these concerns. First, they bring up questions of whether the wording of questionnaire items as well as overly complex statistical analysis can actually reflect what participants think and feel. Second, they point to the fact that validity and

reliability coefficients often cited for such instruments are significantly dated and may no longer hold true if retested. Furthermore, Evans (2000) argues that the measures can be highly subjective, resulting in participants interpreting items unevenly. Overall, this suggests that researchers using quantitative, self-report instruments to measure attitudes must be aware of these inherent limitations.

Qualitative instruments designed to measure math attitudes are less commonly used to measure attitude than quantitative, self-report instruments, but are becoming increasingly employed in research. Martino and Zan's "Me and maths" study (2010) uses a qualitative approach, evaluating open-ended student narrative essays of their relationships with math. The goal of their approach is to "*understand* how students interpret their own experiences with mathematics, rather than to *explain* their mathematical path in terms of cause/effect" (emphasis theirs) (Zan & Martino, 2007, p. 163). Their analysis involves a three-dimensional model for attitude, including emotional disposition, perceived confidence, and vision of mathematics. The dimensions of emotional disposition and perceived confidence as the researchers describe them can be considered to align with the quantitative measurements of enjoyment and self-confidence, respectively, but vision of mathematics, in which students describe math as instrumental (characterized by rules without reasons) or relational (in which understanding includes both knowing what to do and why) plays a more significant role. Zan and Martino assert that these three dimensions can combine in many different ways, and use the information from the narratives to create profiles, with different types of "positive" or "negative" attitude toward math.

Other, less formal instruments have been used to examine dimensions of math attitude in adults, specifically looking at self-confidence or perceived ability, emotional response and value.

One recent study by the nonprofit group Change the Equation found 29% of the 1,000 American adults surveyed reported that they are not good at math, and 36% reported that there are times when they say they “can’t do math.” The “overwhelming majority believe that having good math skills is important,” but many still reported feeling inadequate (15%) or worried (13%) when doing math. Women were much more likely to report these feelings than men. Although this study was not conducted with the same rigor as many studies on students in formal school systems, it offers a view of American adults’ attitudes toward math, outside of the formal schooling system.

Gender, numeracy and math attitudes. As suggested by findings from the NAAL and OECD studies as well as the Change the Equation survey on math attitudes, gender has been shown to be a factor correlated to numeracy skills and math attitudes. Studies have repeatedly found that females perform more poorly in numeracy skills and in general possess more negative attitudes toward math. In fact, early efforts to measure math attitudes, such as the FSMAS, were created with the initial goal of exploring potential explanations for differences in math performance and engagement between male and female students. The literature on gender as it relates to math attitudes and math performance is extensive and largely falls outside the scope of this study. However, Amelink (2012) has described research on the effect that the attitudes of adults can have on children, particularly in the context of gender-based stereotypes of girls. She describes the compounding effect that communication of low-self confidence or interest from adult to child can have, stating “influential parents and teachers need to be careful about the degree to which they reinforce these stereotypes by allowing females to make disparaging comments in relation to math and their math skills as it further negates interest for the individual and among female peers” (p. 7).

STEM in Science Centers and Science Cafés

STEM and science centers. A 2012 congressional report on STEM (science, technology, engineering and math) education describes the field as referring to the “teaching and learning in the fields of science, technology, engineering and mathematics... across all grade levels from pre-school to post-doctorate and in both formal and informal settings” (Gonzalez & Kuenzi, 2012, p. 1). However, although what the acronym STEM stands for may be commonly accepted, what “STEM” actually encompasses is less clear. For example, the NSF uses a broad definition of STEM that includes psychology and the social sciences (economics, political science, e.g.); the Department of Homeland Security uses a narrow definition that excludes the social sciences (Gonzalez & Kuenzi, 2012). Some scholars argue against field-specific definitions for STEM and instead argue that STEM should focus on “an assemblage of practices and processes that transcend disciplinary lines and from which knowledge and learning of a particular kind emerges” (Moon & Singer, 2012, p. 32). Furthermore, a movement spearheaded by the Rhode Island School of Design (RISD) calls for changing “STEM” to “STEAM,” in which the “A” designates the arts and design.

The Association of Science and Technology Centers (ASTC) describes science centers as places which connect people with science, provide firsthand experience and an opportunity to develop intuitions about the natural world, and encourage curiosity (ASTC, n.d.). Many science centers have explicit mission statements or initiatives that refer to “STEM” and some argue for science centers’ importance in STEM education (Miaoulis, 2011). However, traditionally, content related to STEM fields other than science is less commonly found in the science center in an explicit form. Viewing the lack of math-related content in particular as a missed opportunity, in 2001, an NSF-funded commission by ASTC called *Mathematics in Science Centers* studied

five institutions to ascertain the current state of mathematics in science centers and museums (Anderson, 2001). Following this study, NSF funded a second, larger project, *Math Momentum in Science Centers*, with the mission to establish professional development resources for science centers to help them make the math in their exhibits and programming more explicit and accessible.

The *Math Momentum in Science Centers* project, which resulted in a publication of the same name (Makros, 2006), addressed many issues related to incorporation of mathematical content in the science center, including rationale, professional development, issues related to equity, and ideas and strategies outlined for a variety of audience types. One theme highlighted in the publication was the importance of math to actual scientists: Makros noted, “math can help people see what real scientists do as they collect and analyze data, and thereby help people understand the interplay of science and math” (p. 20). However, Makros acknowledges that although math is an organic part of scientific efforts, making the math apparent can be challenging. Since *Math Momentum in Science Centers* was published, a number of exhibits and programs have been created with a specific focus on mathematical content (see, for example, Design Zone (OMSI) and Geometry Playground (Exploratorium)). Exhibits such as these have been designed for a general or young audience; although adults may enjoy them, they have not been created with an adult audience in mind.

Science Cafés. Most science centers offer a variety of programs and experiences for adult audiences, including onsite programs and offsite programs. One common form of adult program used by science centers is the science café. The creation of the science café format is generally credited to Duncan Dallas, a science television producer in the U.K., in 1992 (Grand, 2012). Dallas created the Café Scientifique, which he described as a place “where, for the price of a cup

of coffee or a glass of wine, anyone can come to discuss the scientific ideas and developments which are changing our lives” (Dallas, 1999). He modeled his program after a French program called Café Philosophique, in which people met in cafés on Sunday mornings to discuss philosophy. Since 1992, the science café format has gained significant popularity. It is difficult to determine exactly how many science cafés exist as they are organized autonomously and often volunteer-run. However, cafés can be found on six continents and in at least two hundred and fifty cities worldwide (Café Conference, 2007). Although now sometimes associated with science centers, the science café format began as an independent community program. In fact, science cafés put on by science centers are the minority. It is unclear when the science café format was first adopted by a science center or museum (Einbinder, 2013), but such programs can now be found associated with at least a dozen different science centers across the country.

Science cafés can have a variety of goals and formats, making them difficult to define. However, science café events tend to share similar features that have become associated with the format. One main characteristic is the informality of the event, both in terms of the location and the goal of creating a welcoming atmosphere (Café Conference, 2007). Cafés are generally held in nonacademic locations easily accessible by the public, such as bars, cafés and restaurants. Another defining feature of the science café format is its focus on two-way discussion or dialogue between scientist presenter and participants. Dallas stresses the importance of this feature, stating “we have moved discussion into the public arena – academics going to the public, not the public going to the academics” (Café Conference, 2007, p. 1). However, as Einbinder (2013) states, science cafés often “fail to maximize their potential as dialogue events, and instead may more closely resemble a lecture” (p. 14). Therefore, as he suggests, although informality and dialogue are two important and frequently mentioned features of science cafés, the

separation between a science café and other informal science education events, such as lectures, panels, and forums, is not always clear.

Although many science cafés are open to all ages, most events attract a largely adult audience, likely attributable to the higher-level content of the program as well as the setting. Most science café events run by science centers advertise the events as programs for adults. The specific age range of attendees appears to vary greatly by geographical location, venue and topic (Bitgood & Ahmann, 2008). A 2007 national survey of twenty science café organizers determined that 42% of participants were aged 18-34 (Café Conference, 2007). Ong (2012) determined that the majority (57%) of participants in Pacific Science Center's three science cafés were 45 years or older, noting that differences existed between each specific site. Fewer than 3% of its participants were determined to be younger than 18. Typically, science cafés attract audiences of 50-150 people, largely depending on the venue and the popularity of the individual event (Einbinder, 2013). Science cafés often see high levels of repeat attendees, with up to 60% or greater found at some locations (Bitgood & Ahmann, 2008; Ong, 2012). Several studies (Bitgood & Ahmann, 2008; Cohen & Macfarlane, 2007; Ong, 2012) have determined that the "science café experience" is a primary factor in drawing attendance.

Einbinder (2013) offers a synthesis of previous findings on other demographic characteristics of science café participants across various sites. As most relevant to this work, a study by Ong (2012) determined that males and females were fairly evenly represented in Pacific Science Center's Science Cafés, with females as the slight majority. Overall, the study found that engagement and interest in science was high, with around half of participants having or being involved with a science-related degree or career and 95% of attendees stating that science

is a topic of particular interest to them. Furthermore, the study determined that science cafés attracted a different audience than typical science center visitors or members.

Topics. The topic of a science café is a primary factor influencing attendance (Ong, 2012; Rabe, 2009; Bitgood & Ahmann, 2008). Science cafés generally feature topics from a range of science fields, including physical, natural and earth sciences, with the natural (bio) sciences most heavily represented (Dallas, 1999). Rabe's (2009) study of repeat attendees to a popular science café describes participants' views of topics, putting them into "families of responses including interesting, timely and useful" (p. 62). "Interesting" topics were those described by participants as ones they had little understanding of, or that shocked or fascinated them; "timely" topics were described as current, cutting edge, or addressing advances in science; and "useful" topics were those that were applicable to attendees, relevant to their lives, careers or interests, or broadening of their understanding of a topic. Dallas' (1999) work supports the popularity of "useful" topics, arguing that "probably the most popular subjects for Cafés are those where the audience feel they have some experience to contribute—subjects such as medicine, psychology, pharmacology, and genetics" (as cited in Einbinder, 2013, p. 22).

As relevant to this study, the effect of the challenge level of a particular topic is an area of disagreement. Rabe's study suggests that participants are attracted to potentially challenging topics, with several interviewees explicitly mentioning their enjoyment of topics from fields they knew little about, such as astrophysics. Conversely, Bitgood and Ahmann's (2008) research found a science café on the topic of "Dark Matter" received the lowest incidence of positive comments of ten cafés evaluated. They hypothesized that "this may have been due to the difficulty of theoretical physics which seemed to be reflected in the comments about content" (p.

426). These findings suggest that different audiences may respond differently to potentially challenging or difficult topics.

Learning opportunity. In general, science cafés discourage approaching the program from a deficit model, which assumes that the audience lacks knowledge on a topic until they passively receive it from an “expert;” instead, cafés are designed using a model in which the audience is considered co-creators and collaborators of knowledge, engaging with the material alongside the attending scientist (Ong, 2012). Still, as Einbinder (2013) summarizes, several studies suggest that significant numbers of science café participants describe the opportunity to learn something as their primary motivation to attend. Many participants describe this as a general motivation, without concern to the specific topic or speaker. However, as he states, literature on *whether* and *what* participants learn is almost nonexistent. Some limited research that has been conducted on science café participant learning has used self-report measurements. For example, Newkirk’s (2010) study of fifteen science café participants found strong agreement with the statement “My knowledge of today’s topic has increased.” When asked what they “realized” during or after the café, many cited specific factual information. Although this suggests that participants may feel learning is taking place, it is clear that the opportunity remains for further research on to what extent and which type of learning actually occurs in the science café setting.

Chapter III: Methods

Research Goal and Questions

The goal of this research is to describe the math attitudes and interest levels of adult participants in science center-sponsored science café events. The research sought to answer the following questions:

1. How do science café participants define math and recognize math in the science café setting?
2. What are participants' attitudes toward math, including their self-confidence, value and enjoyment of math?
3. To what extent are participants interested in hearing about math-related topics at science café-type events? Which types of math-related topics interest participants the most?

Research Sites

Science cafés were chosen as research sites for this study because they are commonly offered as adult program options for many science centers, increasing the potential for these findings to be used by science center professionals, and because they involve working with scientists and their data which, as described by Makros (2006), offers opportunities for inherent math to be shared with visitors. Science café programs selected for this research were sponsored by Pacific Science Center (PSC) or Oregon Museum of Science and Industry (OMSI). These museums were chosen as data collection sites for this research because they 1) hosted monthly offsite science café events that had been ongoing for two or more years and 2) had mission statements that included mathematics and/or had demonstrated interest in math through past projects.

1. Pacific Science Center: Founded in 1962, PSC is a large, independent nonprofit science center located in Seattle, Washington. The mission of PSC is to inspire a lifelong interest in science, math and technology by engaging diverse communities through interactive and innovative exhibits and programs. In addition to describing math interest in its mission statement, PSC was examined as one of five case studies in *Mathematics in Science Centers* (Anderson, 2001).

Pacific Science Center's Science Cafés, which have been held since 2008, are cosponsored by KCTS 9 Public Television. The Science Café program includes monthly cafés at three different sites in Seattle and Tacoma, Washington, and has recently expanded to include a monthly teen science café. The Science Café program draws most of its participating scientists from PSC's Portal to the Public program, which seeks to connect local scientists to the public through face-to-face interactions. With the exception of the Teen Café (not used for this research), Science Cafés take place at local pubs, typically in large rooms designed for lectures or presentations.

With the exception of formatting that requires all capitalization, in the body of this study, *Science Café* refers to PSC's specific program; *science café* refers to the program format in general, including Science Pubs and other similar programs.

2. Oregon Museum of Science & Industry: Similar to PSC, OMSI is a large, independent nonprofit science center in Portland, Oregon. OMSI's mission is to "inspire curiosity through engaging science learning experiences, foster experimentation and the exchange of ideas, and stimulate informed action." OMSI has a long history of incorporating math into its exhibits and programs, including its role as a partner in the Math Momentum in

Science Centers Project (Makros, 2006). OMSI has also developed several exhibits and programs with explicit math themes.

OMSI has been running its Science Pub program since 2006. OMSI holds Science Pubs at six participating venues in five western Oregon cities. Science Pubs typically take place at theaters or restaurants with large stage areas. The Science Pub program is run through the Events department, and scientist speakers are drawn from universities, government and nonprofit organizations, and local companies.

Data was collected from participants at six science café events: three Science Cafés sponsored by PSC and three Science Pubs sponsored by OMSI. Table 1 describes Science Café/Science Pub locations and topics. Because previous research on science cafés has demonstrated that these programs have high rates of return participants, each science café location was used as a sample site only once.

Methods

This research was conducted using a sequential mixed methods approach as described by Creswell (2009) as “those in which the researcher seeks to elaborate on or expand on the findings of one method with another method” (p. 14). In the first stage, questionnaires were distributed to a large sample of science café participants. In the second stage, a subsample of questionnaire participants was selected for semi-structured interviews. Using a mixed methods approach allowed the researcher to collect data from a large participant pool as well as probe more deeply into individual participants’ attitudes and interests.

Questionnaires. Pencil-and-paper questionnaires were distributed in person at each of six science café events. The questionnaires consisted of twenty-six attitude and interest items, including Likert-type and rating scales as well as three open-ended items and seven demographic

questions. Instrument design and analysis protocol were informed by the Attitudes Toward Mathematics Inventory (ATMI), a measurement instrument of student attitudes toward math developed by Tapia and Marsh in 2004 (as described in the literature review). Math-related topic categories as used on the questionnaire were informed by events at the Museum of Math and by consultation with thesis committee.

Questionnaires were pilot-tested on 37 people in February 2014. The questionnaires were designed to be brief (requiring five minutes or less to complete), in order to encourage a high response rate. See Appendix A for complete questionnaire instrument.

Interviews. Semi-structured telephone interviews were conducted with a subsample of fifteen questionnaire participants within two weeks of each science café event. Semi-structured interviews were used as they allowed for adaptation of specific questions to each interviewee's questionnaire and interview responses. Interviews focused on the following topics:

- The interviewee as a Science Café/Science Pub attendee
- His/her definition of math and to what extent he/she has recognized math in Science Cafés/Science Pubs he/she has already attended
- Greater detail on his/her math attitude, including comfort with math and value of math
- Greater detail on his/her informal math interests, both general and topic-specific

Interviews were pilot tested with three people in February 2014. See Appendix B for complete Interview Guide.

IRB exemption. The researcher applied for and, on February 13, 2014, was granted Institutional Review Board (IRB) exemption to conduct this research.

Sampling Procedures

All participants over the age of eighteen at each science café event were potential participants for data collection. Although science cafés sponsored by PSC and by OMSI are open to all ages (with the exception of OMSI's Science Pub Mission Theater in Portland), they are designed for an adult audience. PSC's Science Café program is listed on its website under Adult Programs and OMSI's site describes its Science Pub events as "aimed at adult audiences both in level of conversation and in subject matter."

Both questionnaires and interviews used an "opt-in" approach. Questionnaires were distributed to potential participants either as they walked into the venue or as they were seated at tables, depending on the set-up of each event. The goal of the research was stated to potential participants during distribution of the instruments and a statement of consent was written at the top of the instrument.

Interview subjects were selected as a subsample of questionnaire subjects. Questionnaire participants were asked to leave an email address if they were interested in receiving more information about participating in a follow-up interview. From participants who were willing to be interviewed, a deliberate sample was chosen to represent different Science Cafés/Science Pubs attended and a range of math attitudes and interests. Potential interview participants were chosen according to the following criteria, in order:

1. Attendance at a minimum of two science cafés in the previous twelve months (required)
2. Interesting or relevant comments in open-ended questionnaire item
3. Less frequently given Likert or rating scale responses on questionnaire

Potential participants were contacted within three days following each data collection event. A first round of three to six potential interview participants were chosen and contacted; if needed, a

second round of potential interview participants was contacted until the desired number of interview subjects was reached.

<u>Site</u>	<u>Topic</u>	<u>Questionnaire Participants</u>	<u>Interview Participants</u>
OMSI Science Pubs			
Portland (Hollywood Theater)	Humans and Clothing: How Comfortable Are We?	78	2
Eugene	You Are What You Eat: The Evolutionary Importance of Diet in Mammals	62	5
Hillsboro	Urban Infrastructure	65	4
PSC Science Cafés			
Queen Anne	The Science of Dark Chocolate	30	1
Kirkland	Addiction and the Brain	54	2
Tacoma	Urban Watersheds in the Puget Sound Region	51	1
Total		340	15

Confidentiality. In questionnaire data collection, each participant's email information (if he/she had chosen to provide it) was connected to his/her responses through a code only the researcher had access to. In data analysis and in the final product of this research, interviewee names were not used to maintain the confidentiality of their responses.

Data Analysis

Questionnaire data was analyzed using Excel and SPSS software. Each category of data was quantified as needed and entered into Excel following a data analysis protocol as outlined in Tapia and Marsh's ATMI. Quantitative analysis of questionnaire items included descriptive statistics for each questionnaire item and for each of the four subsets of the questionnaire data: self-confidence, enjoyment, value and interest. An ANOVA test was used to determine if significant differences existed between research sites; no significant difference was determined ($p > 0.079$ for all items).

Interviews were digitally recorded and transcribed from audio into text prior to analysis. All interview data was coded and analyzed using the qualitative analysis software NVivo. The coding schema was developed using iterative, inductive coding. See Appendix C for the coding scheme taken from NVivo analysis that was used for interviews, including the codes created for each question, the number of interviewees who responded within each code, key words and phrases representing each code, and examples of direct quotations from interviewees.

Limitations

A variety of sites were used in this study in order to allow for greater generalizability among science café-type events. However, because each site was used for data collection only once, it is impossible to determine whether the results from a single site are attributable to a particular location, a particular program topic, or a combination of those factors. Furthermore, the six program topics used for data collection leaned heavily towards the natural and earth sciences. Although a high percentage of science café participants are “regulars,” who attend the program regardless of the specific topic, many participants reported that the subject matter of the event was their main motivation to attend. Therefore, the results of this survey may have been different if one or more program topics used for data collection were more heavily associated with the physical sciences.

Additionally, two types of data collection, involving both quantitative and qualitative data, were used to build a more complete description of participants’ attitudes and interests. Both instrument types are susceptible to certain biases and limitations that limit their generalizability. Both stages of collection were susceptible to self-selection bias, as both were “opt-in” instruments. Although the category of “self-confidence” was measured for consistency, the necessary brevity of the overall questionnaire limited the number of questions that could be

used for the other subcategories of attitude measurement, thus excluding the option for consistency tests. Interview analysis was conducted by one researcher and subject to her interpretation. All interview data was coded twice to improve consistency.

Finally, attitude measurements are not designed to be reflective of participants' ability in mathematics nor numeracy skills. Therefore, these study results should not be used to generalize on the math-related content knowledge of science café participants. High self-confidence measurements only indicate a perceived comfort with math and cannot be translated to ability.

Chapter IV: Results and Discussion

The first section of this chapter describes the demographic information of participants from each of two stages of data collection. The second section organizes the findings by research question and subtopic within each question, integrating data from both stages of data collection. Implications of the findings are discussed at the end of the chapter.

Demographic Information of Study Participants

In total, 340 science café participants filled out the questionnaire. Table 2 summarizes the demographic information of all participants. Genders were nearly equally represented (56% female and 44% male). A wide variety of adult ages were represented in the sample, with the age range of 55-64 having the highest representation. As supported by previous literature, science café participants are highly educated: 98% of this sample had received or were pursuing a bachelor's degree, and 37% had received a master's, Ph.D. or other advanced graduate degree. Fewer than half of participants self-identified with STEM fields as an educational or career background: 39% self-identified as having or pursuing a STEM-based degree, and 42% self-identified as being involved with a STEM-based career at some point in time. Over half (63%) had been to at least one science café in the past year prior to the one at which they were surveyed, and 24% were "regulars" (defined as having attended six or more science cafés in the past year). Questionnaire participants had been to an average of 2.6 science cafés prior to event at which they were surveyed. The largest percentage of participants (43.2%) indicated that the main reason they attended was because they like Science Cafés/Pubs, while just over a quarter (27.1%) indicated that the main reason was the specific topic or speaker.

Fifteen science café participants were interviewed based on their availability and their questionnaire responses. Nine interviewees were female and six were male. Interview

participants represented a variety of ages, with the largest number of interviewees falling into the 55-64 age bracket, as with the questionnaires (see Table 2). Interview participants, as in the larger questionnaire sample, were overall highly educated, with thirteen interviewees having received a bachelor's degree (and one interviewee currently in college) and eight having received a master's or other advanced graduate degree. Six interviewees self-identified as having or pursuing a STEM-based degree, and five self-identified as being involved with a STEM-based career at some point in time. One of the selection criteria was that each interview participant had been to at least one science café during the past year prior to the science café at which he or she was surveyed. Six of the fifteen were "regulars," having been to six or more science café events in the past year. Twelve participants indicated coming because they like Science Cafés/Pubs, two indicated coming because of the specific speaker or topic, and one participant indicated more than one reason.

	<u>Questionnaire Participants</u> (N=340)	<u>Interview Participants</u> (N=15)
Gender		
Male	141 (44%)	6
Female	180 (56%)	9
Age range		
18-24	17 (5%)	1
25-34	67 (21%)	1
35-44	42 (13%)	3
45-54	47 (15%)	3
55-64	83 (26%)	4
65-74	53 (16%)	3
75+	13 (4%)	0
Highest level of education completed		
High school/GED	6 (2%)	0
Some college	60 (19%)	2
Bachelor's degree	100 (31%)	4
Some graduate school	37 (12%)	1
Master's degree	81 (25%)	5
Ph.D. or other advanced graduate degree	37 (12%)	3
STEM-based degree (earned or pursuing)		
Yes	122 (39%)	6
No	191 (61%)	9
STEM-based career (past or present)		
Yes	130 (42%)	5
No	180 (58%)	10
Number of science cafés attended in previous year		
1	118 (38%)	0
2	57 (18%)	7
3	31 (10%)	0
4	17 (5%)	1
5	17 (5%)	1
6+	73 (23%)	6
Reason for attending science café		
Like Science Cafés/Pubs	121 (43%)	12
Interest in specific speaker/topic	76 (21%)	2
Accompany friend/family	33 (12%)	0
Curious about event	33 (12%)	0
Other	17 (6%)	1

How do Participants Define Math and Recognize Math in the Science Café Setting?

This research question was addressed through interviews only. Subsequent research questions use findings from both interviews and questionnaires.

Definition of math. The definition of “math” was purposefully left open for participants in this research. This allowed all participants to respond to items with their own understanding or usage of math in mind. In order to look more closely at what participants think of when they think of math, interview participants were asked to define math, with the assurance that the researcher was “not looking for a right or wrong answer, just curious about their perception.” Although definition is not an element of attitude research, personal definitions may offer insight into how participants recognize math in their lives and in the science café setting and thus help math be made more explicit in presentations if desired. Definitions given by interviewees varied widely; however, some overlapping themes emerged in terms of the types of definition offered.

Several interviewees defined math broadly and descriptively, using the presence of numbers or quantities as the characterizing factor of math. One interviewee stated, “[Math is] something dealing with numbers and quantities.” Another stated: “I guess I would say that anytime that numbers are involved...numbers are a common theme, but at the same time, rather than concrete numbers they could be things that are representative functions or equations.”

Others provided an extensional definition, listing the subject matter components of math to define the field itself: “The first thing I think of is arithmetic. And then from there, I sort of think of algebra and geometry. And then from there I go into more abstract things.”

Many interviewees described math in terms of its function as a tool or a process. For example, one interviewee stated, “I think when there’s a specific attempt to rank or quantify an observation or experience I would define that as mathematical.” Another stated:

Math is an art in quantifying how to complete a task or a project or to get an objective. So it's pretty straightforward, you just need to set up some foundation to resolve a problem, an issue, solve for x , or whatever you want to say it is, but there is an art to it because there are so many different techniques out there that that's what you're really mastering.

Similarly, others define math in terms of an end goal:

Math is using numbers and relations of numbers themselves to come to some conclusion, to make new some awareness about the world. To learn something new that you didn't know before, whether something simple or complex, something expected or unexpected, you know, I think all of that falls in the realm of math.

Almost all interviewees voiced difficulty in coming up with a definition. One interviewee stated, "I don't know how I would define math, that's funny. It's one of those things that's so obvious, you just don't think about it, except it's not." This difficulty in coming up with a precise definition echoes the variety of definitions of math found in the field.

Recognition of math in the science café setting. Interviewees were asked if they recognized anything they would describe as "math or related to math" in previous Science Pubs or Science Cafés they had attended, including the event at which they completed a questionnaire (see Table 3). Most frequently, they gave responses that related to numbers, measurements, or equations, although several participants qualified their responses in this category by describing one or more of their examples as "not very math-intensive" or with a similar qualification. Other participants stated that they recognized math in the use of statistics or through the visualization of data using graphs. Some participants appeared to determine whether or not they recognized math in previous science cafés based on the specific scientific discipline of the event; that is, some sciences inherently "involve math," and others may not.

<u>Theme</u>	<u>Sample Responses</u>
Numbers, measurements, and equations	"Actually, [the presenter] did show some equations that he found useful. He didn't really describe them much or anything, he just had a slide that showed the equations." "I suppose this is a stretch, but [the presenters] talked about negative temperatures, that's the only real math. Negative numbers is a math concept, so I guess that counts."
Statistics	"Statistics were used. [The presenter] talked about sample size; he talked about the diversity of the data."
Visualization of data	"Graphs were used to present information. So you could understand trends and draw conclusions." "Almost always there are graphs, numerical graphs. And that's math for sure."
Discipline-specific math	"It was kind of like an astrophysics-type lecture, so there was definitely math in the sense of, you know, obviously all of astrophysics has to do with math." "The guy giving the presentation appeared to be a chemist, or a chemical engineer, and I just know that that would involve a lot of...math."
Math in scientific process	"Usually it's about math, somehow. Because that's usually how scientists reach conclusions." "The entire concept of establishing a database for the team, based on very specific criteria of observation, as compared to, you know, anecdotal types of things."

Two additional, interrelated themes arose from this question. One is that a significant subset of participants saw math as always being present in a science café event, although sometimes only “in the background.” For example, one interviewee stated:

I think that it's probably always a component whether it's a significant component of it or whether it's sort of just an aspect of it like this last one, with the statistics and that sort of thing. I think that math is always involved.

These participants tended to be those with higher self-confidence scores, in the positive or strongly positive range, who indicated having educational or career backgrounds in STEM fields.

The second theme, again voiced by a significant subset of subjects, was the perception that scientist presenters obscure or avoid math-related information for the benefit of the audience, or that the audience cannot be expected to understand math-related information. As an example of the former, one participant, after having stated that she did not recognize math, said,

“I would do the same thing. I would eliminate as much math as possible.” This statement does not seem to be influenced by a personal negative attitude toward math, as she indicated generally positive self-confidence in math, an enjoyment of math, and a high level of value for math.

Another participant said, “[Presenters] have shown graphs and odd data to reinforce their idea, although they never expected us to really, you know, understand it.”

Several participants stated that they did not see anything in a past science café event that they would describe as math. This answer came from participants across several sites and with varying levels of math-related self-confidence and enjoyment. Although many interviewees did not elaborate on why they may not have recognized any math, two interviewees’ reasons suggest that their recognition of math may stem from their personal definition of math. One participant defined math in the interview as “something dealing with numbers and quantities.” When asked about recognizing math in the science café setting, she stated, “[the presenter] didn’t have much math in there at all...hardly any numbers at all,” linking back to her personal definition of math. Conversely, another participant stated that past science café events he had attended did not have “anything you’d consider like, robust math. Numbers they used have simply been things like ‘the whale traveled this many miles...’ No, I don’t think very mathematical at all.” He identified the use of numbers in the science café but did not recognize their use as “very mathematical.” His definition of math, while still focused on numbers, used the term “relationships of numbers” and described math as a process “to come to some conclusion, to make some new awareness about the world.” Although reasons participants do not recall recognizing math may be varied, this suggests that their personal definitions of math may reflect how and what they recognize as math-related content in the science café setting.

What are Participants' Attitudes toward Math, including their Self-Confidence, Enjoyment and Value of Math?

Questionnaire participants' responses to items relating to attitude and interest measurements were first analyzed using a one-way ANOVA to determine if significant differences existed between the six different subsets of data by site. No significant differences were determined ($p > 0.079$ for all items). Attitude and interests measurements are therefore discussed only in term of the overall sample and not by individual site.

Self-confidence. Eight items on the questionnaire were designed to measure the subcategory of self-confidence in math. These items were tested for internal consistency and determined to have a Cronbach's alpha coefficient of 0.929, indicating a high degree of consistency. Each item was written as a five-point Likert-type scale response, and coded in analysis from -2 ("strongly disagree") to 2 ("strongly agree"). Responses to items written as negative statements (for example, the statement "Sometimes I find myself saying I can't do math") were reverse coded. Because of the high internal consistency, a "Self-Confidence Score" was computed by summing the responses to these eight items for each subject to give a total score of -16 to 16. Self-confidence scores were only calculated for participants who responded to each of the eight questionnaire items in the self-confidence subcategory, eliminating possible scores for 39 participants.

Figure 1 shows the range of self-confidence scores for questionnaire participants. Half of participants (51.2%) scored high on the self-confidence score scale, falling roughly within the top quarter of possible scores (8-16). An additional fifth of participants (18.9%) scored within the 3-7 range, suggesting weaker but still overall high self-confidence in math. Nearly a third of

participants (29.9%) were calculated to have scores below 2, indicating relatively low self-confidence in math.

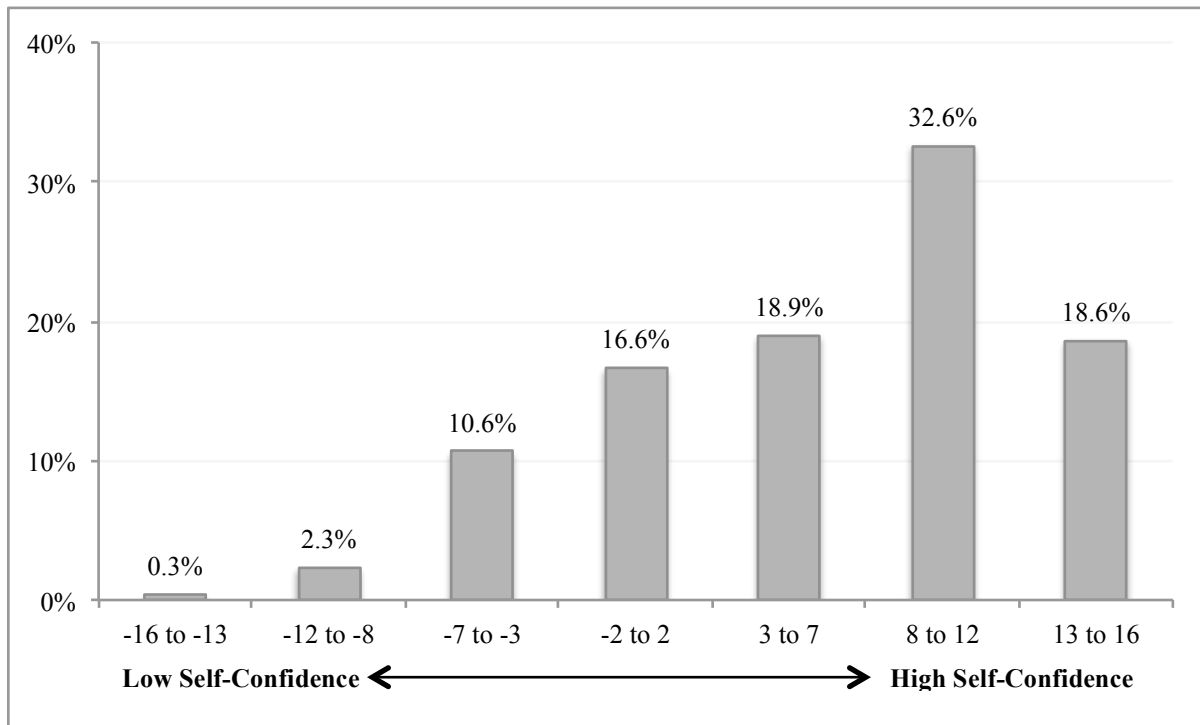


Figure 1. Self-Confidence Scores ($N=301$)

Although self-confidence scores give an overview of the self-confidence subcategory, examination of the individual items from the subcategory of self-confidence offers a more complete description of participants' overall self-confidence in math.

The majority of participants (70.4%) agreed or strongly agreed with the statement “I am good at math” and 15% disagreed or strongly disagreed (Figure 2). Alternatively, a quarter (25.9%) of participants agreed or strongly agreed with the statement, “Sometimes I find myself saying I can't do math” (Figure 3).

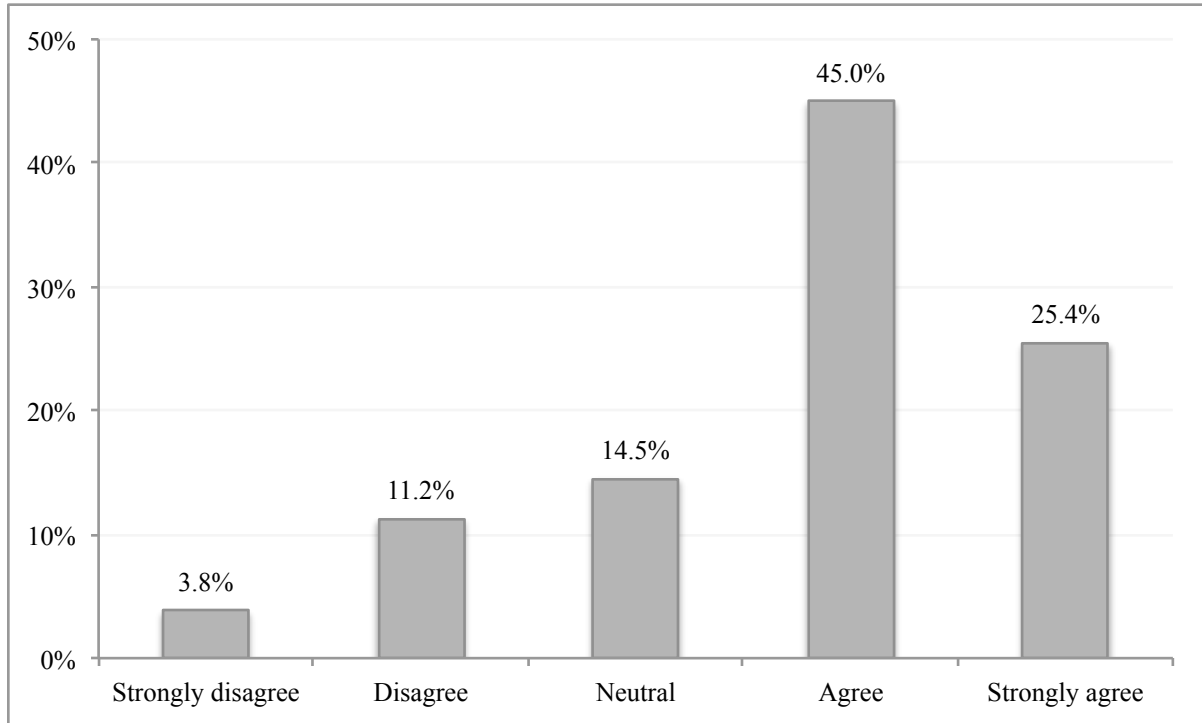


Figure 2. Responses to the Statement “I am Good at Math” (N=338)

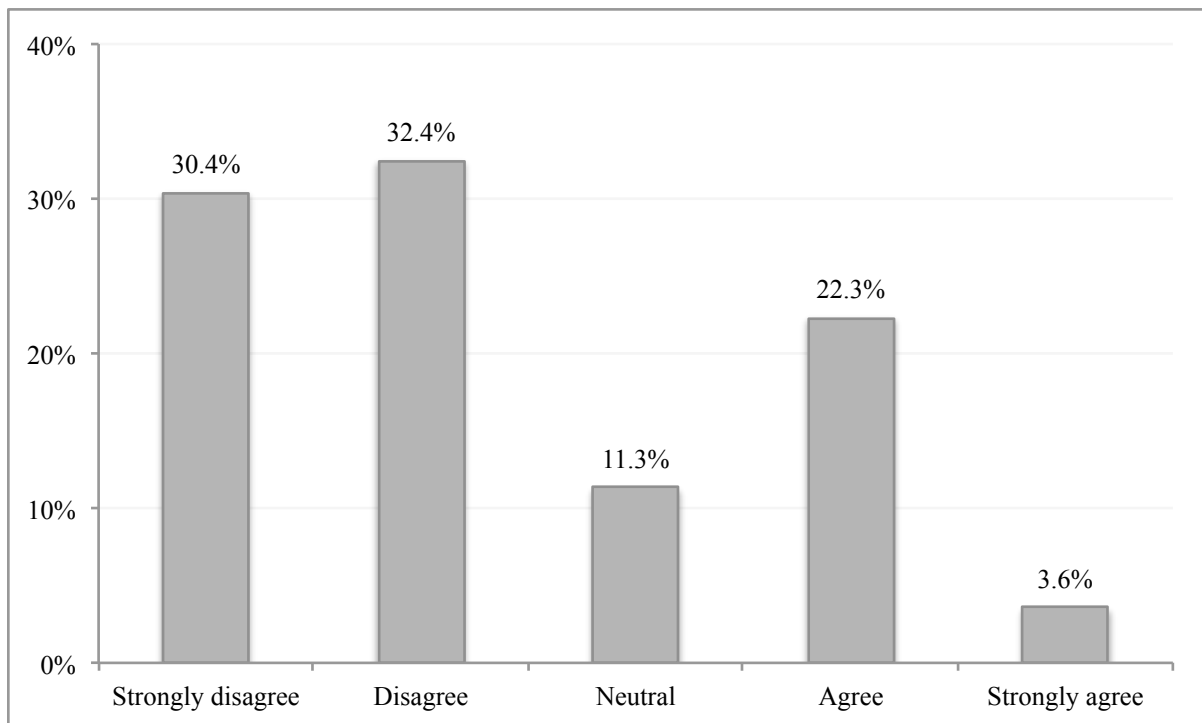


Figure 3. Responses to the Statement “Sometimes I Find Myself Saying I Can’t Do Math” (N=336)

Figures 4 and 5 show responses to self-confidence items that refer to feelings when doing math in everyday life or at work. Most participants agree or strongly agree that “When I do math in my everyday life or at work I feel confident” (75.2%) and fewer agree to feeling “at ease” (60.6%) or “knowledgeable” (64.4%). Similarly, the majority of participants disagree or strongly disagree to feeling the three traditionally “negative” feelings when doing math, with 70.9% disagreeing to feeling “inadequate” and roughly two-thirds disagreeing to feeling “anxious” or “frustrated” (65.9% and 66.7%, respectively).

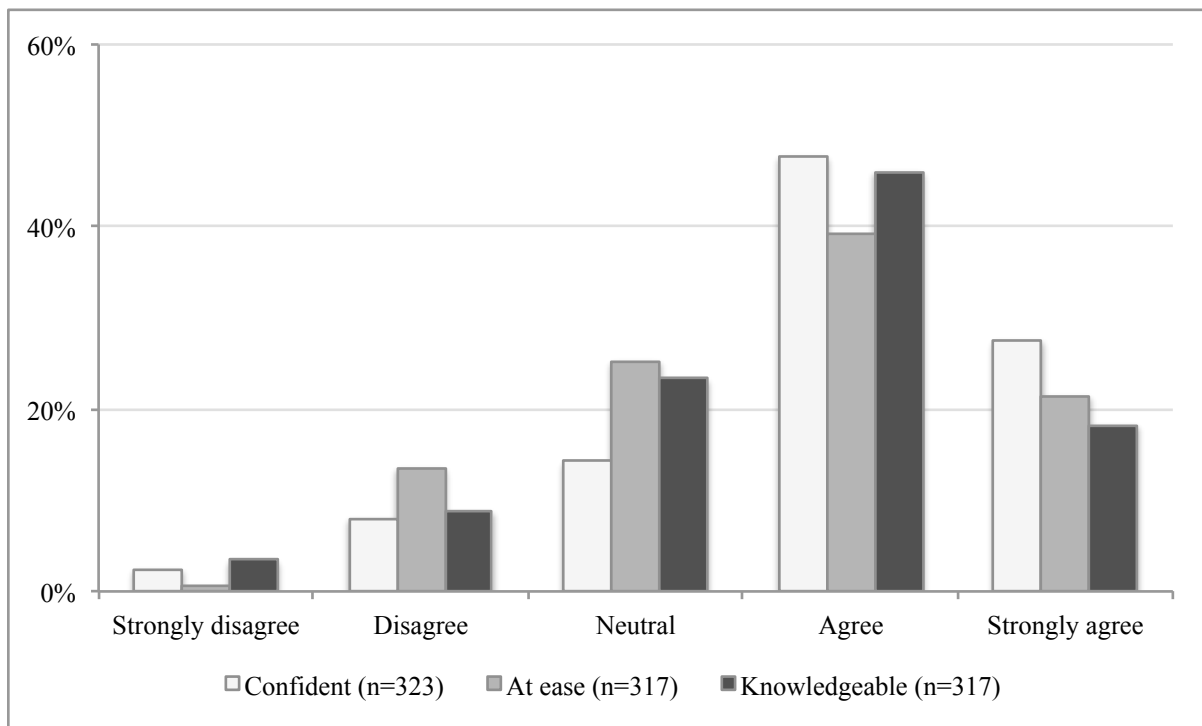


Figure 4. Responses to “Positive” Feelings When Doing Math.

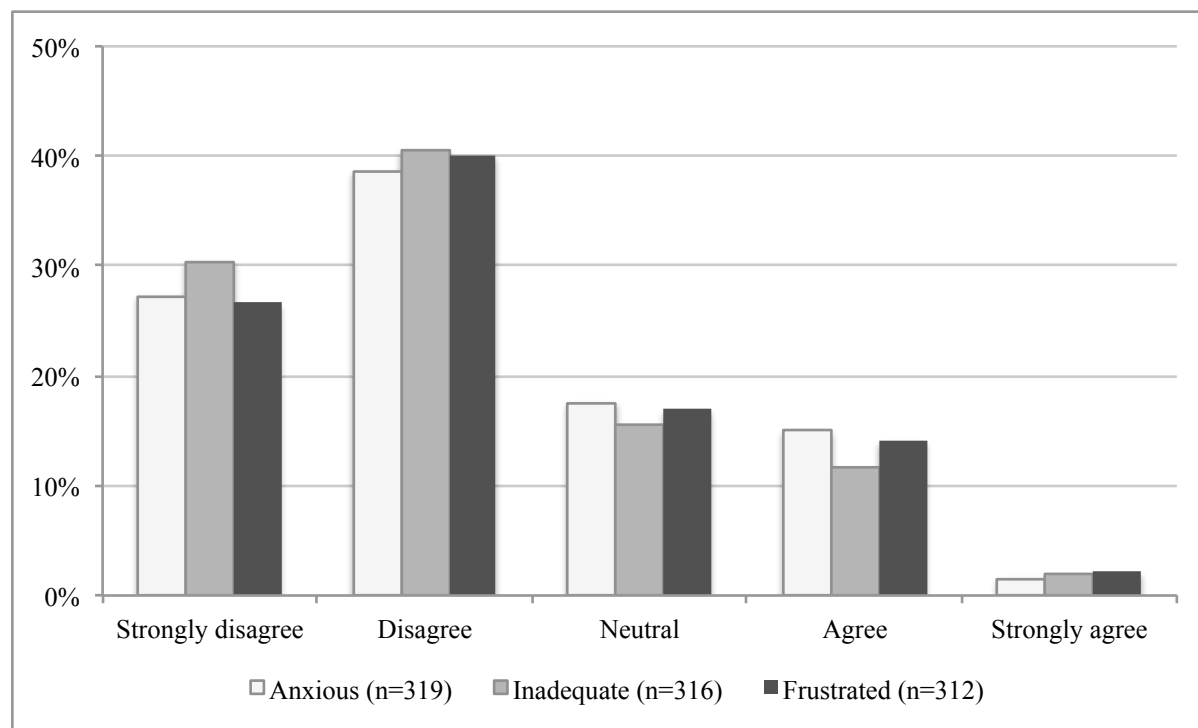


Figure 5. Responses to “Negative” Feelings When Doing Math.

To build off of questionnaire results, interview participants were asked to describe their comfort with math. Although answers vary, three themes emerged from the data regarding factors that appear to correlate with self-confidence level. One factor related to the formal school experience: participants frequently referred to their performance in math classes in school as well as the amount of math-related courses they took. Even older participants, who have been out of the formal school system for many years, suggested that it still has a strong influence on their self-confidence, whether high, (“I’ve had a fair amount of experience in terms of math that I’ve taken...”) neutral (“I don’t have a great deal of higher math education, but that that I do have...I just use it all the time.”) or low self-confidence (“I did terrible in math at school”).

Another relevant factor that appeared is enjoyment. Participants with lower self-confidence scores reported not enjoying math or coping with instincts that tell them they do not enjoy it. For example, one interviewee stated, “I despise math...it bores the heck out of me. I do

it because I have to, I don't do it because I like it." Other participants with higher self-confidence scores reported enjoying math or described it as an enhancement to their lives. As one interviewee with high self-confidence and enjoyment described, the two factors may be "a chicken or egg type of thing... I'm guessing that there are very few people that have some kind of innate enjoyment or appreciation of math, yet recognize that they're not good at it and they have to really struggle to cultivate it... people tend to pursue things that come easy to them."

A third relevant factor appeared to be perceived relevancy and use in everyday life. Both participants in the weakly positive range suggested that they feel comfortable using math but that they do not feel like they have a great need for it. Many participants in higher self-confidence ranges stated that they use math frequently in their lives, and several directly mentioned situations in which they use math (see Table 4).

Table 4 <i>Comfort with Math, by Self-Confidence Score</i>	
<u>Self-confidence Score (from Questionnaires)</u>	<u>Sample Responses (from Interviews)</u>
Weakly negative (-7 to -3)	<p>"I hate math. I have no comfort with math. I did terrible in math in school; I'm an English-history person... It bores the heck out of me...I do it because I have to, I don't sit down to do it because I like it."</p> <p>"I get very confused and I just tend to, like I can feel my brain just kind of closing its eye...I enjoy the challenge of it, but it's very hard to get past that mental block of oh, I'm not good at math, I don't like it, I don't understand it."</p>
Neutral (-2 to 2)	<p>"I've noticed that when I'm in social situations where somebody has to do some math, I tend to say to myself, well let's let one of the younger kids do it...I don't feel like it. [Math] was never my real, real strength."</p>
Weakly positive (3 to 7)	<p>"I think I can understand concepts if they're explained to me. And I can use [math] as I need it in my day-to-day life. I don't need it much. I passed...I mean I did well enough in math in school that I feel comfortable."</p> <p>"I haven't felt the need to do it because I don't use that in my life anymore...I'm fully retired now. So, it's still kind of intimidating for me. I could go back and learn if I had a reason to but I don't, so I don't."</p>
Positive (8 to 12)	<p>"I don't have a great deal of higher math education. But that that I do have, you know, like fractions and percentages and how to do a scale and just simple addition, subtraction, multiplication, I just use it all the time."</p> <p>"I'm not a math-oid...But, as far as everyday and reading lay science pieces, no problem at all."</p> <p>"I use [math] in my day-to-day work, so, that gives me confidence in understanding...when I see or read articles that aren't necessarily related to the field that I work in, I feel pretty confident that I can understand the basics of what they're talking about if they do have some math content."</p> <p>"You know, all through school, math has been one of my favorite subjects. And in physical chemistry I use math almost every single day...I feel like it comes to me easily. And I enjoy it."</p> <p>"I just really like math and taking a lot of courses in it, and I find beauty in broader geometrical mathematical construction...I find it to be enhancing of my life in the same way that music is an art form."</p> <p>"But because I have that [educational] background, it is easier for me to solve everyday math problems at work or wherever it needs to be so I feel very comfortable, very positive about my abilities to do math."</p>
Strongly positive (13 to 16)	<p>"I've always enjoyed and been good at math, or been told I've been good at math...I've always been interested in it and enjoyed it and had some proficiency at it. And so I do enjoy that way of looking at the world."</p> <p>"I've had a fair amount of experience both in terms of classes that I've taken...it's been a while, but...and in terms of the way that math is kind of an integral piece of what I do for a living."</p>

Enjoyment. One questionnaire item measured enjoyment of math and a second questionnaire item measured the related factor of math as a topic of particular interest, both as five-point Likert-type scale ratings from “strongly disagree” to “strongly agree.” Figure 6 shows that the majority of participants (64.7%) agreed or strongly agreed with the statement “I enjoy learning about math.” However, fewer than half of participants (43.5%) agreed or strongly agreed with the statement “Math is a topic of particular interest to me;” the largest percentage of participants selected a “neutral” response.

Interviewees’ responses related to their value and interest or disinterest in math in the science café setting (shown below and discussed at the end of the chapter) offer some possible explanations for the variation seen in the ratings of these two items.

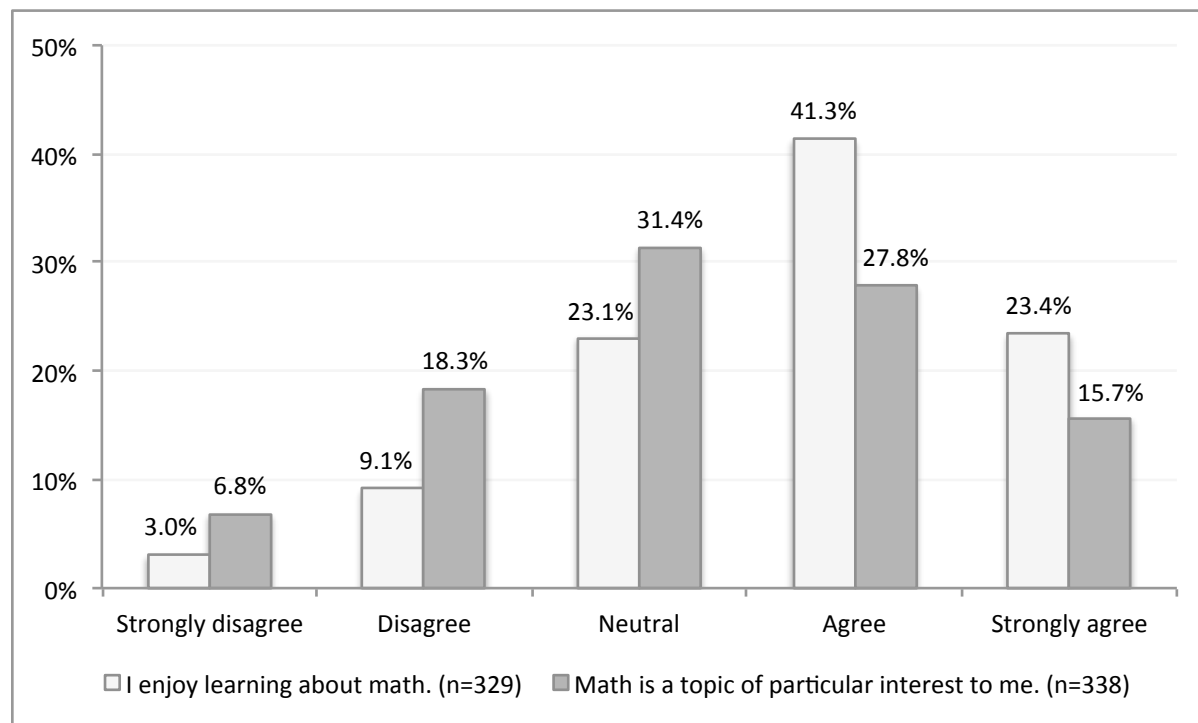


Figure 6. Responses to Enjoyment Measurements

Value. Two items on the questionnaire measured elements of participants’ value of math. Figure 7 shows the distribution of Likert-type scale ratings for the two value measurements. The

majority of participants agreed or strongly agreed with the statements “Math is important in everyday life” (91.7%) and “Understanding math helps one understand the world better” (85.7%), indicating a high overall value of math.

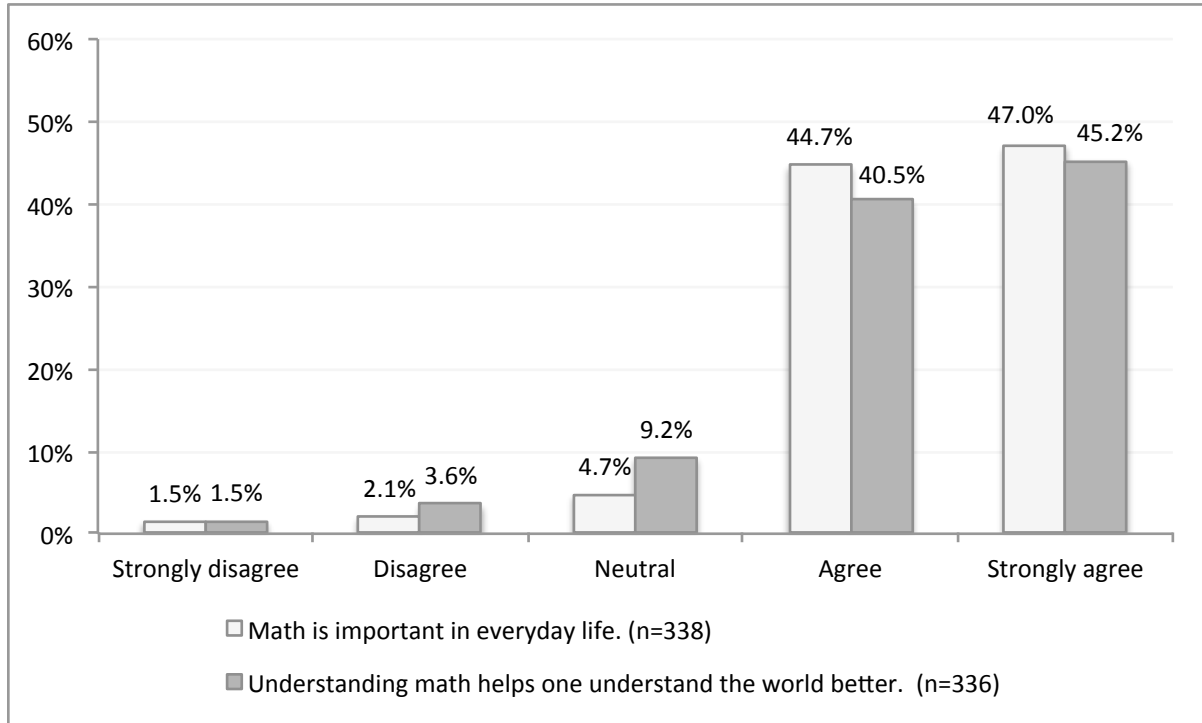


Figure 7. Responses to Value Measurements

Interview data provides richer information on participants’ perceptions of value. Interviewees were asked, “In your opinion, what is the value of participating in math-based learning activities as an adult?” Table 5 illustrates the themes that emerged from interviewee responses. One common theme related to the idea that participating in math-based learning activities as an adult is healthy or good for the brain, particularly in terms of aging well. Some participants explicitly stated that they don’t see this as exclusive to math: participating in math learning activities is just one possible tool for healthy aging. Other respondents noted that for them, participating in math-learning activities helps with decision-making or everyday tasks,

such as budgeting or shopping. Still others discussed needing math to understand concepts or social issues, including disciplines of science, climate change and evolution.

Table 5 <i>Value of Participating in Math Learning Activities as an Adult</i>	
<u>Theme</u>	<u>Sample Responses</u>
Good for brain/ Healthy aging	"I think it's good for your brain in terms of just kind pushing yourself to learn new concepts and new ideas. That aspect of it I think, just from the sense of aging well." "I think it's really, really good for your brain. Because it's like learning a language, or anything that requires nimble thinking is really good for your brain."
Problem solving/ decision making	"Whether I'm using the quadratic equation or not in my daily life, which I don't, doesn't really matter to me because, as far as valuing the process, it helps... me problem solve." "It makes me more able to make smart decisions about investments, you know, whether it's a purchase at the grocery store or whether I want to invest in real estate or the stock market."
Understanding specific concepts/ issues	"I think it is very important as an adult, even going so far as to say to understand scientific concepts...I think if adults are more scientifically and mathematically educated, they might have a little bit better idea of things like evolution and global warming." "The value to me of learning math is it's helping me understand a new subject that I want to understand in physics."
Improving general understanding	"I think the value is to broaden your understanding of how the world works. And to be open to new ideas." "For me, it's kind of a way to expand my horizon and spend time thinking about things in an interesting or deep way that is sort of not directly related to my job."
Everyday life	"Making a budget, sticking to a budget, calculating interest, mortgage payments, things like that, I think math is really important in that way."

Almost all interview participants agreed or strongly agreed with both value statements, with two exceptions. These two exceptions had low self-confidence scores (of 1 and -6) and both disagreed with the statement “I enjoy learning about math,” suggesting that there may be a correlation between these attitude measurements. When asked about the value of participating in math-based learning activities, one of these two interviewees referred to the need to use math in everyday life, saying, “You do need some math to live...you’ve got do your checkbook, you’ve got measure things.” The other interviewee discussed its value for healthy aging, saying, “You

know how they recommend that old folks do crossword puzzles and Sudoku so the brain doesn't fall apart? In order to meet that need in my life I've been studying biblical Hebrew...and it's the same sort of thing." Thus this participant refers to math as being good for the brain, but from a third-person standpoint: learning or practicing math is something someone might choose to do for the purposes of healthy aging, but she chooses another activity.

However, self-confidence score was not correlated to disagreement with the two value statements in all interviewees. An interviewee with a self-confidence score of -7 strongly agreed with both value statements. When asked in the interview about the value of participating in math-based learning activities as an adult, her answer referenced healthy aging and improving decision-making abilities. She also talked about its value in improving her own self-confidence, saying, "I think smart people are good at math. And I am a smart person, so I think that's one area of my intelligence I need to shore up."

Attitude stability and effect on interest in science. Interviewees were asked if they considered their attitudes toward math to be stable or if they changed from day to day or situation to situation. The majority of interviewees, including both those with more positive attitudes (across different subcategories) and those with more negative attitudes toward math, indicated that they believed their attitudes to be fairly stable. Some interviewees talked about examples of situations when learning something new in school when their attitudes toward math (particularly self-confidence) became increasingly negative. For example, one interviewee stated, "When I was taking [quantum mechanics] and I was expected to know these incredibly complex high math functions that I didn't, I felt not very good at math." Others discussed how comparing themselves to other people sometimes affected their personal attitude toward math. One interviewee stated:

Occasionally I read articles that are not in my field...and they have articles that are on all kinds of different things. And occasionally I'll read an article about high-energy particle physics or something like that, and then I'll think, okay, these people are way smarter than I am at math. You know, I'll get bad sensations.

However, other interviewees discussed comparing themselves to others without it having an effect on their own attitude toward math. One interviewee asserted "I know [my stepsons have] more knowledge and are better at math than I am in some situations, but that doesn't affect my sense of math ability. I know what my limits are."

Some interviewees noted times when their math attitude changed, but in a positive direction, using words like "expanded" and "heightened." For example, one stated, "I'm interested in some of the educational videos online that explore areas of math that I hadn't been exposed to and may not seem practical to me but it sort of expands my appreciation, I guess, for mathematics." Similarly, an interviewee with lower self-confidence said:

I would say it's stable but steadily improving, because it's something that I've been actually working on. So it doesn't change drastically, you know, from one situation or one day to the other, but I am working on becoming more capable and therefore more confident with it.

A significant portion of interviewees indicated that their attitude toward math does not affect their interest in science, but reasons varied widely. One interviewee stated that she "never thought of it having any correlation." Other interviewees, both with higher and lower self-confidence scores, indicated that they do not see their math attitude as preventing their access to science, but neither does it enhance their interest in science. One interviewee with low self-confidence stated:

I enjoy it when people present me with facts...or theories, or information that they've used mathematical models to come up with. And present to me for my delectation and interest. I don't say, you know, I'm not going to like this as much because you had to use math to get to it.

Another interviewee with higher self-confidence, on the other hand, said, “Math has not been something that I struggle with. And so it’s never been a barrier.”

Other interviewees described their math attitude as affecting their ability to understand science, as opposed to their interest in science.

I learned science and math together. You don’t have to know math to appreciate certain aspects of physics or science...but it sure helps...I mean that’s how we figured out that [atoms and subatomic particles] exist, scientists using math.

Another interviewee noted:

I feel that it affects my understanding of science. I’m still interested in learning about the science and hearing about the science, but sometimes it gets to a point where I just kind of go, oh, they’ve lost me completely, I have to go on faith that what they’re saying makes sense, when the math is beyond my abilities.

Others felt that their confidence in approaching scientific topics was affected by their math attitude:

I guess it affects it in the sense that I’m very interested in all different types of science disciplines, so it affects it in the sense that I’m confident, so I’m willing to read and learn about and attend lectures in areas that are not my area of expertise.

Similarly, one interviewee with very low reported self-confidence in and enjoyment of math stated, “I don’t interface with things in science as much as I would if I enjoyed math.”

Gender and Attitude

Although this research does not focus on correlations between gender and attitude measurements, the amount of research on gender in the field of math education warrants mention as it applies to findings from this study. Gender did appear to have a significant correlation between certain attitude measurements ($\chi^2 < 0.05$). Males were much less likely than females to disagree with the statement “I am good at math” (8% vs. 20%) as well as “Sometimes I find myself saying I can’t do math” (14% vs. 35%). Interestingly, although no significant difference existed between the genders for the statement “I enjoy learning about math” ($\chi^2 = 0.151$), there

was a difference for the statement “Math is a topic of particular interest to me” (17% of males and 30% of females disagree; $\chi^2=0.008$). No significant differences existed between males’ and females’ responses to the two value-measurement statements, “Math is important in everyday life” ($\chi^2=0.677$) and “Understanding math helps one understand the world better” ($\chi^2=0.366$). However, as described below, both female and male science café participants indicate a high interest in hearing about the topic of increasing female interest and participation in math as well as attending math-related science cafés with female presenters.

To What Extent Are Participants Interested in Hearing about Math-Related Topics at Science Café-Type Events? Which Types of Math-Related Topics Interest Them the Most?

General interest in math at science-café type events. Questionnaire participants were asked to rate their general interest in hearing about math at science café-type events. Participants rated their interest on a five-point scale from “not at all interested,” to “extremely interested.” Roughly one-third of participants selected that they were “very interested” in hearing about math at a science café-type event and an additional one-third selected that they were “moderately interested” (see Figure 8). Twelve percent of participants indicated that they were “extremely interested” in hearing about math-related topics at science cafés. Around one-fifth of participants indicated slight or no interest.

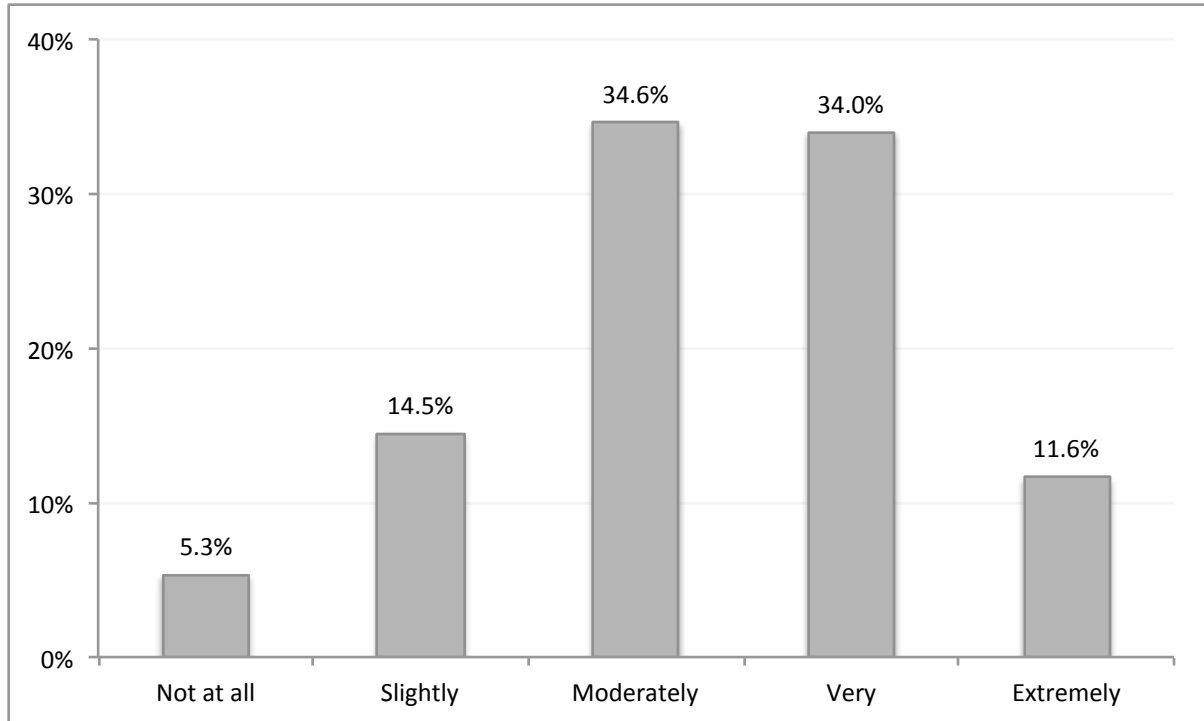


Figure 8. General Interest in Math at a Science Café-Type Event ($N=318$)

Interest in specific math-related topics at science café-type events. Participants were asked to rate their interest in eight specific math-related topics on the same five-point scale. Of the eight specific topics listed on the questionnaire, overall, participants were most interested in “math in the arts” and “math and public health” (see Figure 9). Participants were least interested in “math and the budget deficit” and “current research in math.”

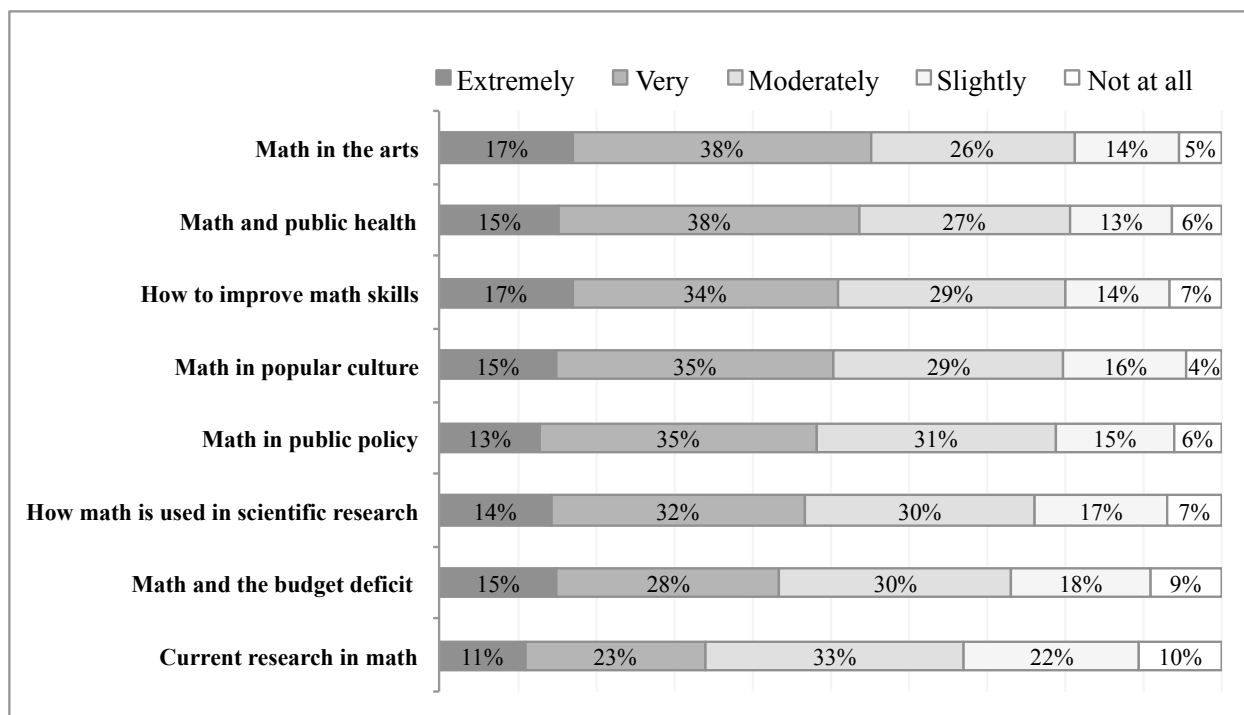


Figure 9. Interest in Specific Math-Related Topics ($N=315-319$)

Factors affecting interest. Interviewees were asked to elaborate on their general interest in mathematics and describe why certain math-related topics were or were not of particular interest to them. Table 6 illustrates five overlapping themes that emerged as why participants found a specific math-related topic to be of interest or disinterest: unexpectedness, relevancy, value, learning opportunity and self-confidence in ability. Responses coded for “unexpectedness” were those in which interviewees talked about topics as “surprising” or “intriguing”: they voiced interest in topics in which unexpected connections to math could be made. “Relevancy” coded responses refer to when interviewees talked about how a math-related topic may or may not have consequence for their lives through their careers, hobbies or personal relationships. Responses coded for “value” were those in which interviewees discussed topics in terms of societal value or importance, particularly in terms of others (that is, something they think other people should know or understand). “Learning opportunity” coded responses arose

when interviewees discussed certain topics as an opportunity or format in which to better learn or understand a particular topic. Finally, responses coded for “self-confidence in ability” relate to interviewees discussing interest or disinterest in a topic based on their confidence in their own math abilities, whether positive or negative.

Table 6

Factors Affecting Interest in Math-Related Topics at Science Café-Type Events

<u>Theme(s)</u>	<u>Sample Response</u>
Unexpectedness; Value	"I'm really intrigued by novel, or things that are new to me, ways of using math... Things that are maybe not what people expect of mathematics. People have such a narrow idea of what math is, and anything that sort of takes that stereotype and shakes it up a bit."
Unexpectedness	"The concept that the universal standard of judging, measuring things about a very concrete and everyday shape...involves an irrational number. I think that's a real mind-blowing thing. I think people would be surprised or shocked that we can't measure the area of a circle with exactitude."
Relevancy	"For me personally, it's a little bit of "been there, done that," and so, not particularly my area where I'm going to choose to use too much energy."
Relevancy	"And then for public health that's what I do for a living...so I find anything to do with that kind of interesting."
Value	"I think people seem to have this idea that math and science are separate from the arts. And, I just think that's really weird....so I'd like to see that undone."
Value	"The other, about public policy, is because I think that it's important to understand that we live in...a so-called representative democracy and it's important for not only the people to be informed...but also, I think people need to be aware..."
Learning opportunity	"I don't have a lot of math background... But by the same token, I mean one of the reasons I go to Science Pubs is I want to learn about things I don't know anything about. So, if it came up, I would go listen to it. If I got one 'aha' out of it, I would feel good."
Learning opportunity	"I think that maybe through the art, I could come to understand math a little bit better. And so I think that would be a good way for me to get at math. A little bit of sugar in the medicine, so to speak."
Learning opportunity; Self-confidence in ability	"I feel like I have the ability to understand a lot of things, if it were taught in a way that I would understand by a mathematician, but I just haven't looked into it yet...I mean there's a lot of math out there that's really exciting and fun, that I just don't even know about."
Self-confidence in ability	"How math is used in scientific research...It'd probably be beyond my ability really to get a lot out of it."
Self-confidence in ability	"Helping people with everyday math concepts may not appeal to me because I feel like I probably would be able to understand most of it anyway, just because I do have a decent background in math."

Interviewee responses to disinterest in “math and the budget deficit” did not fit into any larger themes. The two participants who were asked about their disinterest in this topic both noted the overt political nature of the topic as the cause. One interviewee stated: “Our deficit is important for ourselves and for our future generations, but...to me it’s just more political than interesting.”

“Pure” math versus applied math. One frequent theme, “pure math,” or more abstract math, versus applied math, arose so frequently when talking with interviewees about their math-related interests that it requires individual attention. Interviewee responses may substantiate and help explain the relatively low interest in “current research in math” indicated by the questionnaire data. More than half of interview participants stated that they are not interested in hearing about “pure” or abstract math in the science café format, but rather in more concrete applications of math. Such responses came from interviewees of both genders and a range of age groups, as well as interviewees from both more positive and more negative self-confidence scores. Their disinterest still appears to follow some of the themes outlined in Table 6. Many of these responses suggest that the factor causing their disinterest in the topic is related to relevancy:

It’s hard for me to imagine a topic that would be pure math that would interest me...I need to have, you know, some mammalian evolution or a way to see a trail to someplace I might want to hike to more clearly. I need to have something to attach it to.

Another interviewee stated:

I think I would be more naturally inclined to go to something that was dealing with something that I feel was more concrete. That I can, you know, look at and kind of relate more directly to my everyday life, like water, or you know, something having to do with conservation.

Other respondents appear to be uninterested in pure math topics because they feel it would be beyond their level of ability or understanding. One interviewee stated:

I would be motivated to go if it was exclusively about math as long as I felt like it was math that was within my understanding level. And so I think I certainly wouldn't not go because it was about math, but if I felt that it was about something like calculus, I have no understanding of calculus at all. And so that I would probably avoid.

However, not all interviewees were uninterested in “pure” or abstract math. Some interviewees explicitly discussed their interests in more abstract or advanced mathematical topics, often indicating interest because of the learning opportunity provided. These interviewees tended to be those who had a more positive self-confidence score and higher reported enjoyment of math. For example:

Just sort of these real theoretical, fundamental math for math's sake [type of topics] I think is really fascinating. And so that kind of thing just is neat, I think, if you can get a good mathematician who can actually speak at like a lay level. Basically they can convey their concepts in a way that a general audience can grasp.

Similarly, another interviewee stated:

I guess I would say that I'm equally fascinated by math than science and that it would be interesting to have a math talk. It would be interesting to see...because I don't believe we'd have a pure math talk...it would be interesting to see how a mathematical talk would be presented. And received.

Other topics of interest. Interviewees were asked to describe other math-related topics that would be of interest to them (Table 7). In general, responses could be broken down into three main themes: math in social or public issues, interesting applications of math, and “pure” or abstract math topics. One topic that was frequently discussed was women in the mathematics field, both as a topic (for example, a discussion of why fewer females enter into STEM-based fields and what can be done to encourage them) as well as having a female presenter (for example, one interviewee stated, “a woman presenting it would definitely have me trying to rearrange my schedule to make sure we could go”). Some interviewees did discuss their specific

interest in theoretical math topics; as may be expected, these interviewees had indicated a high self-confidence and enjoyment of math.

Table 7		
<i>Other Math-Related Topics of Interest</i>		
<u>Theme</u>	<u>Topic</u>	<u>Sample Response</u>
Math and social/public issues	Women in math	"Women in math, especially how to... overcome some cultural, perhaps, let's say limitations or fumbling or something on why we're not seeing more women in high-end math."
	Math education	"I would really like to see some really high-quality research on what the best approach is for math education."
		"I think it would be interesting to see something, like a Science Pub, done on math in the family and a way for parents to approach math with their kids."
	Statistics	"How math or statistics is used and misused in the public."
Applications of math	Math and earthquakes	"We have quite an interest in earthquakes in this area.....you know, how do they determine the size of earthquakes, how can they estimate how much damage might be caused by a certain type of earthquake."
	Math and harmonics	"Harmonics, now I know that's part of music, but harmonics are... well it caused the Tacoma Narrows bridge to sink here 60, 70 years ago, something like that."
	Math and architecture	"I would love to know the math that goes into buildings... I'm sure that there's a ton of math that goes into that that I don't even know about."
"Pure" or abstract math	Proof theory	"Proof theory... because it's just kind of neat. And it's math but..it's not really how people normally think of things."
	Fractals	"I think people know about fractals by now but it's just a field of math that shows up in biology and physics and everywhere else."
	Unexpected math	"Something like 'math-a-magic,'" which is a horrible term I can think of to call it, like really cool, kind of like a math magic show. Like a bag of tricks of math that...things, answers that might pop up that you wouldn't initially expect but when you analyze the math it turns out completely true."
	Irrational numbers	"I'm very interested in transcendental functions and numbers and irrational numbers and I think that that is something that people would be interested in, even just at an abstract level."

Discussion and Implications

Findings from this research suggest that when most science café participants do recognize math-related content within science café settings, the characterizing factor is the use of numbers, which they may describe as a less “intensive” use of math, as well as the presence of graphs and statistical data. Some participants indicated a belief that all science cafés feature math to a certain extent, but this minority appears to be those participants who have higher self-confidence in math and extensive STEM-related backgrounds. Other participants indicated that although they believed that math-related content was present or inherent, it was somehow hidden or not meant to be understood by the audience. Perhaps most importantly, participants frequently reported that they did not see any content that they would recognize as math or related to math in previous science cafés they had attended. Although reasons for this may vary, it suggests that in large part, participants do not see math as a strong component in many science café events, particularly those that focus on the natural or biosciences. As a good understanding of math continues to play an increasingly larger part in many scientific fields, largely due to advancements in data collection and modeling programs available, it will become more important for audiences to be able to recognize the role math plays in these fields. If science café organizers are interested in making math a larger component, they may want to consider helping presenters both incorporate math and make its use more evident to the audience.

The majority of science café participants surveyed for this research reported feeling at least moderately confident in math. Fewer participants disagreed with the statement “I am good at math” than agreed with the statement “Sometimes I find myself saying I can’t do math,” suggesting that it is more common for participants to experience low self-confidence in math on occasion than it is to consider themselves always bad at math. In consideration of results from

surveys like those carried out by Change the Equation, findings from this study suggest that science café participants, overall, may have higher self-confidence in math than the general public. Higher self-confidence may stem from many factors, including differences in the overall level of education of participants, interest or background in STEM fields, and value of informal learning opportunities. Regardless of the correlating factors, there still exists a significant minority of science café participants, despite their overall high levels of education, who feel discomfort with math to some extent. Such a gap may offer science café organizers an opportunity to help adult audiences become more comfortable with math and their math abilities.

Despite occasional or frequent low self-confidence in some participants, several findings from this research indicate that, in general, science café participants may respond positively to the incorporation of more explicit math into the existing format of the science café program. Overall, value of math among all questionnaire participants was high. Participants see math learning activities as valuable for better brain health, improved ability to make decisions and use math in everyday life, and increased ability to understand complex social topics like climate change. Although the majority of interview participants across the spectrum of high to low self-confidence, enjoyment and value indicated that their attitude toward math is stable, several interviewees discussed situations in which they felt their attitude was “expanded” or “enhanced” by specific learning opportunities. Interview responses also indicate that many science café participants see a positive attitude toward math as valuable for improving their ability to understand scientific concepts or as a boost to their confidence in approaching scientific concepts.

However, as may be expected from previous findings in the literature, participants’ attitudes across all subscales vary widely. This was particularly evident in two interview

participants who had the lowest self-confidence scores among the interviewees. Both participants were female attendees from the same site, from similar age brackets and with similar levels of education. Both had attended a similar number of science cafés in the past year. However, the value, enjoyment and interest measurements of these participants varied drastically. The first woman reported enjoying learning about math despite her perceived difficulties in understanding it and strongly agreed with both statements about the positive value of math. In her interview, she discussed how she had always struggled with math but was continually “working on becoming more capable and therefore more confident with it.” Her interests in specific math-related topics varied, but she indicated that she was “extremely interested” in several math-related topics.

The second woman, on the other hand, reported a complete lack of enjoyment in learning math and neither disagreed nor agreed with statements about the positive value of math. In her interview, she stated that she only does math when she feels required to, adding, “I would never sit and enjoy math. That will never happen.” She indicated that she was not at all interested in any math-related topics and reported that nothing could motivate her to attend a science café-type event on a math-related topic. These two interviewees illustrate that if science café coordinators and other science center education staff are interested in the opportunity to improve adult participants’ self-confidence in math, they may experience differing levels of resistance. Presenting math in a way that interests and attracts participants may be successful for many attendees, and explicit recognition of math in the presentation may help participants better understand math, but some potential participants will be deterred by any mention of math in the program.

Findings suggest that in general, the majority of science café participants are moderately to extremely interested in hearing about math-related topics at science café-type events. Of specific topics that questionnaire participants were asked to consider, math in the arts and math in public health were the topics with the greatest interest. Responses from interviewees suggest why this and other topics may be of special interest: five factors that increase interest are those that highlight unexpected connections to math, tap into a topic that is relevant or of social value to them, offer a particular learning opportunity, or fit into what they perceive as the range of their own ability in math. These factors align with findings from previous literature on the types of topics that science café participants respond positively to, particularly Rabe's (2009) description of "interesting," "timely" and "useful" topics. Other topics suggested by interviewees as topics of particular interest, including specific topics in the themes of math and social or public issues and applications of math, fit within these five factors.

Conversely, the specific topic of least interest to participants was current research in math. This finding is somewhat surprising, as science café topics often relate to current research in various fields. However, some of the factors affecting interest as described above help explain the lack of interest in this topic. Participants may not see current research in math as relevant to their lives and, because of a lack of understanding of what current research in math actually is, they may not see it as a topic of value. Furthermore, many interviewees stated that they believe that current research in math would be beyond their level of math ability or understanding. Instead, most participants prefer to hear about applications of math, in order to "have something to attach it to." However, participants with stronger educational or career-based backgrounds in math did indicate an interest in current research in math and other more abstract math topics,

particularly when they aligned with factors related to unexpectedness and a learning opportunity they may not be able to find elsewhere.

Math can be incorporated into science cafés in two ways: by highlighting math that is used in the processes and results of existing topics and presentations, and by focusing on math and math-related content as the presentation topic itself. Findings from this research suggest that although the audience may respond positively to both strategies, focusing on specific, math-related topics may prove more successful. Audiences may not recognize math-related content in many science café presentations, so efforts to make the use of math more explicit may still prove challenging. Furthermore, interest in “how math is used in scientific research” was relatively low. Math-related topics, alternatively, make the use of math “explicit” simply by the nature of the topic itself and can draw on the five factors that affect visitors’ interest.

Finally, the incorporation of increased mathematical content into the science café format may prove successful largely because of the success of the format itself. The high number of repeat and “regular” attendees indicates that many participants come to the event no matter the specific topic. Several interview participants also indicated confidence in the format, stating that even though they may not have an extensive educational background in math, they would expect to learn something at a science café event because of what they perceive as a strong track record. And overall, most science café participants indicated an enjoyment of learning in general, without concern to the specific topic, which may explain the discrepancy between the number of participants who indicate enjoyment of learning math versus math being a topic of particular interest. As a final example, one interviewee summed up his views on learning math, representing many of the findings from this research:

We have some good friends who have a son who’s really quite a brilliant theoretical physicist. And I wouldn’t begin to talk to him about the math of some of his

experiments...because I don't know that much. But I enjoy listening to him and trying to glean what I can from what he says. Because I like to keep learning. But [math is] certainly not something that I would go back to school on again, although I do have a positive attitude about...how important it is to things everyday.

Chapter V: Conclusions and Recommendations

Findings from this study support previous literature on demographic information of science café audiences. Science cafés attract participants from a wide range of ages and of both genders almost equally. Furthermore, this research reiterates the appeal the science café format has for a lay audience: fewer than half of participants reported having a STEM affiliation through formal education or career background. Many participants also reported coming to a science café event solely because they enjoy the format, regardless of the specific topic.

The “science café” format has been used for other content beyond science, including history and social science (as well as philosophy, from its origins as the Café Philosophique). The Museum of Math in New York City currently offers a program called *Math Encounters*, a “popular public presentation series celebrating the spectacular world of mathematics.” However, museums focusing on math are unlikely to become as common as science centers, and the ties between various STEM fields and content make science centers a natural fit for math-based programs. Additionally, the success of the science café format as a forum for popular science and its ability to attract so many “regular” participants make it poised to incorporate more mathematical content for an already interested and engaged audience.

The results of this research indicate that science café audiences may be receptive to increased math content in the program. Responses from interviewees suggest that most participants, particularly those without strong math backgrounds, often do not recognize any use of math in the program beyond some mention of numbers or statistics or the use of graphs. However, most participants feel at least moderately self-confident in their math abilities. Perhaps more importantly, a large percentage of participants indicated enjoying learning about math and the vast majority rated the value of learning math highly. Interviewee responses

suggest that participants particularly value math-based learning activities as benefits to brain health as well as for their ability to improve decision-making and understanding of specific concepts. Finally, many interviewee participants indicated that there are times when they feel that elements of their attitude toward math are “enhanced” after particularly interesting or positive learning experiences. This suggests that positive math-related learning experiences in a science café or other similar format may be able to offer similar “enhancing” effects to participants.

Furthermore, findings from this study suggest several approaches for science café organizers who would like to incorporate increased math or more explicit math into their programs. First, because of the common perception of math learning as being valuable for brain health and aging as well as the relatively older age set of participants, science cafés may be able to use a “healthy aging” approach to attract participants to math-related topics. Second, science café audiences indicate a particularly high interest in math in the arts, suggesting that initiatives in the growing field of “STEAM” would be successful in this setting. Third, audiences indicate a comparatively low interest in current research in math. Interview findings corroborated this, suggesting that participants are turned off by the “abstract” nature of pure math and prefer topics that they perceive as more relevant to their lives. Fourth, audiences’ preferences for math-related topics in science café settings align with and expand upon previous findings on general preferences for science café topics: in regard to math-related topics, participants prefer topics that are relevant, unexpected, and personally valuable, as well as those that provide a unique or desirable learning opportunity. Finally, it appears to be important that participants view any math-related content matter to be within their perceived ability in math, a factor that may be more important for math-related topics than those in science and may reflect attitudes toward

math as a particularly challenging or difficult endeavor. However, as previously noted, many participants come to the science café no matter the specific speaker or content, and several interviewees stated that if the topic were math-related, it would not change their regular attendance. Such responses reflect positively on the success and popularity of the science café format.

Future Research

It was beyond the scope of this research to examine correlations between different attitude and interest measurements. However, correlations may help identify unique profiles of participants and segments of audiences who would respond differently to varying levels of math incorporation. Future research may choose to look for potential correlations. Additionally, although interview responses and information on STEM-related educational and career backgrounds may hint at the math-related experience level of participants, this research did not look at the mathematical abilities or numeracy skills of adults in science cafés. It may be interesting to assess both the baseline level of numeracy skills as well as whether attending science cafés correlates to an improvement in numeracy, in order for science centers to play an even larger role in national efforts to improve the numeracy levels of audiences of all ages.

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Appendix A: Questionnaire Instrument

Math Attitudes and Interests of Adult Science Café Participants

University of Washington

Researcher: Anna Johnson Email: annaj4@uw.edu

Thesis Advisor: Kris Morrissey, Director of the Museology Graduate Program

Phone: 206-685-8207 Email: morriss8@uw.edu

I am asking you to complete a survey that is part of my Master’s Thesis research at the University of Washington. The purpose of this research is to describe the math attitudes and interest levels of adult participants in science center-sponsored science café events. Your participation is voluntary; refusal to participate will involve no penalty or loss of benefits, and you may discontinue participation at any time. Even if you provide your contact information (optional) at the end of the survey, your responses will remain confidential. If you have any questions now or in the future, you may reach me through the above contact information, which is copied on cards available for you to take with you.

By continuing to the survey below, you agree to take part in this research.

Part 1: Math Attitudes and Interests

This survey consists of statements about your attitudes toward and interest in mathematics. Please think about each item and check the box that most closely represents how you feel.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1. I am good at math.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Sometimes I find myself saying I can't do math.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. When I do math in my everyday life or at work I feel...					
Confident	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Anxious	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
At ease	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inadequate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Frustrated	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Knowledgeable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. I enjoy learning about math.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Math is a topic of particular interest to me.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Math is important in everyday life.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. Understanding math helps one understand the world better.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

8. Please list three situations or activities in which you use math in your work environment (if applicable).

9. Please list three situations or activities in which you use math in your everyday life, outside of a work environment.

	Not at all interested	Slightly interested	Moderately interested	Very interested	Extremely interested
10. How interested are you in hearing about the following topics in math at a science café-style event or similar program?					
Current research in math	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
How math is used in scientific research	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Math in the arts	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Math and public health	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Math in popular culture	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Math in public policy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
How to improve math skills	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Math and the budget deficit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11. In general , how interested are you in hearing about math-related topics at a science café-style event or similar program?					
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

12. Please use the space below to provide any comments you have related to this topic.

Part 2: Demographic Information

1. Please write in your gender: _____

2. Please select your age:

- 18-24 25-34 35-44 45-54
- 55-64 65-74 75+ Prefer not to answer

3. What is the highest degree or level of schooling that you have completed?

- High school/GED Some graduate work Prefer not to answer
- Some college Master’s degree
- Bachelor’s degree Ph.D. or other advanced graduate work

4. Including tonight, how many Science Cafés (any location) have you attended since March 2013? _____

5. Do you have or are you pursuing a degree in a STEM*-based field? Yes No

6. Have you held or do you hold a position in a STEM*-based career? Yes No

*STEM=Science, Technology, Math or Engineering

7. What is the MAIN reason you came to his event tonight? (Please pick one.)

- I am interested in this specific speaker/topic. I was curious about the event.
- I came because I like science cafés. Other (please specify below)
- I came to accompany a friend/family member. _____

----- [Researcher cut here] -----

If you are willing to participate in an approximately 20-minute interview to further explore these ideas, please leave your email address or phone number here:

Thank you for your participation!

Appendix B: Interview Guide

I'd like to record this conversation so it will be easier for me to transcribe later, but it is completely optional. Do I have your permission to record the interview?

[If “no”, turn recorder off immediately.]

I am asking you to participate in an interview that is part of my Master's Thesis research at the University of Washington. The purpose of this research is to describe the math attitudes and interest levels of adult participants in science center-sponsored science café events. Your participation is voluntary; refusal to participate will involve no penalty or loss of benefits, and you may discontinue participation at any time. I will be asking you questions about your experience with and perception toward science cafés, your attitude toward math, and your interest in math as it relates to science cafés. No identifying information will be linked to your answers in the report. Do you have any questions for me about the interview?

Do you agree to participate in the interview?

[Participant must say “yes” before proceeding.]

Just so you know, I'm looking at your survey responses to guide some of my questions.

Questions

First we'll talk a little about your experience with Science Pubs/Science Cafes as well as how you recognize math.

- You attended the Science Café/Science Pub that was about {insert topic}. Can you tell me a bit more about why you chose to attend that particular Science Café/Science Pub?
- Do you remember seeing or hearing anything during the Science Café/Science Pub that you would describe as math or related to math?
- Do you feel like you have seen or heard content you would describe as “math-related” in other Science Cafés/Science Pubs you have attended?
- This may sound like a tough one, but I'm not looking for a right or wrong answer, I'm just curious about your perception. How would you define math?

This next section goes into greater detail on the attitudes toward math that you indicated on the survey. I'm using your survey results to guide some of these questions.

- Your survey results suggest that you feel {positive/negative/neutral/mixed} about your ability to do math. Can you talk to me a bit about your comfort with math?
- Do you consider your attitude towards math to be stable, or does it change from day to day or situation to situation?
 - [If it changes] In which situations do you feel most confident or comfortable?
- Do you feel that your attitude in math affects your interest in science?
- In your opinion, what, if any, is the value of participating in math-based learning activities as an adult (and I'm using "learning" in a broad sense here)?

In this final section I'll ask you about your interests in specific math concepts as they might relate to Science Cafes. Again, I'm using the information you provided on your survey, so I'll remind you of your selections.

- You indicated on the survey that, in general, you {were, were not} interested in hearing about math-related topics at science cafes. Can you tell me more about that preference?
- [If they indicated preference in some topics but not others] Can you tell me more about your specific interest in {insert topic(s)}?
 - It looks like you aren't particularly interested in {insert topic(s)}. Can you tell me more about why this is not a topic of particular interest to you?
- Are there any math-related topics that I didn't list that would be of particular interest to you?
- What would motivate you to attend an event sponsored by a science museum like {PSC, OMSI} that was explicitly about math?

Appendix C: NVivo Coding Scheme

Definition of math			
<i>I'm not looking for a right or wrong answer, I'm just curious about your perception. How would you define math?</i>			
<u>Code</u>	<u>Number of Sources</u>	<u>Key Words/Phrases</u>	<u>Example</u>
Numbers and quantities	7	numbers quantities/quantitative	"The ability to work with numbers " "Something dealing with numbers and quantities "
By subject matter	3	arithmetic calculus geometry	"The first thing I think of is arithmetic " "All the way up of course to calculus " "There's geometry , too, spatial relationships and of course use of space."
Tool or process; Means to an end goal	9	tool application [implied] process method learning/understanding	"It's a tool to help identify and see these various relationships and processes." "I even include things like... calculating a tip on a check ...very basic, day-to-day things." "It's a process to quantify things in our lives." "I think a symbolic method of understanding the universe." "To learn something new."
Language	2	language communication	"A symbolic language for describing everything." "It's a basic form of communication that we do use all the time."
Other	1		"The art and science of measurement."

Recognition of Math			
<i>Do you remember seeing or hearing anything during that Science Café/Science Pub that you would describe as math or related to math? Do you feel like you have seen or heard content you would describe as "math-related" in other Science Cafés/Science Pubs you have attended?</i>			
<u>Code</u>	<u>Number of Sources</u>	<u>Key Words/Phrases</u>	<u>Example</u>
None/Did not recognize	7		"I don't recall anything specifically related to math."
Numbers, measurements and equations	8	numbers [quantities, implied] equations formulas measurements	"Some numbers related to contaminant levels and flow rates." "She gave some information on how much water will fit in a certain size water vein, that kind of thing." "He did show some equations that he found useful." "Something to do with formulas and amounts of this or that." "Just understanding units of measurement ."
Visualization of data	5	graphs figures	"Almost always there are graphs ." "They had some figures I think."
Discipline-specific math	4	[implied]	"The guy giving the presentation appeared to be a chemist, or chemical engineer, and I just know that would involve...a lot of math."

Statistics	5	statistics probability/odds	"There were some statistics and that sort of thing..." "It was more of a discussion of, um, really the probability ..."
Math in scientific process	3	[process, implied]	"They talked a lot about growing grapes... and it seems to me that had something to do with formulas and amounts of this or that."
Always involved	5	always all	"Again, it's always there in the background." "Almost all of them have math in them."
Math obscured/hidden	5	eliminate/hide don't need to understand	"I would do the same thing, I would eliminate as much math as possible." "No heavy, heavy math though...nothing that you'd have to... understand their process."

Self-confidence/Comfort with math			
<i>Can you talk to me about your comfort with math?</i>			
<u>Code</u>	<u>Number of Sources</u>	<u>Key Words/Phrases</u>	<u>Example</u>
School-related: positive	4	school words (classes, courses, education) and positive words: enjoy, did well, good teacher	"I really enjoyed math and history and statistics in high school ."
School-related: negative	5	school words and negative words: hate, did poorly/terribly, bad teacher	"I did terrible in math in school ."
School-related: neutral	6	school words and no positive/negative words	"Well, I don't have a great deal of higher math education ."
Emotions/feelings /attitudes: positive	12	like/enjoy/love confidence/"good at" interest	"I just really like math." "I feel pretty confident about math." "I've always been interested in it."
Emotions/feelings /attitudes: negative	5	dislike not confident/"not good at" disinterest confusion	"I despise math. It bores the heck out of me." "It was never my real, real strength." "I kind of wasn't as interested necessarily in the subject matter." "I get very confused ..."
Relevancy/use: high	7	always/all the time everyday/day-to-day	"I use math to solve little things all the time ." "And in physical chemistry I use math almost every single day ."
Relevancy/use: low	3	don't need/don't use	"I don't need it much."

Attitude Stability			
<i>Do you consider your attitude towards math to be stable, or does it change from day to day or situation to situation?</i>			
<u>Code</u>	<u>Number of Sources</u>	<u>Key Words/Phrases</u>	<u>Example</u>
Expanded/improved	3	expanded improved enhanced/heightened	"I guess I would say that it's stable but it has been expanded ." "I would say it's stable but steadily improving ." "There are times when it's heightened ."
Comparing self to others	6	[in context, implied]	"I know they've more knowledge and better math than I am... but that doesn't affect my sense of math ability." "And then I'll think, okay, these people are way smarter than I am at math ."
Challenges/became more negative	3	[in context, implied]	"I would say the only time that it's ever really dipped is my first year of grad school." "If I'm really tired I'm much less interested in working through a problem."

Attitude toward math affecting interest in science			
<i>Do you feel that your attitude in math affects your interest in science?</i>			
<u>Code</u>	<u>Number of Sources</u>	<u>Key Words/Phrases</u>	<u>Example</u>
Affects ability to understand	8	understand helps [other, implied]	"I feel that it affects my understanding of science." "...it definitely helps to figure out those things." "I wouldn't think you can do science without math."
Affected career choice	2	career, explicit and implied	"You could say my attitudes about math... maybe drove... my career trajectory." "I thought about becoming a geologist, but there was so much math involved in it."
Affected choice to engage	1	engage/approach	"I don't interface with things in science as much as I would if I enjoyed math."
No/Does not affect	7	no/don't think so [implied]	" I don't think so because even before I discovered that I enjoyed math I liked science." "I don't say, you know, I'm not going to like this as much because you had to use math to get to it."

Value of math			
<i>In your opinion, what, if any, is the value of participating in math-based learning activities as an adult (and I'm using "learning" in a broad sense here)?</i>			
<u>Code</u>	<u>Number of Sources</u>	<u>Key Words/Phrases</u>	<u>Example</u>
Good for brain/healthy aging	6	brain health/healthy aging/age	"I think it's good for your brain in terms of... pushing yourself to learn new concepts..." "And there are health benefits." "I think just keeping my brain active will help as I age to stave off a lot of problems."
Problem solving/decision making (general)	3	problem solve decision	"As far as valuing the process, it...helps me problem solve. " "It makes me more able to make smart decisions. "
Understanding specific concepts/issues	5	learn/understand [topic/concept]	"The math would help me learn about whatever the topic is." "I think more people should understand you know, error in scientific assumptions."
Understanding how the world works (general)	5	understanding (general) broaden horizons better/improved/richer life	"I think the value is to broaden your understanding of how the world works." "For me, it's kind of a way to expand my horizons. " "I still think that everything you learn gives you a richer life. "
Everyday life	5	[everyday tasks, implied]	"Math is incredibly important, whether it's... like how much driving is going to cost on a road trip. "

General interest in math-related topics			
<i>You indicated on the survey that, in general, you {were, were not} interested in hearing about math-related topics at science cafés. Can you tell me more about that preference?</i>			
<u>Code</u>	<u>Number of Sources</u>	<u>Key Words/Phrases</u>	<u>Example</u>
Not interested in "pure" math	8	not interested/not applicable and pure or abstract math	"Because it might suck. If somebody is in there talking to me about math the whole time and I can't follow, I'm like, man, this was such a bad idea..." "If it's pure math , it doesn't relate to anything in the real world...just very abstract ...I don't think it would hold my attention much." "If somebody said, 'well, come and we'll talk about math formulas ,' I would say, 'Oh yeah, thanks but no thanks. '"
Learning opportunity	7	learn learning opportunity	"I mean, one of the reasons I go is because I want to learn about things I don't know anything about." "I feel that I should learn more about math." "I do like those topics as a learning opportunity , and they bend towards math..."
Curious in presentation (not subject matter)	2	interested/curious and presentation	"It would be interesting to see how a mathematical talk would be presented. "

Factors affecting interest in math-related topics			
<i>Can you tell me more about your specific interest in {insert topic(s)}? It looks like you aren't particularly interested in {insert topics(s)}. Can you tell me more about why that is not a topic of particular interest to you?</i>			
<u>Code</u>	<u>Number of Sources</u>	<u>Key Words/Phrases</u>	<u>Example</u>
Unexpectedness	6	Surprise didn't know [implied] new/novel	"I think people would be surprised or shocked that we can't measure the area of a circle with exactitude." "And you're like, oh cool, I was doing it the long way , you know, like long division, like I was born in 1902." "How somebody is using this new idea in math to do something else."
Relevancy	7	relevant/relatable related to career [implied] no longer needed [implied]	"So, relevance for my life." "And then for public health that's what I do for a living ." "For me, personally, it's a little bit of ' been there, done that .'"
Value	7	important good [to know] people [should know...]	"So it's very important to me." "Improving math skills I just think that's really good for everybody, including me." "I think people seem to have this idea that math and science are separate from the arts...so I'd like to see that undone."
Learning opportunity	3	learn/understand explain/teach opportunity [implied]	"I think that maybe through the art, I could come to understand math a little bit better." "I would love for somebody to explain entropy to me in a way that I can understand." "A good mathematician who can actually speak at a lay level...I think that's kind of neat."
Self-confidence in ability	4	below my level [implied] above my level [implied]	"Helping people with everyday math concepts may not appeal to me because I feel like I probably would be able to understand most of it anyway ." "It'd probably be beyond my ability to really get a lot out of it."

Other math topics of interest			
<i>Are there any math-related topics that I didn't list that would be of particular interest to you?</i>			
<u>Code</u>	<u>Number of Sources</u>	<u>Key Words/Phrases</u>	<u>Example</u>
Math and social/public issues	7	females/women/girls (4) education/teaching (2) statistics (1)	"I think number one interest would be girls in math.." "Some high quality research on what the best approach is for math education ."
Applications of math	3	earthquakes (1) harmonics (1) architecture/buildings (1)	"I would love to know the math that goes into buildings ."
Pure or abstract math	4	proof theory (1) fractals (1) unexpected math [implied] (1) irrational numbers (1)	"Answers that might pop up that you wouldn't initially expect ."