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Making Waves: An Exploration In Learning Through Art, Science, And Making

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Abstract
For nearly one hundred years, from progressive education to critical pedagogy, philosophers, researchers, and educators have advocated for listening, respecting, and providing space for the learner's voice within education. When teaching challenging science content, it is vital to provide both a context for the knowledge and a reason for learning the content. It can be difficult to provide a learning environment that allows learners to gain an understanding of demanding content while being able to have creative self-expression—agency—without turning youth culture into a static banal concept. This study aimed to tackle the challenge of providing context, a reason for learning, and space for youth voice for a diverse group of teenagers. I explored how a multidisciplinary art and science maker workshop focused on sound encouraged a diverse set of young people to understand sound as energy and creatively express themselves. As part of outreach programming for a large, northeastern science museum in the United States, ten rising sophomores participated in a workshop where they created original sound pieces and built homemade speakers as part of an art exhibit. This mixed-methods early stage/exploratory study found youth exerting their agency through the sound pieces, homemade speakers, and artist statements. There is also evidence of youth gaining understanding of the science of sound. In the discussion, I address how these findings begin to push against two criticisms of the maker movement: what artifacts count as maker projects, and who is considered to be a maker. I go on to examine how, for some youth, learning the science of sound through a multidisciplinary workshop led to having a purpose for understanding challenging science content.

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MAKING WAVES: AN EXPLORATION IN LEARNING THROUGH ART, SCIENCE, AND MAKING

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ABSTRACT

MAKING WAVES: AN EXPLORATION IN LEARNING THROUGH ART, SCIENCE, AND MAKING

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For nearly one hundred years, from progressive education to critical pedagogy, philosophers, researchers, and educators have advocated for listening, respecting, and providing space for the learner's voice within education. When teaching challenging science content, it is vital to provide both a context for the knowledge and a reason for learning the content. It can be difficult to provide a learning environment that allows learners to gain an understanding of demanding content while being able to have creative self-expression—agency—without turning youth culture into a static banal concept. This study aimed to tackle the challenge of providing context, a reason for learning, and space for youth voice for a diverse group of teenagers. I explored how a multidisciplinary art and science maker workshop focused on sound encouraged a diverse set of young people to understand sound as energy and creatively express themselves. As part of outreach programming for a large, northeastern science museum in the United States, ten rising sophomores participated in a workshop where they created original sound pieces and built homemade speakers as part of an art exhibit. This mixed-methods early stage/exploratory study found youth exerting their agency through the sound pieces,

homemade speakers, and artist statements. There is also evidence of youth gaining understanding of the science of sound. In the discussion, I address how these findings begin to push against two criticisms of the maker movement: what artifacts count as maker projects, and who is considered to be a maker. I go on to examine how, for some youth, learning the science of sound through a multidisciplinary workshop led to having a purpose for understanding challenging science content.

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Chapter 1: Introduction

Educational philosophers, theorists, and researchers have time and again called for teaching that connects to learners' lived experiences, allows for agency, and respects the learner (Dewey, 1938/1963; Esach & Schwartz, 2006; Papert, 1980; Sieler, 2000). As these recommendations have been made for almost one hundred years, it is clear that it is not easy to achieve such a learning environment. This study explores a novel approach to connecting learning to youth's lives, creating space for agency, and improving science knowledge, all through a multidisciplinary art and science maker workshop. In particular, this study synthesizes ideas of funds of knowledge (Moll, Amanti, Neff, & Gonzales 1992) and constructionism (Papert, 1980) along with self-expression through art, in a project on sound. I chose sound as it is easily relatable to individuals' lived experiences and is also a challenging science concept to understand (Asoko, Leach, & Scott, 1991; Esach & Schwartz, 2006; Houle & Barnett, 2008; Linder, 1992; Pejuan, Bohigas, Jaen, & Periago, 2012; Wittmann, Steinberg, & Redish, 2003).

Many physics education researchers point to the need to contextualize sound to help students understand this concept (e.g., Esach & Schwartz, 2006; Hernandez, Couso, & Pinto, 2012; Linder, 1992). There are several prominent ways to create context in a learning environment. Progressives and critical pedagogues alike have advocated for allowing learners to have voice in their education (Dewey, 1900/1956; Moll, Amanti, & Neff, & Gonzales 1992). When youth feel respected for their existing knowledge and

skills, they engage and grapple with challenging science content (Basu & Barton, 2007; Basu, Barton, Clairmont, & Locke 2009; Seiler, 2001). Another proven way to create context is through incorporating making in a learning environment. Making comes out of Papert's theory of constructionism (1980) which suggests that individuals learn best through the production of artifacts, digital or physical, while conversing about these experiences. Making provides context by giving students a purpose to learn vital information in order to complete their artifact (Fields, Kafai, & Searle, 2012; Kafai et al., 2013b).

Along with providing context for learning, it is important to respect the learner. Respecting the learner means the educator has to honor the diverse experiences that students bring into the learning environment. However, this comprehensive respect can be challenging. For example, studies that focus on individuals' funds of knowledge tend to only privilege a few persons' experiences (Hammond, 2001) instead of the broad array of individuals in the learning environment. It can also be challenging to create a learning experience that does not assume a static notion of youth culture in an attempt to create a connection to youth (Ares, 2006). One approach to combat these issues could include multidisciplinary STEAM (science, technology, engineering, art, and math) projects. Incorporating art into a learning experience could potentially allow for the expression of a diverse set of experiences and knowledge. Expression through the creation of artifacts has been successful in bringing youth voice into learning environments (Barton et al., 2013; Barton & Tan, 2009; Gonsalves, Rahm, & Carvalho, 2013). Creative self-

expression using the knowledge and practices of a particular context which helps individuals develop their identities and perhaps advance their positions in the world is agency (Barton & Tan, 2010; Basu, Barton, Claremont, & Locke 2009; Hoechsmann & Poyantz, 2012; Sheridan, Clark, & Williams, 2013). Along with engaging youth agency, incorporating the production of art into a learning experience allows making to become a part of the learning environment. Making of a physical object is inherently multidisciplinary (Blikstein, 2013) requiring engineering, design, mathematics, and more to complete a project. When making is combined with art this often results in increased engagement with the learning experience (Kafai et al., 2013a).

This study investigates how an art and science making workshop helps youth gain in science knowledge and have agency over the learning experience. In particular, this study explores an electronic crafting project focused on sound. Youth built their own functioning speaker and created their own sound recording as part of a collaborative art installation. Through conversations, writing, and making, youth explored both the science of sound and how sound artists create environments through sound. The following research questions underpin this study:

1. In what ways were a diverse set of youth able to express their agency within this making learning environment?
2. In what ways did youth improve in their understanding of sound through creating a sound piece and speaker?

Chapter 2: Literature Review

The literature review will begin with a brief explanation of Dewey's notion of experiential learning and Moll's concept of funds of knowledge will follow. Both point to the importance of connecting learning to learners' lived experiences and giving room for agency. I will make an argument for integrating arts into STEM (science, technology, engineering, and math) education as a means for including agency, a key aspect of funds of knowledge studies. Including art in STEM allows making to become part of the learning environment. An explanation of constructionism will follow, which emphasizes ownership and intention in the learning processes and is one of the major theoretical foundations of making. A review of several electronic crafting studies and an investigation into two primary critiques of the maker movement ensue. The literature review will close with an exploration of the common challenges to learning sound, as well as recommendations for improving instruction.

In the following section I will briefly delve into Dewey's experiential learning and Moll's funds of knowledge in order to emphasize the importance of creating a connection to learning and helping to encourage youth agency.

Creating Relevance in Learning Through Connecting to Students Lived Experiences

Dewey was an advocate for intentional experiential learning. An intentional learning experience, according to Dewey (1938/1963), is a student's experience that a

teacher crafts to provide an authentic moment of learning. To be an educative experience, it must lead to gains in knowledge and understanding (Dewey, 1938/1963). For Dewey (1900/1956), education is about more than preparing for the future; it is about being engaged in the present. To obtain this level of engagement, a child must experience all of the following: conversation, inquiry, making things, and artistic expression (Dewey, 1900/1956). Furthermore, learning and progress take place when the ideas of the present build upon the ideas of the past. Since learning builds on past experiences, knowledge is accumulated over time through intentional learning moments, which are found both within and through the society in which one lives. Dewey (1938/1963) notes, "[W]e live from birth to death in a world of persons and things which in large measure is what it is because of what has been done and transmitted from previous human activities" (p. 39). Knowledge is transmitted from individual to individual through intentional, authentic experiences. Likewise, learning builds and grows out of the information and knowledge held not only within the individual but also within the larger community.

Dewey emphasizes the importance of having due regard for students and where they are coming from. This is what Moll et al. (1992) call funds of knowledge. In defining funds of knowledge, Moll et al. (1992) state that the notion of funds of knowledge pertains to the specific "social, economic, and productive activities of people in a local region" (p. 139). Acknowledging the resources and information that families and communities have does not mean that schools should be teaching these same skills and knowledge. Instead, "…student experience is legitimated as valid, and classroom

practice can build on the familiar knowledge bases that students can manipulate to enhance learning in…other content areas" (Gonzalez, 2005, p. 43). The instructor's role is to create a bridge between the information and skills that learners already have from being part of a community and family, and the institutional knowledge they need to gain (Moll et al., 1992).

Funds of knowledge are the wealth of information and skills that individuals pick up from their day-to-day experiences. The information and skills could include, among other things, how to sew a quilt, how to find the healthy snacks at the corner store, how to cook a meal with vegetables from a household's kitchen garden, or how to walk safely from home to school. Knowledge and skills gained from the community are learned, in context, from individuals one trusts (Moll et al., 1992). Utilizing this resource enables learners to engage deeply with the experience and have agency in the learning. Learning then takes place in context of prior knowledge and experiences, instead of remaining abstract and detached.

The creation of bridges from learners' funds of knowledge to institutional knowledge is often achieved by listening, hearing, and respecting the individual (Basu & Barton, 2007; Gonsalves et al., 2013; Hammond, 2001; Seiler, 2001), leading to a new space of shared respect and understanding. Openness is also necessary while making room for the learner to have ownership—whether the learner helps to create curriculum (Basu et al., 2009; Barton and Tan, 2009; DeGennaro & Brown, 2009); or plays an active role in the learning processes (Barton et al., 2013; Hammond, 2001). By creating an

artifact, be it a house (Hammond, 2001) or a video (Barton et al., 2013), the learner's active role in the learning process helps to construct the bridge.

These bridges can lead to increases in students' learning in science. Some researchers have argued that urban youth fail to perform well in science because no bridge is built between learners' funds of knowledge and scientific knowledge (Bouillion & Gomez, 2001; Brickhouse, 1994). However, many researchers have found that if one is able to tap into youth's funds of knowledge, youth increase their conceptual understanding of science (Basu & Barton, 2007; Basu, Barton, Clairmont, & Locke 2009; Seiler, 2001) and may even develop a sustained interest in science (Basu & Barton, 2007).

While these studies on funds of knowledge show highly interesting accomplishments, and suggest the importance of lived experience for learning, they all tend to privilege only a few individuals' funds of knowledge. For example, a teacher invites just a few students to participate in curriculum creation instead of asking all of the students to help (Barton & Tan, 2009), or works with one minority community instead of engaging all of the various community groups at a school (Hammond, 2001). Furthermore, Barton and Tan (2009) point to the need to "…identify more teaching practices and pedagogies that foster the creation of hybrid spaces that are more practical and can be carried out on a more frequent basis" (p. 71) than are currently employed.

When creating curriculum that attempts to connect to youth, it is vital to avoid boiling down "youth culture" to a hackneyed idea (Ares, 2006). For example, a

curriculum that relates to Pokémon, a popular card game, does not mean that teaching through Pokémon creates a connection to all youth's lived experiences, nor that the game will continue to be significant to youth in the next implementation of that curriculum. This raises the question: How do educators create a place where all participants have a chance to express their own knowledge, expertise, and agency without reducing the learner's funds of knowledge to a meaningless, trite notion (Ares, 2006)? This question has important ramifications, not least of these being that a flexible, pluralistic approach to what constitutes knowledge provides the validity of youth's funds of knowledge. One solution may be through including self-expression. Self-expression does not require the teacher to recreate the curriculum each year due to a new population of learners (Basu & Barton 2010; DeGennaro & Brown, 2009), nor does it take on a prescriptive notion of youth culture (Ares, 2006). Importantly, instead of just privileging a few individuals' funds of knowledge, making self-expression part of the learning environment allows *all* individuals an opportunity to bring their own knowledge into the learning environment.

The following section will focus on art as a form of expression that is centered on the individual. By adding a dimension of art to science, technology, engineering, and math—turning STEM into STEAM—it may be possible, in such truly multidisciplinary projects, to create learning environments that give voice and privilege to youths' funds of knowledge, while also providing space for youth to co-create the experience and learn. For, if art is a form of expression, it is able to give voice and agency to the maker in its creation. Art may be able to provide context and connection for learning.

Artistic Expression as a Form of Youth Agency

In funds of knowledge studies, expression has proven to be an important way to connect to one's experience, for example, through the co-creation of lesson plans (Barton & Tan, 2009), through the creation of a collage (Gonsalves et al., 2013), or through the making of a video on green energy (Barton et al., 2013). Art as a form of communication (Dewey, 1900/1956) is a way to increase room for expression in the classroom for all students. Art, as used in this study, does not simply involve traditional practices such as life drawing or watercolor painting, practices which might be judged in terms of the learners' ability to draw or paint. Instead this study views art as universal practices of elemental creativity which, arguably, everyone has though may not always use. Art is not purely the craft of drawing a picture or the skill of building a sculpture. Art is the practice of creativity which, as understood in this study, means noticing problems and finding unique and unexpected solutions that are manifest in an artifact (Finke, Ward, & Smith, 1992; Kelly, 2001; Sawyer, 2012; Tardif & Sternberg, 1988).

There are multiple ways of learning with the arts: *in, about,* and *through*. Learning *in* the arts refers to acquiring particular techniques, such as how to paint with watercolors (Upitis, 2011). Learning *about* the arts refers to learning about various domains of art, such as cubism, modernism, or the history of tango (Upitis, 2011). Learning *through* the arts uses the arts as an entry point for other subject matter; for example, learning about plant morphology through a drawing class (Halverson, 2013; Peppler, 2010; Upitis, 2011). All of these forms of learning with the arts – *in, about,* and

through – are valuable. In this study, I am interested in learning *through* artistic production.

In viewing art as a form of self-expression, it is important to view it like other forms of communication that improve with critique and reworking. Fleming (2008) explains that one pitfall of perceiving art as only expression is that it can lead to a challenging place where there is no room for critique of the creation. The result is a very shallow learning of art (Fleming, 2008). However, to view art as a form of expression, one need not reduce it totally to *self*-expression, which can be so defensively personal that it opposes all critique. To the extent that personal expression is aimed at communication, it is open to critique. Art, as understood in this study, is a form of communication centered on the individual, and in this sense an expression of the individual. Art as an expression of the individual means the artists are referencing personal, or internal, ideas or notions in their work, rather than established knowledge (Milbrant & Milbrant, 2011). Just as writing an essay takes work, time, and critique in order to become the best it can be, so the creation of a piece of art needs to go through similar processes of critique and revision. If artwork is to be an expression of the self in the interest of communicating the individual's funds of knowledge, then it is vital to afford art equal value and respect with other elements in the learning process.

If art is an expression of the individual, then it can be a means for allowing youth agency into a learning environment. Agency as understood in this study is creative self-expression achieved through using the knowledge and practices of a particular context

which helps individuals develop their identities and perhaps advance their positions in the world (Barton & Tan, 2010; Basu, Barton, Claremont, & Locke 2009; Hoechsmann & Poyantz, 2012; Sheridan, Clark, & Williams, 2013). Focusing on agency within a learning environment highlights how learning is "…a complex social activity" (Arnold & Clarke, 2014, p. 736). This is not a surprising statement, as funds of knowledge studies emphasize the complexity of learning in terms of where knowledge comes from and whose knowledge is privileged. In looking at art as means for youth agency, the question is raised if art gives all learners a space for creative self-expression and a way to bring in their own ideas into the learning environment, thus creating a connection for learning. Many have touted the creation of a connection to one's lived experience as an important step to teaching challenging content (Basu & Barton, 2010; Esach & Schwartz, 2006; Hernandez, Couso, & Pinto, 2012; Linder, 1992; Seiler, 2001). However, it is also important to have intention or a purpose for learning the material at hand. Making can provide intention for learning (Peppler & Glosson, 2013).

The following section focuses on making which is anchored in constructionism and provides several examples of making that have led to an increase in knowledge, engagement, and purpose for learning science content. For these reasons, this study focuses on making as an important aspect of the learning environment on sound. This section ends with a discussion of two of the primary critics against the maker movement and how I hope to begin to combat these critiques.

Providing a Purpose for Learning through Making

Learning takes place through the processes of making and discussing the creation of things which are digital or physical (Papert, 1980; Harel & Papert,1990). The construction of digital or physical objects, and discussions that occur around them, have fueled the theory of constructionism, where the two main goals are "developing new kinds of activities in which children can exercise their doing/learning/thinking" and an "...emphasis on project [activities] which [are] self-directed by the student within a cultural/social context that offers support and help in particularly unobtrusive ways." (Harel & Papert, 1990, p. 2). It is through agency over the project, produced within a certain context and with support, that a student learns. Learning happens in the physical creation of artifacts that take into account the "cultural/social" (Harel & Papert, 1990, p. 2) context of the learner.

It is the making, together with reflecting, that is important to learning. For the best results, Papert argues that one must not only do or create something in order to learn, but one must also participate in conversations about the experience (Harel & Papert, 1990). According to Papert, one learns best through thinking, listening, and making something. Since Papert first expressed his theory of constructionism there have been a multitude of studies exploring making and its affordances for learning. Researchers have found, for example, that making in education results in students feeling a greater reason for learning in order to complete the project at hand (Resnick, Berg, & Eisenberg, 2000). Other studies have noted that involvement in design and creation can lead to a deep connection

to learning (Bennett & Monahan, 2013). In addition to the making, the processes of getting stuck and unstuck while completing one's final product can lead to a rich learning experience (Petrich, Wilkinson, & Bevan, 2013).

Electronic crafts intersect multiple disciplines. There are many different examples of making, ranging from the fabrication labs that are popping up in schools across the country (Blikstein, 2013) to building electronic puppets (Peer, Nitsche, & Schaffer, 2014) to tinkering at a science museum (Petrich, Wilkenson, & Bevan, 2013). This study focuses on the making of electronic crafts to examine if the production of art is able to build bridges between learners' funds of knowledge through youth agency while providing purpose for learning STEM content. An electronic craft is a project that combines electronic parts such as LED lights, sensors, or other such high-technology pieces with low-technology crafting skills.

Electronic crafts have the unusual distinctions of bridging disciplines (e.g., Kafai & Peppler, 2014) while teaching physical science (e.g., Peppler & Glosson, 2013), and building connections between home knowledge and institutional knowledge (e.g., Fields & Lee, 2014) while lying at the intersection of engineering and art (Peppler, 2013). Electronic crafts have the ability to be truly multidisciplinary projects with the potential to connect with each learner's funds of knowledge by allowing for expression through agency and providing a purpose for engaging in learning STEM content knowledge. For all of these reasons, my workshop uses a multidisciplinary electronic crafting project as the maker aspect of my curriculum.

STEAM learning through electronic crafts. The next several paragraphs explore existing research on learning through electronic textiles, a kind of electronic craft along four dimensions. I'll begin with a discussion on the importance of artistic vision for student engagement, followed by an investigation on how the concrete creation of electronic textiles encourages learning. This section will continue by looking at how artistic design allows for all students to express their funds of knowledge. Finally, the closing paragraph explains how these STEAM projects have been able to overcome some of the challenges characteristic of research that deploys funds of knowledge.

Artistic vision encourages engagement and pride resulting in STEM learning. Including the arts increases engagement and contributes to motivation to learn scientific content knowledge. Giving room for making in a learning environment encourages youth to think creatively and bring new ideas into the space (Lasky & Yoon, 2011). In these new ideas, there is often a tension between the individuals' artistic design and required technical function which can stretch youth to grapple with both their artistic desires and their technical knowledge. This tension can result in a failed first attempt at a project. However, failure to create a functioning piece, accompanied by time for the learner to redesign and create a working project, is a rich learning experience (Fields, Kafai, & Searle, 2012). Failure and redesign resulted in youth learning complex coding (Fields et al., 2012) and electrical engineering concepts (Peppler, Sharpe, and Glosson, 2013). The inner imperative for self-expression results in a need to learn more advanced STEM content knowledge in order to have the art piece be the way the individual has

envisioned, creating a strong connection between the artistic creation and the STEM learning (Fields et al., 2012; Kafai et al., 2014a, Peppler et al., 2013). Youth exhibited increased motivation to learn challenging concepts "just in time" (Gee, 2003). The desire to complete one's artistic vision along with the space to fail and try again not only led to learning STEM concepts, but often resulted in more sophisticated projects than the researchers had first expected the youth to be able to complete (Kafai, Fields, & Searle, 2014a).

Working with concrete materials facilitates STEM learning. Not only does the final artistic vision push individuals to learn, but the actual making forces youth to tackle challenging concepts. Peppler and Glosson (2013) found that youth (ages 7-12) who engaged in creating projects with electronic textiles made significant gains in their ability to diagram a circuit while increasing their understanding of current flow, polarity, and connections. Peppler and Glosson (2013) claim that this gain in knowledge is due in part to constructing with persnickety materials. The delicate nature of the materials requires learners to understand more fully how circuits work to ensure that their projects succeed. For example, in order to make a path that electricity can flow through, they must pay attention to avoid crossing threads so as not to short the circuits. This level of detail is not needed when using insulated alligator clip wires for creating circuits.

The physical production of the projects allows learners to "literally *see* the connections between physical actions, visual patterns, and relevant theories from physics, electrical engineering, and computing" (Buechley, Peppler, Eisenberg, & Kafai, 2013, p.

2). It is through the production of the object, including figuring out how to work successfully with the finicky materials, that individuals learn. The creative production forces youth to make connections and understand the theoretical concepts being taught in order to successfully complete their project. By having a project that youth are invested in finishing, and that depends upon the correct handling of delicate materials, learners are, in a sense, forced to grasp challenging scientific concepts so they can complete a functional project.

STEAM privileges all students' funds of knowledge. The arts construct a bridge between the learner's funds of knowledge and STEM learning. For example, in a college-level course on making, with a focus on circuitry, coding, and crafting, one of the projects was to create a quilt that included electronic textiles. Through such projects, the class became a "space where…[students'] out-of-school experiences were legitimized and valued" (Fields & Lee, 2014, p. 11). Knowledge that is often not valued within academic settings, such as the craft skills needed to sew a quilt, suddenly had a place of high regard (Fields & Lee, 2014). Artistic skills of quilting were valued, placing a traditional home craft into an academic setting. Respecting individuals' funds of knowledge provided the learners space to feel like experts, and encouraged them to spend time engaging with the technological aspects of the project (Fields & Lee, 2014). Art created space for students' funds of knowledge.

In a study looking at Native American youth's indigenous funds of knowledge and electronic textiles, researchers hoped that youth would take the opportunity to pull

from their indigenous cultural knowledge in the creation of their projects. The Native American youth used complex stitching and sophisticated designs to hide the lights and microcomputer behind pieces of felt, tapping into the craft knowledge of their community -- but not necessarily into the historic cultural knowledge of the community (Kafai, Searle, Martinez, & Brayboy, 2014b). The authors of this study make the important point that "culture is not static; its dynamic nature allows that the integration of electronic technology and popular culture need not necessarily be at odds with the culture of one's ancestors" (Kafai et al., 2014b, p. 245). It was through the artistic design of the projects that youth had the opportunity to show self-expression, voice, and agency in the project by tapping into their funds of knowledge. The youth created connections to STEM by learning computing and electrical engineering and getting to express their culture. In and through the production of art, funds of knowledge are given a space of legitimacy within the traditional classroom, creating an entry point and motivation for learning challenging STEM content.

Electronic textile STEAM studies overcome challenges found in funds of knowledge studies. The key advancement over the earlier examples of funds of knowledge endeavors highlighted in this study is that these STEAM studies allow *all* learners a voice, unlike the privileged few in the former. For the youth, the inclusion of the arts, as an academic discipline valued equally with science, opens the possibility for self-expression, which in turn helps to create a bridge from the student's funds of knowledge, through agency, to STEM knowledge. Electronic crafts, if done well, have

the potential to be a readily practical option for an educator to create context and purpose for learning. No doubt there are other projects that could be similarly effective. For the purposes of this study, however, it is the epistemological shift to a disciplinary pluralism that intermingles art with science and technology. This shift seems to point the way to one very viable approach to utilize the resources of funds of knowledge and include making in a learning environment by privileging youth agency. However, to ensure that all youth learn, it is vital to respect the knowledge and experiences youth bring with them into the learning environment (and not to assume a deficit), and to remain open to a range of creative products.

In the next section I explore critiques of making in terms of who is a privileged to be a maker and what projects are viewed as maker projects.

Critique of making – who is entitled to be a maker and what is privileged to be a maker object. In a critique of *Make* magazine, the branded popular media voice of the maker movement, Buechely (2013) found that over 80 percent of the magazine covers featured white boys and men. *Make* magazine has a particular idea of who is considered an exemplar maker. Beyond the popular media, there is a larger view of makers as middle-class individuals who have leisure time and money to spend on creating things (Buechely, 2013; Rose, 2014). Yet, creating things by hand is a necessity for a large portion of the population, as Rose (2014) points out:

> Working-class folk have not had the luxury of discovering making and tinkering; they've been doing it all their lives to survive—and creating exchange networks to facilitate it. Somebody across the street or down

> the road is a mechanic, or is wise about home remedies, or does tile work, and you can swap your own skills and services for that expertise (p. xxv).

Rose is not the first to notice that when the middle class "discovers" practices of the working class this can result in an erasure of the working-class within that space. In a feminist critique of the Do-It-Yourself (DIY) movement Dawkins (2011) points out a similar class and race bias towards who is considered a "crafter." In both of these instances, with the middle class "uncovering" creation through their own labor, the working class and non-whites are frequently ignored as participants in the movement.

The concept that working with ones' hands as a rich learning experience is nothing new. Learning through doing was a centerpiece of progressive education, and during the Arts and Crafts movement of the 19th century there was a similar push to make personal objects, as seen in the maker movement of today (Rose, 2014; Vossoughi et al., 2016). Even though creating artifacts is not new and has been a rich part of working-class culture for a long time, the education community has a tendency to view "…working-class communities of color…as targets of intervention rather than as sources of deep knowledge, and skill…" while dominant communities are seen as having "something to teach or offer rather than something to learn" (Vossoughi et al., 2016, p. 212). Within the maker research community little is known about how non-dominant youth interact and experience maker activities and maker spaces (Barton, Tan, & Greenberg, 2016). This speaks to a need to create maker learning environments that give voice to all learners and respects the knowledge and skills they all bring with them.

Along with analyzing who was on the covers of *Make,* Buechely (2013) found three main areas of projects on the covers: robots, electronics, and vehicles. This focus on tech-forward projects eliminates a wide variety of artifacts that still incorporate STEM concepts, skills, and knowledge, are created by youth, but could be art-focused instead of tech-focused. Making is more than flashy tools or particular projects (Vossoughi & Bevan, 2014). The rich learning through arts is often ignored even though studio art classes promote learning by doing and creating artifacts (Halverson & Sheridan, 2014) and many maker spaces are set up using similar pedagogy practices to those found within the studio arts (Vossoughi & Bevan, 2014). Yet there have been few studies that explore the arts side of making (Halverson & Sheridan, 2014). My study speaks to a need to embrace the multidisciplinary nature of making that values *all* of the disciplines involved, not just the technology used to create a product; along with the need to respect *all* of the learners' knowledge and experiences, no matter their class or race, through providing space for agency within the learning environment.

In the following section I will highlight common challenges to learning about the science of sound and recommendations from physics educators for improving instruction.

Common Challenges in Understanding the Science of Sound

By studying sound, scientists have gained insight into how whales communicate (Parks, Clark, & Tyack, 2007), how urban centers affect animal populations (Slabbekoorn & den Boer-Visser, 2006), how to more accurately map the subsurface of the earth (Claerbout, 1971), and more. Yet sound which is constantly part of our lived

experience is a difficult concept to understand (Asoko, Leach, & Scott, 1991; Esach & Schwartz, 2006; Houle & Barnett, 2008; Linder, 1992; Pejuan, Bohigas, Jaen, & Periago, 2012; Wittmann, Steinberg, & Redish, 2003) and is often poorly taught (Hreptic, Zollman, & Rebello, 2010).

Sound is energy; or, as stated slightly differently, "sound is conceived as the event produced by the vibrations of an object called the sound source. These vibrations are propagated through an elastic medium which gradually transmits its state of compression or dilation, without transport of matter" (Hernandez, Couso, & Pinto, 2012, p. 703). Imagine the sound event as a drum being hit by a mallet. As the mallet hits the surface of the drum, the surface vibrates. This vibration causes air molecules to collide creating a zone of dense air (compression). Where the air molecules were before the vibration is now less dense (rarefication). This "layer cake" effect of dense and less dense air ripples through the medium. It is this movement through the elastic medium, in this case, air, that is transferred outward. The individual air molecules stay more or less in the same place, but the mechanical energy of the vibration continues to move concentrically away from the sound source. Only when one's ear interprets these layer cakes of dense and less dense air can one hear the drum beat. Figure 1 is an illustration of this phenomenon. It is important to understand that mechanical energy is pulsing through the medium and the particles, besides getting slightly jostled, are *not* moving through the medium.

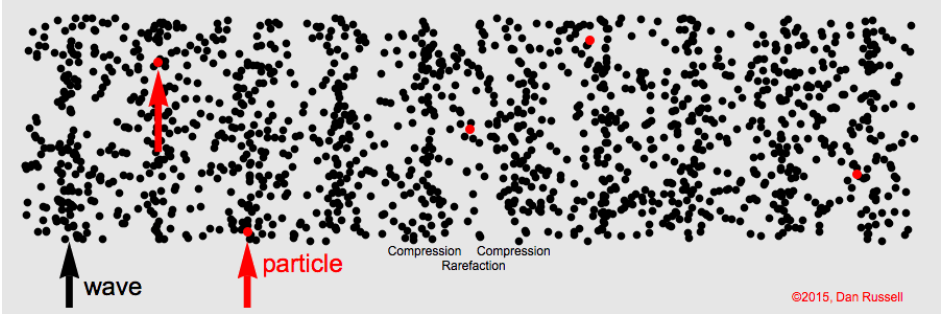

Figure 1 Illustration of layer cake of dense and less dense zones of a medium as sound energy moves through the medium. The wave is the movement of energy.

Sound is a process of energy transfer (Lawrence, 2008) and as such is an abstract concept. Comprehending sound as energy is very challenging. Many individuals hold the common misconception or preconception that sound is a physical object being moved through space. This is true for elementary students (Mazens & Lautrey, 2003), for middle school students (Houle & Barnett, 2008), for secondary students (Eshach & Schwartz, 2006) and for undergraduate physics students (Hreptic, Zollman, & Rebello, 2010).

Typical methods for teaching about sound involve explaining the macroscopic functions of mechanical waves (frequency, amplitude, etc.) and a microscopic description of how molecules move when vibrations of sound energy pass through (Hernandez, Couso, & Pinto, 2011). This is a very theoretical and abstract approach to teaching and learning. Previous examples of curriculum that have attempted to create context for learning sound include connecting to the human body through a unit focused on auditory health (West & Wallin, 2013), and focusing on the local natural environment through a unit that explored how birds' songs change in an urban environment, compared to a more natural environment (Houle & Barnett, 2008).

West and Wallin (2013) implemented their curriculum through written assignments, experiments, group work, and discussions. The discussions included students figuring out how to draw the transmission of sound. West and Wallin (2013) provided little space for youth agency within their curriculum, but did find an increase in understanding of sound as energy after their intervention. Houle and Barnett (2008) used their unit to challenge their students to "explore how birds living in the city adapt their communication systems to deal with urban noise" (p. 243). Students posed research questions, and collected and analyzed data using sound visualization software and sound recordings. Houle and Barnett (2008) created the potential for youth to express their own agency by having them create their own experiments. However, as this study did not explore agency, it's unclear if students felt they could express it. Unlike West and Wallin (2013), Houle and Barnett (2008) found no significant gain in students' understanding of sound. They attribute this non-gain in knowledge, in part, to the robust preconceptions students have with regard to sound.

There have been several recommendations concerning how to improve youth's understanding of sound. West and Wallin (2013) found that classes that used formative assessments had students who performed better in overall understanding of sound compared to classes that did not utilize formative assessments. In the classes that implemented formative assessments, the teachers either gave encouraging feedback to students, or carefully adjusted the next day's instructions based on students' understanding of sound. Eshach and Schwartz (2006) suggest the perception that sound

waves behave the same as water waves could be due, in part, to the colloquial understanding of the term "wave," as associated with water that appears to have a sinusoidal action. A sound wave is a mechanical compression wave and does not travel the same way as an ocean surface wave. Along with cautioning against confusion over the word "wave," Hrepic, Zollmand, and Rebello (2010) recommend saying "propagate" rather than "travel" or "loudness" rather than "volume" to proactively avoid possible misunderstandings. Other researchers have pointed out how common demonstrations, such as using a Slinky to show wave propagation, can confuse rather than enlighten the learner on how waves move (Houle & Barnett, 2008; Linder, 1992). Leite and Afonso (2001) note that most textbook illustrations of sound movement support common misconceptions instead of refuting them.

Along with these more detailed recommendations, many physics education researchers have pointed out the need to connect learners' lives to learning about sound, therefore creating context for learning (e.g., Esach & Schwartz, 2006; Hernandez, Couso, & Pinto, 2012; Linder, 1992). It is unclear from previous studies if youth felt a connection to the learning, or reason for learning, about sound— a key idea for improving learning about sound (Esach & Schwartz, 2006; Hernandez, Couso, & Pinto, 2012; Linder, 1992). My hope is that, in this multidisciplinary science and art workshop, youth will gain in knowledge and find a connection and purpose to learning about sound.

Chapter Summary

Progressive educators and cultural pedagogues advocate for respecting the knowledge and skills learners bring with them and giving agency to learners (Barton & Tan, 2010; Dewey, 1938/1963; Moll et al., 1992). While these ideas are well established, it can be challenging to create such a learning environments. For example, just trying to provide a connection to learning particular content can be hard to do (Seiler, 2001). Providing context and a purpose to learning content has been suggested by many as a way to help learners understand the science of sound, a particularly challenging science concept (Asoko, Leach, & Scott, 1991; Esach & Schwartz, 2006; Linder, 1992; Pejuan, Bohigas, Jaen, & Periago, 2012; Wittmann, Steinberg, & Redish, 2003). Funds of knowledge researchers have found that when youth are given a space for self-expression—agency—learners feel valued, and more engaged and interested in learning STEM content (Basu & Barton, 2007; Basu et al., 2009; Hammond, 2001). When trying to create a connection to the taught content, educators face the challenge of boiling down to pithy details the learner knowledge and skills (Ares, 2006). Including the production of art in a learning environment can give youth a means for creative self-expression. Maker activities through multidisciplinary projects can provide both a purpose for learning content (Field et al., 2012; Pepper & Glosson, 2013) and a way to value the skills youth have (Kafai et al., 2014b) while helping youth feel engaged in learning (Kafai et al., 2014a). Yet we as a research community know little about how non-white non-middle-class youth experience maker activities (Barton et al., 2016; Vossoughi et al., 2016).

There has been a tendency within the maker community to assume that white middle-class individuals have more knowledge and skills in terms of making compared to working-class non-white individuals (Buechley, 2013; Rose, 2014; Vossoughi et al., 2016).

My study presumes that a multidisciplinary art and science maker workshop, where youth learn about sound from both a science and art perspective while building their own functioning speakers, will give a diversity of youth both agency and a purpose for learning the science content. In the following section, I explain the conceptual framework underlying the design decisions I made in creating such a learning environment for *all* youth.

Conceptual Framework and Research Questions

This study aims to determine if youth are able to have agency and find relevance and intention for understanding challenging science content by participating in a multidisciplinary art and science maker workshop. Research on funds of knowledge, electronic crafts, and challenges to learning sound underpin the curriculum for this study, along with Dewey's experiential learning, Papert's learning theory of constructionism, and the view of art as means of self-expression. **Error! Reference source not found.** shows a visual of my conceptual framework, which gives making more space than self-expression and science. It is my hypothesis that the intersection of self-expression and science through making will allow youth to experience their agency while finding relevance for learning and understanding challenging concepts.

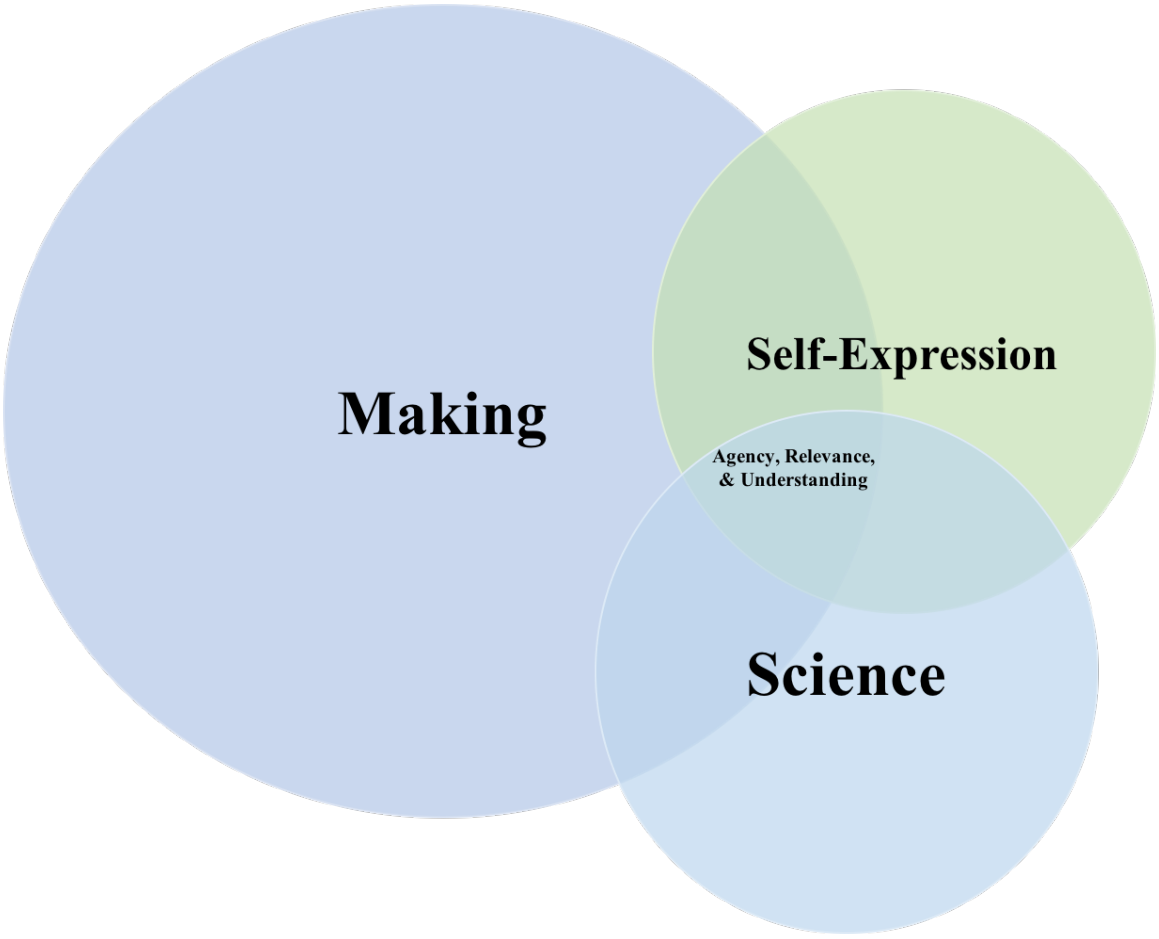

Figure 2 Conceptual framework diagram.

In the funds of knowledge literature, it has been pointed out that when learners are given room for self-expression, oftentimes through production of an artifact, they are able to bring in their own knowledge and feel respected (e.g., Barton & Tan, 2010; Hammond, 2001; Seiler, 2000). This maker workshop incorporates self-expression primarily through a sound art piece. Participants collect noises, both in the real world and from the internet,

and edit these into a piece of their own choosing. These sound pieces will be played through a handmade speaker. To help the sound piece communicate well with others, they will also be critiqued and reworked (Fleming, 2008). By providing an aspect of the project where the youth, with a few constraints, have control over the end result, I believe participants will be able express their agency without the project attempting to create a superficial connection to them (Ares, 2006). By providing a space for self-expression, my hope is that a diverse group of workshop attendees would be able to have agency in the learning experience, and a space that honors their knowledge and life experiences.

The science aspect of the project follows the recommendations of providing a reason for learning how sound propagates along with careful use of language and demonstrations (Esach & Schwartz, 2006; Hernandez, Couso, & Pinto, 2012; Linder, 1992). Formative assessment of student knowledge has been shown to improve student learning (West & Wallin, 2013); for this reason, each day ends with the participants filling out an exit ticket which includes, among other questions, "What did you learn today? Tell me in a sentence or two." Based on the individuals' responses to this question, the following session's activities will be adjusted. The time devoted to understanding how sound is mechanical energy will be greater than half an hour (Houle & Barnett, 2008).

The making aspect of the project includes times for discussion, as well as time for deconstruction and construction (Papert, 1980). Each participant will build a functioning speaker out of simple materials: wire, recycled plastic bottles, cardboard, magnets, and

electrical tape. As the sound pieces and speaker are part of an art installation, each artist will write an artist statement. The speaker will play the sound piece that the youth themselves created at the end of the workshop, during the art exhibit. Through framing the workshop's culmination in an art exhibit I hoped, to honor the multidisciplinary nature of the experience.

This study aims to answer the following questions:

1. In what ways are a diverse set of youth able to express their agency within this making learning environment?
2. In what ways do youth improve in their understanding of sound through creating a sound piece and speaker?

Chapter 3: Methodology

This chapter discusses the methodology I used to answer my research questions. I begin by explaining why I conducted a mixed-methods study. Following, I describe the site where my workshop took place along with the participants who attended my workshop. I explain the day-to-day activities I designed to teach about sound from both an artistic and scientific perspective. Finally, I delineate the data collection and data analysis performed to answer my research questions. In brief, I conducted a concurrent embedded design, mixed methods, Early-Stage/Exploratory research study (Creswell, 2009; IES, 2013).

Methodology

The *Common Guidelines for Educational Research and Development* (IES, 2013) has six stages of research, beginning with foundational research and ending with scale-up research. My study falls into stage two: Early-Stage/Exploratory research. The goal of this level of research is to examine "…important constructs in education and learning to establish logical connections that may form the basis for future interventions or strategies to improve education outcomes" (IES, 2013, p. 9). Exploratory research builds on existing research to explore the "development, modification, or evaluation of an intervention or strategy" (IES, 2013, p. 12). Since my workshop was a new intervention

using previously studied tools and theories, this study was an exploration of the proposed intervention to determine if it was a worthwhile learning experience for youth.

This study aimed to determine if youth were able to gain knowledge, and to explore if youth were able to have agency. I answered these two inquiries through the use of a mixed methods study. A major advantage of mixed methods is that multiple forms of data allow for a triangulation of results. Triangulation relates to having multiple kinds of data to better understand a particular phenomenon (Creswell, 2012), just as sailors use multiple points in the sky to locate where they are on a map.

In particular, this study followed a concurrent embedded design (Creswell, 2009) in which both qualitative and quantitative data are collected concurrently, but the overall study primarily uses one type of data. In this study, both research questions involve qualitative data, with only my second question using a small sample of quantitative data. Therefore, the quantitative measure is embedded within a larger qualitative study.

In the following section I describe the setting and participants.

Context and Participants

This study was part of the summer workshops for an outreach program conducted by a large science museum in the Northeastern United States. My decision to work with this outreach program was fueled by an interest in broadening the places being studied as part of the Maker Movement. The Maker Movement has been portrayed as democratizing access to science and engineering by providing tools, community, and knowledge to make things (Hatch, 2013). Few studies have looked closely at making by

underprivileged youth of color (Barton et al., 2016; Vossoughi & Bevan, 2016). In an effort to increase the scholarship on the broad range of makers, I chose the science museum's outreach program as a partner.

Teenagers from the metropolitan region volunteer to apply to be a part of this outreach program for their entire high school career. Each fall, it admits 15 promising freshmen who are passionate about various STEM fields, have a GPA of at least 3.5, and who come from "challenging socioeconomic backgrounds[1]." The program provides weekly STEM enrichment throughout the academic year, summer workshops that run Monday through Thursday in July and August, and, for junior and senior participants, help with ACT preparation and college applications. The larger program has participants from 14 different high schools and 23 different area codes, with the following racial makeup: 72% African-American, 12% Hispanic, 7% Caucasian, and 9% youth who identify as Other[2].

My workshop ran over four days in July of 2016. I worked with the rising sophomores who traditionally spend a week of their summer learning about sound. This allowed my workshop to easily slip into the curriculum plan of the larger program. Table 1 shows the demographic makeup of the youth who participated in my workshop. There

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[1] This is the language used in recruitment material for the outreach program.

[2] Data comes from the outreach programs website.

were ten participants: five male and five female who were all fifteen years old. No individual identified as White.

Table 1

Demographic data of workshop participants

Name (pseudonyms)	**Gender**	**Race/Ethnicity**
Alexander	Male	Mixed Race
Alice	Female	Black
Eliza	Female	Black
Haider	Male	Arab
Lucy	Female	Black
Mark	Male	Asian
Sam	Male	Asian
Talia	Female	Afghani
Tom	Male	Haitian/West Indian
Yarrow	Female	Black

Workshop Curriculum

Through four 3.5-hour sessions, youth learned about sound from a scientific and artistic perspective while making a functioning speaker. In honoring the multidisciplinary nature of making, I followed a hybrid pedagogy (Vossoughi & Bevan, 2013), picking and choosing the pedagogy that would best serve the content or skill being taught. I took

aspects from studio art teaching practices including demonstrations, critique, and open-ended projects (Hetland, Winner, Veenema, & Sheridan, 2007). A typical studio arts class involves a brief demonstration-lecture, in which the instructor provides information that is immediately useful to the students and then leaves them ample time to create. While the students work on the assignment, the teacher walks around providing as-needed instruction. Time is also set aside for reflection and discussion through critiques of student work.

Time for reflection is not only an important aspect of studio arts education, but an integral part of learning as understood from a constructionist perspective (Papert, 1980). The act of making things is a major aspect of constructionism, and so I also included parts of the engineering design cycle (Tayal, 2013) to help facilitate youth making. The engineering process includes time to brainstorm, design, analyze, build, test and iterate. In particular, my curriculum required that the participants draw a plan (Tayal, 2013) of their speaker before they could build it.

In terms of learning about the science of sound, I heeded the advice of physics education researchers (e.g., Houle & Barnett, 2008; Linder, 1992). For example, I included formative assessment (West & Wallin, 2013), ending each day with an exit ticket that asked, "In a sentence or two tell me what you learned today," and adjusted the next day's lesson (if necessary) based on the formative assessment. I included a dynamic visualization instead of the more traditional Slinky demonstration for how sound travels. The Slinky demo has been shown to confuse instead of illuminate understanding (Houle

& Barnett, 2008; Linder, 1992). I chose to use an animation of how sound travels through a medium, as animations have been shown to improve youth understanding of science concepts (Hoffler & Leutner, 2007) while many static images of sound movement have been shown to be confusing (Leite & Afonso, 2001).

I made all of these pedagogical choices to allow for self-expression, space for making, and learning science; and to help facilitate agency, relevance, and understanding. Along with mapping the curriculum onto my conceptual framework, I also aligned the content of the activities with national standards for science, language arts, and studio arts. The curriculum and the national standards can be viewed in full in Appendix A.

Day 1 Silence	Day 2 Creating Sound Pieces	Day 3 Making Speakers	Day 4 Art Exhibit
What is silence? I asked youth to define the term "silence." We held a discussion around what this term means and if one can experience silence on earth.	**How does sound propagate?** After defining matter and explaining that sound is mechanical energy, I showed an animation of particles of matter being pushed by a wave of sound energy.	**Sound piece** Time was given for youth to complete their sound pieces based on the critique from the day before.	**Artist statement** I explained what an artist statement is, gave an example, and provided a worksheet for youth to complete for their artist statement.
Sound audit Three sound audits were completed: one of the lobby of the museum, one on the front steps of the museum, and one in the workshop classroom. Youth were instructed to sit quietly and write down everything they heard over the course of two minutes.	**Layering and building sound** To emphasize how sound can set a mood I displayed a photo of a rainy day and played the sound of a quiet rainstorm. I asked the youth how this scene made them feel.	**Sound is energy** A demonstration of how sound waves can make sugar dance to emphasize that sound is mechanical energy was conducted.	**Sound transfer** Youth removed their sound piece from their computers onto an MP3 player.
Sound scavenger hunt Using smartphones to record ,we spread out to capture sounds in the museum and the surrounding neighborhood.	**Sound piece** Youth were given time to work on their sound pieces.	**Smashing speakers** Youth were instructed to deconstruction an earbud and to record all the pieces they discovered.	**Construction** Youth were given time to complete their speakers
Sound piece The sound piece project was introduced and and the following instructions were given: *Create a sound piece that is one minute in length, conveys something about yourself, and uses twenty seconds of your collected sounds, along with any additional sounds you create or find*. Before starting to create their sound pieces, youth were given a worksheet to brainstorm their ideas for their project	**Critique** I introduced why people critique artwork and gave a model critique of a hypothetical piece, pointing out the importance of saying more than "I liked it." I also provided the youth with critique worksheets and instructed them to fill them out for each sound piece we listened to; the completed worksheets were then given back to each participant.	**Construction** I explained how to create a simple circuit, shared the materials available, and required youth to complete a design worksheet before beginning to make their speakers.	**Art exhibit** Employees of the science museum came through to experience the art exhibit that the youth created over the week.
Exit ticket	**Exit ticket**	**Exit ticket**	**Clean-up and debrief**

Figure 3. Workshop day-to-day activities: the yellow highlighted squares are activities for the sound pieces creation, the blue highlighted squares relate to building the speakers, the grey are science-specific activities, the white played a dual role (for example, learning about both the science and the art of sound), and the green are activities related to the art exhibit.

Daily Workshop Activities. Figure 3 shows a visual of the daily activities. The youth produced three artifacts over four days: sound piece, speaker, and artist statement. Creating the sound piece (yellow squares) stretched over three days, while building the speaker (blue squares) took two days and the artist statement (green squares) was written on the morning of last day. Below I describe in detail the day-to day-activities that took place during the workshop.

Day 1: Silence

Activity 1: Introduction and paper work (15 min)

I introduced myself and the projects which would be created over the course of the week: a sound piece and speaker which would be displayed in an art exhibit on Thursday afternoon. Youth took the pretest on the understanding of sound as energy (please see the section on Data for more information on this survey instrument).

Activity 2: What is silence? (45 min)

I asked youth to define the term "silence." We held a discussion around what this term means and if one can experience silence on earth. Three sound audits were completed: one of the lobby of the museum, one on the front steps of the museum, and one in the workshop classroom. Youth were instructed to sit quietly and write down everything they heard over the course of two minutes. We held a discussion about what the different spaces' silences were and why they were different.

As an example of how different spaces have different silences, I shared an interactive piece from the *New York Times* on sound architecture. The article shows photos of different spaces and plays a recording of that space. This illustrated how, through design, different spaces have different experiences of noise.

To think further about silence and to emphasize how what one individual considers silence may be music to someone else. I played a clip of John Cage, an avant-garde musician and composer talking about what he understands silence to be and why he loves the sound of New York City traffic.

Activity 3: Sound scavenger hunt (45 min)

Using smartphones to record, we spread out to capture sounds in the museum and the surrounding neighborhood.

Activity 4: Sound piece (50 min)

The sound piece project was introduced and the following instructions were given: *Create a sound piece that is one minute in length, conveys something about yourself, and uses twenty seconds of your collected sounds, along with any additional sounds you create or find*. Before starting to create their sound pieces, youth were given a worksheet to brainstorm their ideas for their project (the worksheet can be found in Appendix A).

I went over how sound is graphically displayed so they could understand what they would be seeing in the sound editing software, Audacity. I demonstrated how to

import sounds into Audacity, and how to do some basic editing. Youth were then given time to begin to create their sound piece.

Activity 5: Exit ticket (5 min)

Before being dismissed for the day all of the youth were given an exit ticket to complete (see Appendix A for the exit tickets).

Day 2: Creating Sound Pieces

Activity 1: Review of last class (5 min)

I held a quick review over what we talked about the day before: What is silence and can one experience true silence on earth?

Activity 2: How does sound propagate? (25 min)

After defining matter and explaining that sound is mechanical energy, I showed an animation of particles of matter being pushed by a wave of sound energy. A discussion was held around what the animation showed. To help reinforce that matter is required for sound to travel, I showed a picture of the moon and asked if one can hear in space. A discussion was held as to why one cannot hear in space.

Activity 3: Layering and building sounds (25 min)

To emphasize how sound can set a mood I displayed a photo of a rainy day and played the sound of a quiet rainstorm. I asked the youth how this scene made them feel. I then played a thunderstorm and asked how this scene now makes them feel.

To show how layering sounds together can build a mood. I shared a YouTube clip of a sound installation that Alan Berliner, a documentary film and sound artist, created. I

asked the youth to tell me what is the mood of this piece, and how did Alan Berliner create this mood?

As their sound pieces required incorporation of some of the founds sounds from our sound scavenger hunt, I played an NPR segment on Olivia Block, a noise artist. Block often brings found sounds into her pieces.

Activity 4: Working on sound piece (60 min)

I reminded the participants of the assignment for their sound piece and handed back their brainstorms from yesterday. Youth were then given time to work on their sound pieces.

Activity 5: Critique (80 min)

To facilitate the critique session, I introduced why people critique artwork and gave a model critique of a hypothetical piece, pointing out the importance of saying more than "I liked it." I also provided the youth with critique worksheets and instructed them to fill them out for each sound piece we listened to; the completed worksheets were then given back to each participant. Figure 4 shows the critique sheet that youth filled out for each other's sound pieces. The critique worksheet asked the participants to identify the mood or story of the piece, an aspect they enjoyed of the piece, something that could be improved in the piece, and if they learned anything about the artist from the piece.

Artist Critique

Name of Artist	Name of Critic
What mood(s) or story is this piece conveying?	What do you like about this piece and why? (Be specific)
What would you change about this piece to make it better? (Be specific)	What did you learn about the artist from this sound piece?

Figure 4 Critique sheet for youth sound pieces.

Activity 6: Exit ticket (5 min)

Day 3: Making Speakers

Activity 1: Complete sound piece (50 min)

I handed back the critique sheets from the day before, put up on the screen the requirements for the sound piece, and let youth work on their sound projects.

Activity 2: Sound is energy (20 min)

The day before, an individual had asked, why does helium make your voice high-pitched? I answered this question.

I did a demonstration of how sound waves can make sugar dance to emphasize that sound is mechanical energy.

Based on the exit tickets from the day before, there was some confusion over if sound can travel through the ground, so I went back over the concept that sound travels through matter.

Activity 3: Smashing speakers! (20 min)

Youth were handed a worksheet and an earbud and given the following directions: *Inventors, tinkers, and makers take things apart to figure out how they work. Take the next several minutes to completely deconstruct the speaker in front of you. Make sure you draw and identify all of the parts you find as you take it apart.*

Activity 4: How does a speaker make sound? (10 min)

Youth were asked the following questions: Why did the sugar dance? What has to happen for sound to occur? And what might you think would be in a speaker to make this happen?

Activity 5: Construction (115 min)

After going over what the youth found when taking apart the earbuds, I shared a diagram of a speaker and pointed out the components analogous to the earbud parts.

Before they built their own speakers, I gave a brief explanation of how to create a simple circuit and showed all the materials to which they would have access. I put up a slide showing a seven-step process for creating a speaker (see **Error! Reference source not found.**), and handed out a design worksheet for planning out their speakers (see **Error! Reference source not found.**). The design worksheet asked youth to think about how their audience will listen to their speaker; if they were going to make one or two speakers; what materials they will be using; and finally, the design worksheet required youth to draw a plan of their speaker. I had to approve their plan designs before they were able to begin making.

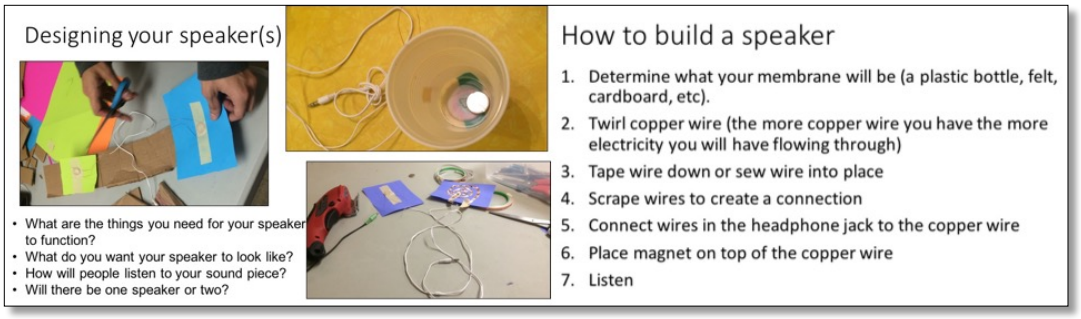


Figure 5 Instruction youth were given for designing and building their speaker(s).

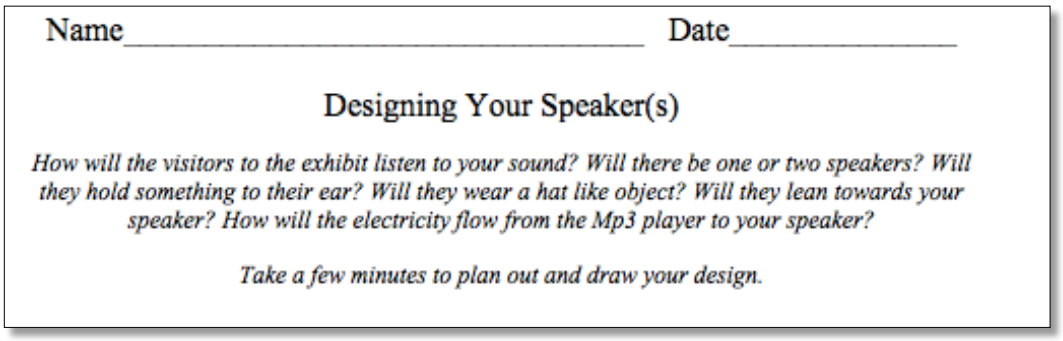


Figure 6 Design worksheet for speaker(s).

Activity 6: Exit Ticket (5 min)

Day 4: Art Exhibit

Activity 1: Review last class (5 min)

Activity 2: Artist statement (30 min)

Before having youth write their artist statements, I explained what an artist statement is: An artist gets to communicate with the public, typically through "short…written narratives discussing the motives, influences, and creative direction of a body of …work" (Graham, 2010, p. 19). I gave an example of hypothetical artist statement I would have written if I had created a sound piece. See **Error! Reference**

source not found. for my example artist statement. I also provided the youth with sentence prompts to help them write their artist statements. Theses prompts asked the participants to give their piece a title, explain why it is significant and what emotions the piece evokes, and why they chose to create this particular piece. I included emotions as a prompt because, when learning about sound as an art form, we had a whole discussion about how sound can set a mood or express a feeling. Alan Berliner's sound piece was an example of creating a feeling though layering sounds. Emotions were also included for, as some have pointed out, "arts based practice requires expression of feelings" (Batsleer, 2011, p. 427). Figure 8 shows the artist statement prompts.

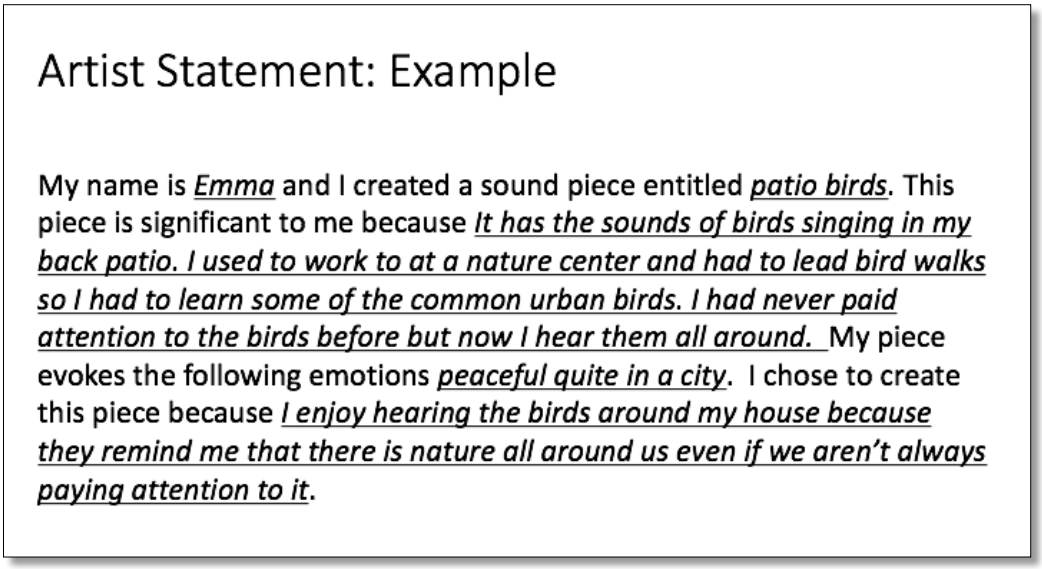
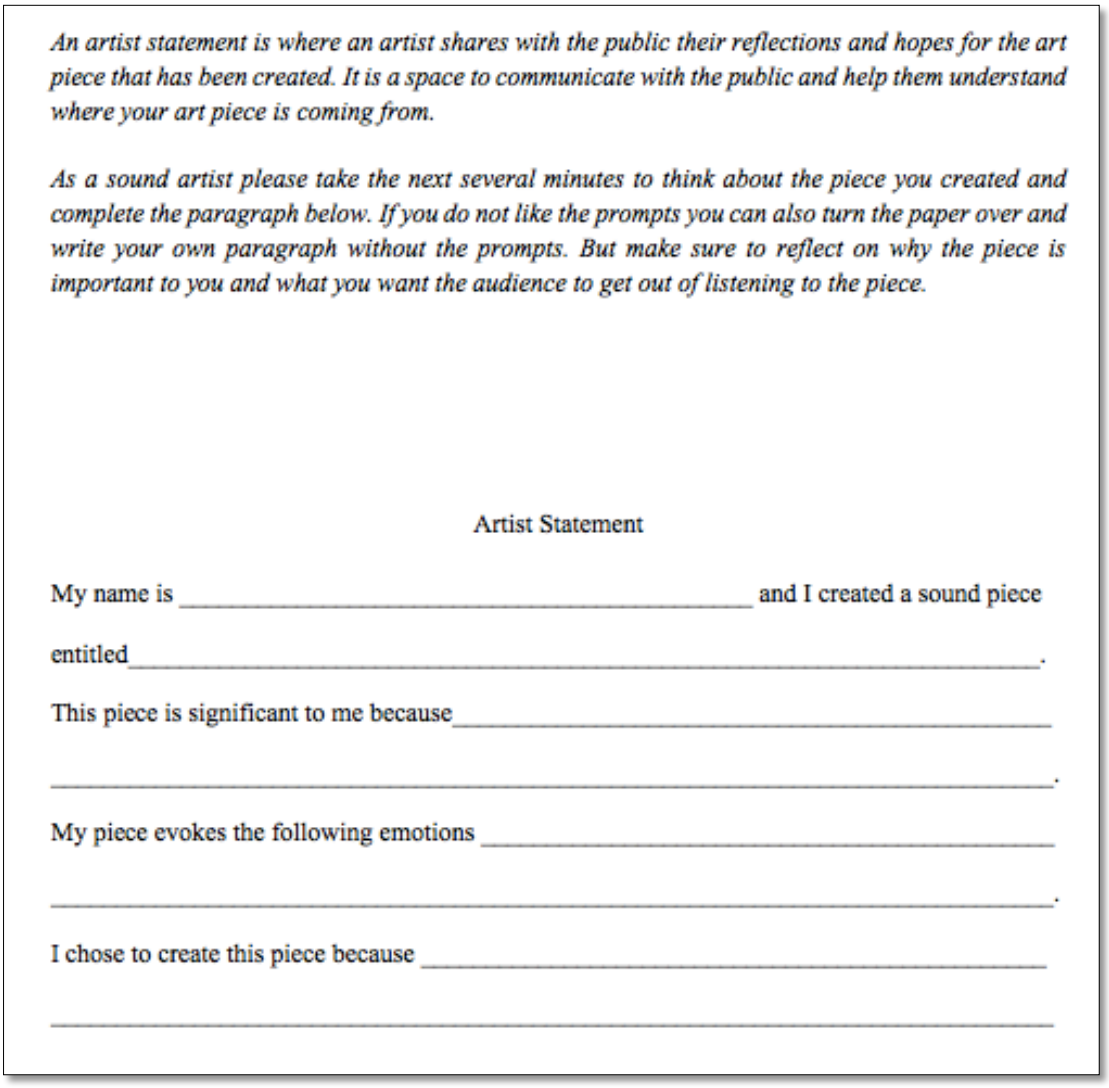


Figure 7. Example artist statement presented to the youth to model what was expected from their artist statements.



An artist statement is where an artist shares with the public their reflections and hopes for the art piece that has been created. It is a space to communicate with the public and help them understand where your art piece is coming from.

As a sound artist please take the next several minutes to think about the piece you created and complete the paragraph below. If you do not like the prompts you can also turn the paper over and write your own paragraph without the prompts. But make sure to reflect on why the piece is important to you and what you want the audience to get out of listening to the piece.

Artist Statement

My name is _____ and I created a sound piece

entitled_____.

This piece is significant to me because_____

_____.

My piece evokes the following emotions _____

_____.

I chose to create this piece because _____

_____

Figure 8 Artist statement prompt worksheet youth were encouraged but not required to fill out these sentence prompts when writing their artist statements.

Activity 3: Sound transfer (20 min)

I explained how to transfer their sound pieces onto a micro SD card and into the mini MP3 players. Youth then followed through and transferred their sound off of their computers.

Activity 4: Finish creating speakers (60 min)

Youth were provided more time to work on completing their speakers.

Activity 5: Set up for art exhibit and paperwork (20 min)

Youth completed the posttest on sound knowledge. We held a discussion to determine if there were any special instructions the youth wanted the art show attendees to have.

Activity 6: Art show (55 min)

Employees of the museum came through in several waves to see the exhibit of the youth sound installation.

Activity 7: Clean-up and debrief (10 min)

Youth cleaned up from the art exhibit (all chose to take their speakers home). I thanked the participants for being part of the workshop over the last week and asked about how they felt the art exhibit went.

Artifacts created in the workshop. As is clear from the daily activities of the workshop, youth created three artifacts for the art exhibit: a sound piece, a homemade speaker, and an artist statement. In the following paragraphs, I describe why I made the curricular design decisions for how these artifacts were taught in the workshop.

To craft the lessons around creating the sound pieces, I used studio arts teaching strategies. These strategies included introducing youth to various sound artists, demonstrating how to edit sounds, stipulating a constrained but open-ended project, and providing time to reflect on the projects being created (Hetland et al., 2007). Along with studio arts teaching techniques, I brought in notions of learning as understood by

constructionism, as seen in the time to talk about youth work through the critique, and in providing a project that gives space for youth to make it their own through a constrained but open project challenge (Harel & Papert, 1990).

The second artifact that the youth created was a functioning speaker. In designing the activities around building the functional speakers, I took ideas from notions of learning through both constructionism and engineering design. Having the youth take apart a speaker to figure out what materials they might need and requiring them to plan out their speakers comes out of the engineering design process (Tayal, 2013). The physical building of the speakers is directly related to notions of learning as understood in constructionism (Papert, 1980).

The final artifact that youth had to produce was an artist statement. The choice to include an artist statement allowed an additional place for youth to reflect on the work they had created, which is an aspect of both studio arts teaching techniques and constructionism notions of learning.

Data

To answer my two research questions, I collected both qualitative and quantitative data. Table 2 displays which data sources I used to answer each of my research questions. Below I describe in detail the data that I collected to answer each research question.

Table 2

Data sources used to answer my research questions

Research Question	**Data Sources**				
	Artist Statement	**Field Notes**	**Photo of speaker**	**Pre/Posttest**	**Semi-Structured Interviews**
RQ1: In what ways were a diverse set of youth able to express their agency within this making learning environment?	X	X	X		X
RQ2: In what ways do youth improve in their understanding of sound through creating a sound piece and speaker?				X	X

Artist statement. As art in a gallery or museum always has an artist statement attached to an artifact or larger exhibit, youth wrote their own artist statements to explain their sound piece or speaker. Figure 8 shows the artist statement prompt that youth completed. The artist statement played multiple roles within my curriculum, from helping to frame the workshop as an art and science workshop to providing a space for youth to reflect on the work they produced. All ten of the youth handed in their completed artist statements at the end of day four.

Field notes. At the end of each day's workshop, I took an hour to write down all the current happenings. I made sure to include moments of tension where youth were struggling, along with questions they brought up. I highlighted any plans that needed to be adjusted in the next day's workshop.

Photos of speakers. Photos of youth speakers were taken while the youth were building and once they had completed their speakers. These photos documented the range of speakers all ten participants created. All of the youth chose to take their speakers home with them, and so photographs and not the physical objects were used as a data source.

Pre/posttest. Participants were given a pretest on their first day of the workshop before any other activities started. On the last day of the workshop, before the art exhibit began, youth were given a post-assessment. To make sure that the test was fresh, the order of questions was shuffled from pre to post test. The questions for this assessment

came from Esach's (2014) vetted and verified test for youth's understanding of sound. The original test is many pages long, and due to the time constraints of the workshop I selected seven questions that pertain to understanding sound as energy and not as a material. The seven questions include five true or false statements and two multiple-choice questions. The multiple-choice questions gave the following instructions "*Circle the correct explanation below. There may be more than one correct explanation."* One of the multiple-choice questions included two correct answers. I chose two focuses:(1) The questions asked if sound is matter, for example, "True or False: Sound is NOT matter." This is a true statement as sound is energy; (2) several questions focused on how sound travels. For example, one of the multiple-choice questions states, "When we strum a guitar string, we hear a sound because…." The correct response is, "(d) a vibrating string causes changes in density and pressure of the air around it. This change in density and pressure travel to our ears and enable us to hear." See Appendix B for the complete pre/post assessment. All ten youth took both the pre and posttest.

The pre/posttest true/false multiple-choice test, can show an increase in knowledge but it is limited in being unable to show a nuanced understanding of sound. For this nuanced understanding, I asked youth to explain sound to me in their semi-structured interviews.

Semi-structured interview. All ten youth participated in one-on-one semi-structured interviews after the end of day four. Interviews were on average 21 minutes long. Youth were asked questions that related to their knowledge of the science of sound,

their experience with art, and the learning that took place while making their speaker and sound piece.

In terms of understanding agency, in the interviews I asked youth the following questions: 1) How does your sound piece reflect you? 2) Of all three aspects of this project—learning about how sound moves, building a speaker, and creating a sound piece—which was most important to you and why? 3) What aspect of the project are you most proud of?

To gain a more holistic understanding of youth comprehension of sound as energy, in the semi-structured interview I asked them the following questions: 1) Explain to me how sound moves, and 2) Is sound matter? I also asked follow-up questions, for example: 1) Can you hear in outer space? 2) How do you make a loud sound?

To investigate in what ways youth were able to learn about the science of sound, I asked questions about what helped them learn and what role creating their sound piece, deconstruction, and construction played in their understanding of sound as energy. See Appendix C for the complete interview protocol.

Data Analysis

In the following paragraphs, I describe the data analysis that was performed to answer each of my research questions. In brief: For research question one, I explored the, artist statements, field notes, speakers and youth interview responses, for evidence of agency. For research question two, I ran a Wilcoxon signed ranked test on the youth pre/posttest and thematically coded youth interviews for what helped or hindered their

learning. Below I describe how each of the data sources was analyzed in order to answer my research questions.

Artist statement. Agency, as stated earlier, is understood in this study as creative self-expression achieved through using the knowledge and practices of a particular context which helps individuals develop their identities and perhaps advance their positions in the world (Barton & Tan, 2009; Basu et al., 2009; Hoechsmann & Poyantz, 2012, Sheridan et al., 2013).

Identity is how people come to understand themselves within a particular context (Urrieta, 2007; Nasir & Hand, 2008). Identities are complex and ever-evolving. Artifacts both mediate and expand one's identity and therefore one's agency (Holland, Lachicotte, Skinner, & Cain, 1998). This means one can explore identities and agency through artifacts which may be both sharing who one is, and at the same time, shaping how one views themselves. For example, Barton et al., (2008) used artifacts that youth created in their science classrooms to understand how they were able express their agency and transform their identities.

The youth artist statements were analyzed for evidence of agency. My hypothesis was that more variety in the artist statements would correlate with a greater level of agency. As stated earlier, the artist statements had several prompts including: (1) why the piece was significant, (2) what emotions the piece evoked, and (3) why the youth chose to create the piece. Youth were able to write about either their sound piece or their artist statement. First, I went through the artist statements and categorized the statement in

terms of what artifact was being written about: sound piece or speaker. Second, I read the artist statements to determine if youth wrote about an aspect of their identity, or an action that they were taking through their sound piece or speaker. In my third reading, I counted both the number and variety of emotions written about across artist statements. As mentioned earlier, part of art work is being able to express feelings (Batsleer, 2011). To validate this coding scheme, I trained a second researcher and had her code all ten artist statements. When there were instances where our coding was incongruent, we discussed until we came to a consensus code. Table 3 shows an example coding of a youth artist statement.

Table 3

Example coding of a youth artist statement

Artist Statement	**Speaker or Sound Piece?**	**Identity or Action?**	**Number of emotions**
My name is Mark and I created a sound piece entitled City Walk. This piece is significant to me because it portrays the sounds of city all day long; sirens, traffic, and vehicles. My piece evokes the following emotions comfort	Sound Piece	Identity	1: Comfort

from the city. These sounds have become what I hear every day. I chose to create this piece because I have lived in the city for my entire life and these sounds have become nature for me, I always hear these sounds even if I don't think about it.			

Note: Statements were coded for what artifact was written about, if the statement was focused on youth identity or taking an action and the number of emotions mentioned.

Field notes. I examined my field notes to understand what took place over each day of the workshop. I used this information to help build the two cases that I present in my findings section. In reading the field notes I did open coding (Corbin & Strauss, 2007), wherein I focused on how youth struggled with the making activities, along with their ability to express themselves, and any notable moments of learning.

Photos of speakers. Agency as understood in this study is in part creative self-expression. Creativity is the processes of discovering problems *and* solutions (Sawyer, 2012). This process includes taking one's ideas for a solution and combing these ideas in new and unexpected ways through external means of creating an artifact (Finke, Ward, & Smith, 1992; Kelly, 2001; Sawyer, 2012; Tardif & Sternberg, 1988). Therefore, in looking for evidence of creative expression in the youth-built speakers, I was looking for

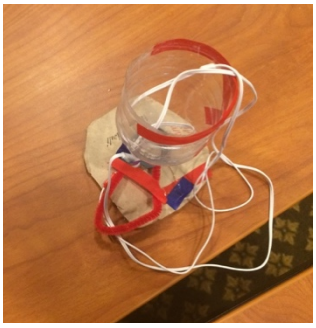
evidence that youth were able to find unique and unexpected solutions to the problem of making a speaker.

I examined the materials used to construct the speaker, the shape of the speaker, and the number of speakers built. I hypothesized that if youth did *not* have agency, then I should see the same shape and materials used over and over again (i.e. no unique problem-solving); however, if youth were able to have creative expression, then I should see a range of different speakers built (i.e. unexpected problem-solving) and this would be evidence of agency. **Error! Reference source not found.** has an example of how I analyzed two different speakers for materials, number of speakers, and shape. The shapes of speakers are emergent codes based on what actual shapes youth built for their speakers.

Table 4

Example of coding for shape, materials, and number of speakers as evidence of creative self-expression

Student Name	**Photo of speaker**	**Description of speaker**
Eliza		**Materials**: cardboard, copper wire, head phone jack, magnet, electrical tape

		Number of speakers: One **Shape**: flat disc
Haider		**Materials**: plastic bottle, cardboard, copper wire, head phone jack, magnet, eletrical tape **Number of speakers**: One **Shape**: 3D cone

Pre/posttest. In order to understand in what ways youth gained in scientific knowledge, I first had to determine if youth gained in understanding and comprehension of sound as energy. To establish if there was a significant change in youth understanding from pre to posttest I ran a Wilcoxon signed rank test (Wilcoxon, 1945). With only ten participants, most likely the distribution of scores violated the normal distribution assumption of a paired sample t-test, which is why I ran a Wilcoxon signed rank test instead of a paired sample t-test. Because many researchers believe in the importance of

reporting effect size, I calculated a matched-pairs rank-biserial correlation (Kerby, 2014) to determine effect size for the Wilcoxon singed rank test. I have not interpreted the effect size, as the sample size is so small the effect size does not elucidate much information, but have included it as a formality. What is more important is the potential found in the Wilcoxon signed rank test result.

Semi-structured interview. The semi-structured interviews were used to understand both youth understanding of sound and for evidence of youth agency. To gain a nuanced understanding of youths' comprehension of sound in the semi-structured interview, I asked the youth if sound is matter, to explain how sound moves, and several follow-up questions. To score their responses I created a codebook based on West and Wallin's (2013) coding scheme and Wallin's (2011) interview coding scheme for youth understanding of sound. I used these coding schemes as they provide a clear delineation of levels of understanding of sound and were created similarly from interview responses. As a reminder, sound is a process of energy transfer and does not have properties of matter (Hernandez, Couso, & Pinto, 2011). Understanding that sound is energy is a very challenging concept and a primary goal of the curriculum I created.

Youth responses were scored on a three-point scale from having (1) a material or little understanding, to (2) having a hybrid or some understanding, to (3) having a process view or a high level of understanding. Table 5 shows the coding manual for sound. A material understanding is a belief that sound is a thing and has properties of matter. A hybrid understanding is an incomplete understanding of sound; while the youth may

know that sound is not matter, they may not understand how the amount of energy in the system relates to the volume of sound. In a process understanding, youth comprehend that sound is not matter and that to make a louder sound more force is needed in the system. To validate this coding scheme, I trained a fellow researcher on the coding manual and had her code all ten responses. In any instance where we had a disagreement, we had a discussion until we agreed upon a consensus code.

Youth interview responses were coded question by question. If youth answered the first question, "Is sound matter," with a positive response i.e., "sound is matter" then their total response was given a code of a material view of sound. However, if youth were able to answer that sound is not matter, and could explain why you cannot hear in space, along with being able to explain how to create a loud or quiet sound, then they were given a processes level of understanding.

Table 5

Knowledge of sound as energy coding manual

Category	**Example**	**Explanation**
Low level of understanding (Material): Sound is a physical thing and therefore has properties of matter.	I**nterviewer:** So can you tell me how sound moves? **Alice:** Like through vibrations I think. Like when something vibrates it sends off a sound. It's like	*Using the phrase "it sends off a sound" indicates that Alice views sound as a physical thing.*

	when something vibrates it sends off a sound and then you can hear sound waves travel. **Interviewer:** Okay great. So is sound matter? **Alice** I think everything is matter so we actually –	*When asked if sound is matter Alice responds "I think everything is matter…" further showing an incorrect understanding of sound.*
Medium level of understanding (Hybrid): While there are some instances of showing an understanding of sound as energy there are also instances where the youth has an incomplete understanding of sound, using, for instance, notions of sound as having properties of matter.	**Interviewer**: So, can you tell me how sound travels? **Alexander**: It travels through matter and it travels in waves. One being the compression wave, which is a decrease or increase in pressure in the air. **Interviewer**: Just in the air? **Alexander**: In matter.	*Alexander understand that sound is not matter and that you cannot hear in space because there is no medium for sound to travel through however he is unable to explain how to create a*

	Interviewer: Right. So, is sound matter? **Alexander**: No. **Interviewer**: And can you hear sound in space? **Alexander**: No. **Interviewer**: Why not? **Alexander**: Because space has no matter when it comes to air. But, if you're in a planet like the moon and you jump, you can hear, slightly, if you put your ear to the moon's surface. **Interviewer**: So, how would you make a loud sound? **Alexander**: You would vibrate your vocal cords at a higher frequency.	*louder sound, revealing a misunderstanding of how to increase the volume there has to be more energy in the system.*

	Interviewer: Does it just have to be a higher frequency? **Alexander**: No. It has to be a... What's the word? **Interviewer**: What is sound? **Alexander**: Sound is vibration, so it has to be a louder vibration. **Interviewer**: How do you make a louder vibration? **Alexander**: By increasing... I don't know how to -- **Interviewer**: We talked about this remember how we were saying if you wanted to make a louder speaker, what did you need to do? You'd need more	

	something. **Alexander**: You needed more amplification. **Interviewer**: That would be one way. What's another way? **Alexander**: Vibration. **Interviewer**: How would I make the vibrations louder? **Alexander**: By increasing the frequency. **Interviewer**: Frequency is how often something goes past a point. So, I could have a lot going past a point, but not very loud. So, how would I make it louder? **Alexander**: The coils around the wire.	

	Interviewer: That has something to do with it. **Alexander**: And so that -- so when vibrates...	
Sophisticated understanding of sound (Processes): Sound is energy	**Interviewer**: Yeah, I think a lot of people think that, so can you tell me a little bit more about what sound is and how it travels from one place to another? **Talia**: Yeah, so sound is like mechanical energy and what it—it comes in like waves so it's like compressions and I think decompressions and it's like initiated by like a starting force and it's also initiated like a vibrating thing that like sends out a starting force and then like	*Here Talia is able to explain that sound is mechanical energy and as such is a process. Talia is clear that a force has to begin a vibration that travels through matter.*

	the louder the sound is like, the taller the waves are but if it's like quiet and the waves are like longer or yeah and then like it travels through matter and particles like such as the air and the ground and stuff like that but it doesn't travel through a vacuum because a vacuum doesn't have particles to like, travel through and — **Interviewer**: So how would I make a loud or a quiet sound? **Talia**: Oh by either increasing or decreasing the amount of force.	

Along with wanting to know if youth learned about the science of sound, I was curious about what aspects of the workshop helped them learn. I wanted to know, according to the youth, what experiences from the workshop, including deconstruction and construction, helped them to learn. As described earlier, the activities for building the speaker(s), included taking apart an earbud to learn firsthand what materials one might need to build a speaker. Youth also had to plan out and physically make their own speaker. In the semi-structured interviews, I asked about these experiences to understand how the design decision helped or hindered youth learning.

To investigate the answers, I followed categorization analysis to figure out what helped youth learn (Maxwell, 2013). The responses to the questions were first coded for what was helpful for youth learning. In the second round of open coding (Corbin & Strauss, 2007), wherein I looked for what youth said was most important to why that particular activity helped them learn, I developed descriptive codes (Maxwell, 2013). These descriptive codes help to explain why these aspects of the workshop helped or hindered youth learning. Table 6 is an example of how I coded one interview for youth perceptions of their learning.

Table 6

Example of coding for youth perceptions of what helped or hindered their learning

Interview response	**What helped youth learn?**	**descriptive code**

I: So, what do you think helped you learn how sound moves -- a particular demonstration, building a speaker, making your sound piece? What do you think helped you learn? S: I think what helped me learn was like the actual presentation like before that I didn't know anything about sound but after that I know more about it. I: What about the presentations helped you learn? S: I learned like how it travels on the pitch and frequency.	Lecture/PowerPoint Presentation	Specific content knowledge was learned
I: Was creating your sound piece motivation to learn about how sound travels? S: I think it did because on the actual program its not like the	Sound piece motivating to learn about sound	Allowed for experimentation

sound waves, it was like low pitch and like high pitch and they showed me how like it can louder or lower.		
I: Did taking a speaker apart help you learn? S: I think it was because it helped us know what materials we need to create the speaker like copper, magnet. Because before that I would never know that a magnet was important to the speaker.	Taking apart a speaker helped to learn about sound	Saw all the materials/parts that make up a speaker
I: Did building a speaker help you learn about sound? S: I think it did because it helped us, showed us where does the sound come from. Because I always thought sound comes out through the air but I	Building a speaker helped with learning about sound	Illuminated a concept or new knowledge

learned that it comes from vibrations.		
I: Did building a speaker give a purpose to understand how sound moves? S: I think it did because like how sound travels through the air and like travel through the materials we used.	Building a speaker gave purpose to learning about sound	Pushed one to have a deeper understanding of sound
I: What helped you learn the most? S: I think the presentation because it show us how to put stuff together and how to add, edit stuff, make the speakers too.	Lecture/PowerPoint Presentation	Helped to understand the why and/or how of sound

Along with investigating the science youth learned and what helped them to learn, I used the semi-structured interviews to explore for evidence of youth agency. In terms of

this agency, for the question "How does your sound piece reflect you?" I followed open coding (Corbin & Strauss, 2007) to create two descriptive codes (Maxwell, 2013). The sound piece either shared a particular trait or shared an explanation of who the youth are. Table 7 shows Eliza's response to how her sound piece reflects her. In her statement, she explains, "I am like actually peaceful." It is this one trait that Eliza says her sound piece reflects of her. She is not attempting to show how multiple ideas come together to explain who she is.

Table 7

Example coding for youth agency from interview for identity either as a trait or explanation

Name	**How does your sound piece reflect you?**	**Trait or Explanation**
Eliza	It shows the peaceful side of me even though I'm like — my parents always call me loud and stuff but I am like actually peaceful.	Trait

I also investigated what role self-expression played in the workshop according to the youth. As understood in this study, creative self-expression is part of agency, and I wanted to know if youth believed they had space to express themselves; and then if this was important to their workshop experience. I first located what youth said was important

to their workshop experience (learning about how sound moves, building a speaker, or creating a sound piece). I then counted how many youth felt each of these aspects were important. From the responses as to why this aspect of the workshop was important, I followed open coding (Corbin & Strauss, 2007) and found three descriptive codes (Maxwell, 2013): act of creating, self-expression, and knowledge. I followed a similar pattern in terms of what youth were most proud of. I first located what they said they were proud of from the workshop, counted how many youth felt they were similarly proud, and then did open coding (Corbin & Strauss, 2007) to create descriptive codes (Maxwell, 2013) of why they were proud of these aspects of the workshop. Two descriptive codes emerged: accomplishment and overcoming a challenge. Table 8 shows how I coded Tom's interview responses for why creating the sound piece was most important for him and why he was most proud of making his speakers. Tom found creating the sound piece most important because he was able to express himself, and was most proud of accomplishing building two functional speakers.

Table 8

Example coding of the role of self-expression as revealed in the youth interviews

Interview Response	Descriptive Code*: Act of Creating; Self-Expression;*	**Interview Response**	Descriptive Code: *Accomplishment; Overcoming a*

	Knowledge		*challenge*
Interviewer: Of all three aspects of this project: learning about how sound moves, building a speaker, and creating a sound piece, which was most important to you and why? **Tom**: Creating the sound piece. **Interviewer**: Why was that the most important? **Tom**: Because it gave me creativity that other assignments would not give to me and I'll be able to express myself.	Self-Expression	**Interviewer:** What part of the project are you most proud of and why? **Tom**: Speakers. **Interviewer**: Why you are most proud of that? **Tom**: Because I got them both to work.	Accomplishment

Triangulation

To answer both of my research questions, I used multiple data sources to understand the phenomena I explored in this study (Creswell, 2012). In terms of my first research question (*In what ways were a diverse set of youth able to express their agency within this making learning environment?)* I explored several of the youth artifacts and their semi-structured interviews for evidence of agency. From the youth artist statements, I was able to explore if youth were able to take action or express their identity. The speakers helped to show if youth were able to have creative self-expression. The semi-structured interviews helped to explore how the participants were able to express themselves and if they felt that self-expression was important to their workshop experience. Through using a diversity of data sources, I was able to gain a greater understanding of whether youth had agency, and if having space for self-expression was important to them.

To investigate my second research question (*In what ways do youth improve in their understanding of sound through creating a sound piece and speaker?)* I first had to understand if youth gained in knowledge. I used both the pre/posttest and the semi-structured interviews to determine what knowledge they had in terms of understanding sound is energy. To understand in what ways youth learned, I looked at the semi-structured interviews to understand what helped them learn and why. These multiple data sources allowed for a richer comprehension of youth understanding of sound and what helped them learn.

Validity and Reliability

In this section I discuss the steps that were taken to ensure the validity and reliability of the data analysis undertaken to answer my research questions. As this is a mixed methods study, there are different means of validation for the qualitative and quantitative analysis.

Qualitative validity pertains to the accuracy of the findings, while qualitative reliability is about using consistent methods established across various projects (Creswell, 2009). To explore agency, I used established research methods for coding of qualitative data—for example, using open coding (Corbin & Strauss, 2007) to determine descriptive codes (Maxwell, 2013). To ensure validity of my qualitative findings, I made sure to employ multiple forms of data (youth built artifacts, youth written reflections, and youth interviews) to triangulate on the answers to my research questions.

In quantitative data, validity refers to the strength of the conclusions while reliability is the consistency of the measure (Creswell, 2009). To ensure the reliability of the pre/posttest measure I modified an already vetted and validated test created by Eshach (2014). The order of the questions in the pre and posttest were reordered in hopes of keeping the questions fresh for the youth. To ensure the validity of youth comprehension of sound from youth interviews I conducted I training a second researcher on my coding scheme. The second researcher coded all ten responses, and we discussed any disagreement in responses until we came to a consensus code.

Chapter Summary

In this chapter I explained in detail my research methodology, data sources, and data analysis employed to answer my research questions. This was a mixed-methods early stage/exploratory study. In the following chapter I present the findings that emerged from the data analysis.

Chapter 4: Results

This study explored if youth were able to learn challenging science content while having agency through a multidisciplinary art and science maker workshop. In this chapter I present the results of my data analysis. I begin by sharing a close look at two individuals' experiences within the workshop. These experiences highlight how these two individuals engaged with the various activities within the workshop, how these activities helped or hindered their expression of agency and science learning, and any moments of challenge they experienced. Following these two cases, this section goes on to investigate evidence of agency and science learning across the whole cohort as found within the sound pieces, homemade speakers, and artist statements. This chapter then reveals youths' perceptions of the workshop, and finally discloses if youth learned that sound is energy.

Yarrow's and Tom's Workshop Experiences

I delved into Yarrow's and Tom's workshop experiences for three reasons; first, to discover what struggles they faced in the workshop while creating their sound pieces and making their speakers. Second, I wanted to explore if, and therefore how and why, the learning environment privileged their agency; and last, to understand what aspects of the workshop helped them learn.

As a reminder, this study defines agency as creative self-expression using the knowledge and practices of a particular context which helps individuals develop their

identities and perhaps advance their positions in the world (Barton & Tan, 2010; Basu, Barton, Claremont, & Locke 2009; Hoechsmann & Poyantz, 2012; Sheridan, Clark, & Williams, 2013). Creativity is a process of noticing problems, finding solutions, and creating an artifact with those unique solutions (Finke, Ward, & Smith, 1992; Kelly, 2001; Sawyer, 2012; Tardif & Sternberg, 1988). Self-expression means the individual is referencing personal or internal ideas or notions in their work, rather than established knowledge (Milbrant & Milbrant, 2011). Evidence of agency would therefore be moments where youth are able to solve problems in unique ways while being able to share ideas that both come from within themselves, and help to develop a sense of self and/or take action.

The following section investigates Yarrow's hidden creative self-expression and Tom's learning through creating, breaking, and making. For each of these sections I begin by revealing background information about the individual. I then focus on their experience creating their sound piece and go on to investigate how they went about building their functioning speaker. I end each case focusing on what part of the workshop Yarrow and Tom were most proud of.

Yarrow: Hidden creative self-expression. Yarrow loved K-pop (Korean-style pop music) and science. She felt encouraged by her mother to pursue her love of science, as they often discussed what she learned at school that day. Her mother also encouraged her to pursue a career in science, as Yarrow pointed out there are

> not a lot of people in my community …[that]…like a – has a job that's in science so [my mother] encourages me to do that. (Interview, 7/15/2016)

As a young black female, Yarrow is in the minority of individuals who continue on to obtain jobs within science fields. In explaining why she enjoyed science, Yarrow expressed that, in part,

> I guess it's easier for me than arts because it's like a specific thing you have to do and I'm not very creative so I just think it's easier for me and so I do well in it. (Interview, 7/15/2016)

Creativity was not something that Yarrow felt she possessed, which, she believed, made the arts harder for her. Along with not feeling she was creative, Yarrow did not believe that she was good at making things, as she mentioned "…I was bad at it…" (Interview, 7/15/2016), even though she and her brother often cook dinner for their family.

Yarrow's ability to be artistic through her sound piece. There were three requirements for the sound pieces that youth created: 1) the piece had to be one minute in length, 2) it had to convey something about the maker, and 3) it had to use at least 20 seconds of the sound the maker had collected from the museum and/or the neighborhood. To help facilitate the creation of these sound pieces, I shared three different sound artists with the youth, demonstrated how sound could set a mood, had youth complete a brainstorm sheet for their piece, and also facilitated a critique of the youth's rough drafts of their pieces. After the critique, there was time the next day to rework and complete this project.

Yarrow found art challenging, yet in creating her sound piece she was able to express herself. When she brainstormed ideas for her sound piece, she only shared a declaration that she liked K-pop. However, during the critique session for her 17-second

rough draft of a sound piece, Lucy observed that Yarrow loves K-Pop but didn't include any in her piece. Yarrow was very nervous during the critique and giggled through the first playing of her sound piece. However, as the other attendees began to talk about how she could improve her piece, she stopped giggling and was focused on what her peers were suggesting. Like many of the other attendees, Yarrow had not done a critique before, so it was unsurprising that, as the first person to have her piece discussed, she was anxious as evident by her giggling.

In her final piece, Yarrow spliced together several different sound clips (including some K-pop) to paint a picture of her personality. Yarrow described her sound piece as:

> It was basically me giving someone a letter through sounds describing who I am to them. And so it was like different parts of me and my personality put into one piece. (Interview 7/15/2016).

Through choosing her clips and then putting them together, Yarrow believes she was able to explain these different parts of herself. In her artist statement, Yarrow further explained why she created this piece: "because I enjoy sounds that may be unlike but match well together" (7/14/2016). Yarrow was showing how the individual characteristics of her personality may appear to be incongruent but together they make sense—just as the sound clips on their own may not make sense, but all together they go well. This is evidence of self-expression as Yarrow revealed information that comes from herself and not from outside knowledge. Through making her sound piece Yarrow was able to share part of who she is—evidence of her expressing agency in this making activity.

Yarrow's struggle to make her speaker. Along with evidence of Yarrow's agency in her sound piece, there was evidence of her having creative expression through her speaker design. A speaker requires four elements: a membrane, a magnet, copper wire, and access to electricity which in this workshop was provided through a headphone jack. In designing her speaker Yarrow chose to use a plastic cup for her membrane. She also harnessed the shape of the cup so that one would bring the cup's open side to one's ear for listening purposes.

Yarrow struggled with both choosing a design and getting her speaker to function. A major pitfall in her understanding was how to create a simple circuit. She did not realize that the copper wire had to be one continuous piece. This caused Yarrow at first to create a speaker with an incomplete circuit. Only after I helped her problem-solve for why her speaker was not making noise, and explained again how and why to create a simple circuit, was she able to create a functioning speaker. After this interaction, Yarrow stated, "Yes I get it. It is starting to make sense" (Field Notes, 7/13/2016). With this clearer understanding, she was able build a functioning speaker with a complete simple circuit.

Even with this stumble, Yarrow really enjoyed making her speaker—in part because she worked so hard to get it to function. As she stated:

> Because it was fun. I never really created a thing or worked that hard. So usually when it comes to like making stuff I really don't like it because it seems like–I mean I thought I was bad at it but it actually was pretty fun. Just making this out of nothing and then just seeing how it ends up being something. (Interview, 7/15/2016)

Yarrow continued to explain that creating her speaker was hard, in part, because she had a tough time coming up with an idea:

> Wednesday, when we started our speakers, it was hard because I wasn't getting any ideas and everyone else—they were like moving fast and so they got ideas and they started. I couldn't really think of anything and so just thinking of an idea was hard for me and I think that was like the hardest part. But once I got the idea I was able to move forward and finish. But I think me thinking of an idea and that's pretty hard. (Interview, 7/15/2016)

Yarrow struggled to figure out how to begin to design her speaker and also needed help to determine how to get her speaker to function. Through overcoming these challenges she was able to creatively solve how to make a speaker out of everyday items. And in the end, she created the loudest of all the speakers.

Yarrow's proudest moment from the workshop. Having completed their speakers and written artist statements, on the second half of day four youth set up the classroom for the culmination of the workshop: the art exhibit. Each individual stood next to their artist statement, their speaker connected to an MP3 player or computer. I put out some cookies, as art openings often have snacks. We had a brief discussion as a group about any rules we needed for the exhibit, and agreed to inform the attendees that the speakers were very quiet and it may be hard to hear the sound pieces. Then, in three different waves, staff members from the museum came through to listen to the projects and to interact with the creators.

Ultimately, what Yarrow was most proud of from her workshop experience was neither the sound piece she created, nor the speaker she struggled to make, but her ability to speak well to the public during the art exhibit. As she pointed out in her interview:

> Me being able to talk to the public because I usually am shy towards people and what I accomplish and stuff so I don't like talking to people much. But I started to get more comfortable and I was like happy that I was able to not be scared to talk to them like I usually am. (7/15/2016)

After the first set of exhibit visitors had left, Yarrow was beaming from ear to ear and asking when more visitors would arrive. It was clear that she really enjoyed being able to share the artifacts she had created during the workshop.

Yarrow came into the workshop with a love for science and a trepidation towards creative pursuits. She felt she was not good at art because it required creativity, nor did she excel at making. However there is evidence in her speaker and sound piece of her ability to express herself and come up with creative solutions to challenging problems. From this workshop experience, Yarrow discovered that she was good at making things, could express herself well through sound, and could overcome her shyness to talk to the exhibit visitors. Or, to state it slightly differently: Yarrow was able, through this workshop, to express her own agency as seen through both her speaker and sound piece. The making projects pushed her beyond her comfort zone and helped her learn more about what she is capable of doing.

Tom: Grappling with understanding sound through creating, breaking, and making. Tom came into the workshop as a sort of renaissance individual who was passionate about music, visual arts, making things, and science

among others. He enjoyed playing music and creating his own compositions and had recently painted a mural in his bedroom. At the time of the workshop, he and his sister were in the process of building their own drone.

Tom, like Yarrow, felt that his family encouraged him to pursue science. His father is a former science teacher who often discusses science and engineering with him. Tom's father encourages him by helping him get the supplies he needs for the next new project he is attempting.

Not only is he encouraged to pursue science, but Tom explained that he likes science

> Because it gives me the chance to explore different things, find things that people haven't learned yet. (Interview, 7/15/2016)

Through science, Tom believed he could find new knowledge and explore new things.

Tom's struggle to artistically express himself through his sound piece. In order to create the sound pieces, youth had to learn and use sound editing software. I had installed Audacity, a free sound editing software, onto each of the program's computers. In the software, sound is displayed graphically, so I spent several minutes explaining how to interpret these graphs, including having youth come up and draw loud and quiet sound graphs. I also demonstrated how to do basic functions within the software, including how to import sounds. After introducing the software and going over the requirements for the sound piece, I set the youth free to begin to create.

Tom asked if he could use software he was already familiar with instead of Audacity. I said he could use any program he wanted, but that I wouldn't be able to provide support for unfamiliar software.

As youth began to create their sound pieces, it was clear that Tom was engrossed in the project. Before starting the critique of the draft piece on day two, I gave the attendees a break to stretch their legs and get a snack. Tom asked if he could just keep working, I said of course he could, and so he kept his computer open and eyes and ears focused on making.

While Tom was very focused on creating his sound piece, he experienced more than his fair share of technical hassles. In using a web-based program, Tom was limited by the poor-quality internet connection at the museum and so struggled to create his sound piece. This was evident during the critiques on day two when Tom was unable to download a version of his sound piece to play for the whole class. Tom did not end up having his sound piece critiqued, but did participate in critiquing other participants' pieces. Even with challenges, Tom believed that the sound piece was the project within the workshop that allowed him the most creativity and therefore had the highest value.

Like several other individuals, Tom chose to use the sound piece as a place to unravel parts of his own complex identity. He wanted his sound piece to illuminate how his mind was always jumping from topic to topic, highlighting his inquisitive, curious nature. Through splicing together different sound clips from song excerpts, spoken word, and sound collected from the museum, Tom hoped to portray how his mind was always

hooking onto new ideas. As he wrote in his artist statement, "I chose to create this piece because it shows that I never focus on just one topic at a time" (7/14/2016). Through his sound piece Tom was able to express himself and share how he believes his minds functions. This is evidence of Tom being able to have agency within this project.

Tom learned through making, the interaction of artifacts, and his peers.

Before making a speaker, each participant was given an ear bud and told to completely deconstruct it. I provided a worksheet to draw images of the parts that were found while taking apart the speaker. I observed Tom and several other youth discover that if they removed the covers from the outlets located in the floor in the room, they could use these covers to crack the casing around the earbud and then take apart the earbuds more easily. While breaking his earbud, Tom exclaimed, "It's a magnet!" (Field notes, 7/12/2016). The magnet is a key part of a speaker, for the push and pull between the magnet and electricity help create the vibration which reverberates sound outward. In discovering the magnet, Tom found an integral component of a speaker, which was why he felt that taking apart a speaker before making his own was a useful exercise:

> Because before if you had just asked me to build a speaker I would be searching through the internet looking and looking. But when we took apart, and now know all these components and how they working together. I learned that…(Interview, 7/15/2016)

By taking apart a speaker Tom was able to figure out what materials he would need to build his own speaker.

After taking apart speakers, youth received design worksheets to sketch out the designs for their speakers. Tom was one of only three individuals in the workshop who

attempted to make two speakers, and one of only two who were successful in creating two functioning speakers. Tom's speaker design included two cups that you could pick up to your ears like cones in order to listen to his piece. In making his speakers, Tom struggled like several of the other participants to remove the coating from the insulated copper wire without snapping the wire. This is a necessary step in being able to create a simple circuit between the headphone jack and speakers. When asked what was most challenging about the workshop Tom stated:

> Tom: Building the speakers.
>
> Interviewer: Why were they so challenging?
>
> Tom: Because especially when it came to shaving the wires, I would start and start and the wires would just break and then I'd have too...I'd be frustrated but I'd have to keep my cool in order to go and try again.
>
> Interviewer: So how did you get over this challenge?
>
> Tom: Pure will. (Interview, 7/15/2016)

The tedious task of scrapping the coated copper wire was frustrating to Tom. In persevering and trying again, he was able to overcome this challenge. For Tom, of all aspects of the workshop, he was most proud of getting both his speakers to function.

In spite of the frustrations, Tom believed he learned a lot from the act of making a speaker. He described himself as a hands-on learner, so

> Just reading it or writing about it, I would've learned it but kept it on mind, as easily as, as if when I've built the speakers. (Interview, 7/15/2016)

It was through putting together his own speakers that Tom believed he learned. He believed he learned more than he would just through reading about how a speaker works.

In the process of building his speaker Tom spent time:

> Really think[ing] about how the speakers work and how the sound come out and how do you project it. (Interview, 7/15/2016)

It was not just the making of his speaker that helped Tom to think more deeply about sound, but it was through the interaction of his speaker projecting his sound piece that he felt he learned. Attempting to figure out how to make sure the sound piece he created could be heard through his quiet speakers forced him to think more about sound. Playing around with his piece until he made the sounds loud enough to be heard, while also having the variation in volume he wanted, helped him learn. Through the interaction of these two artifacts, Tom had to grapple with his understanding of how a speaker functions and how to make sure it projects the sounds he wanted it to.

Along with learning from creating his sound piece, taking apart a speaker, and building his own, Tom felt that he learned a lot from listening to the ideas of his peers. In particular, he believed he learned about the notions of silence:

> It gave me a different point of view how one person may say silence is absence of a sound or another person may say silence is the background noise you wouldn't notice anymore or another person may say that silence is static on the radio. (Interview, 7/15/2016)

In hearing the other people's ideas about what silence is, Tom thought about and learned more about how he understands the notion of silence.

Similar to Yarrow, there is evidence in Tom's sound piece and speaker of his ability to creatively express himself; but beyond just having agency, there is also evidence of his learning from creating his sound piece, breaking a speaker, and making a

speaker. For Tom it was the interaction between his speaker and his sound piece that had him thinking more deeply about sound. What is important to understand from his workshop experience is that, through both creating his sound piece and making his speaker, Tom found a context and connection for learning about sound. The making projects created a purpose for learning about sound.

Summary of Yarrow and Tom's workshop experience. In the above cases, it is evident that, due to in part to the knowledge, experiences, and skills that Yarrow and Tom brought with them into the workshop, they struggled in different ways with the various activities. In terms of building a functioning speaker, Yarrow's difficulty understanding simple circuits led to initial failure, while Tom found the skill of gently scraping coating from the copper wire particularly challenging.

In these two individual experiences, there is also evidence of youth learning and expressing themselves through the maker artifacts. Yarrow, through making her sound piece, was able to express how her individual identity characteristics go together well. Tom was able to share an intimate aspect of himself in how his mind functions. This is evidence of self-expression, a key component of agency. Along with self-expression, Yarrow and Tom each uniquely solved how to design and build a functioning speaker out of everyday object. While there were similarities across their speaker designs, they were not the exact same design. This is evidence of these youth being able to creatively express themselves—an aspect of agency.

Both Yarrow and Tom believed that making their speaker was important for their learning, though what they learned varied. Yarrow gained an understanding of simple circuits. She also mentioned how feeling the sound vibrate through her speaker helped her to understand how sound energy moves through a medium. Tom felt he learned about sound from the interaction between his sound piece and his speaker. All of this is to say that the learning which took place within this workshop was multifaceted, and that there were many places within the various activities that allowed youth to learn.

Through these maker activities, not only did they have a space to express themselves and take ownership of the projects, but they also learned about science. It is in the intersection of these experiences that Yarrow discovered she is creative and can make things. In this juncture, Tom was able to think more deeply about sound and be creative. Both Yarrow and Tom had a rich learning experience due to the overlapping of self-expression, science, and making within these workshop activities.

In the following sections I move beyond a deep dive into two individuals' experiences and instead look across the whole cohort for evidence of agency and for how and why various aspects of the workshop helped or hindered youth learning.

Evidence of Agency and Learning through the Maker Projects Across the Cohort

From the above cases, a picture has begun to emerge of youth's experience in the workshop. In this section I look across the entire cohort to understand broadly what the attendees' experiences were and, in particular, if there is evidence of youth having

agency and learning about science. I begin by focusing on the sound pieces for evidence of agency and if creating a sound piece provided context or connection for learning about sound. Following, I explore the homemade speakers for evidence of agency and to see if taking apart and building a speaker helped youth learn about sound. Finally, this section investigates the artist statements for evidence of agency.

Evidence of youth agency in their sound pieces. Agency is, in part, creative self-expression. As I mentioned earlier, creativity is a process of noticing problems, finding solutions, and creating an artifact with those unique solutions (Finke, Ward, & Smith, 1992; Kelly, 2001; Sawyer, 2012; Tardif & Sternberg, 1988). Self-expression means the youth in their work are referencing personal or internal ideas or notions, rather than established knowledge (Milbrant & Milbrant, 2011). In the youth sound pieces, I was looking for evidence of creative self-expression and ability to share aspects of their identity and/or take action via the sound pieces.

In the post-workshop interviews I asked youth to explain what their sound pieces were about. Table 9 provides youth responses to this question. I was interested if individuals were able to reflect themselves in their pieces, and so it is that which I have analyzed and not the youth descriptions. I provide these descriptions to give the reader a taste of what was created and to help the reader understand how youth believed these pieces reflected themselves. From these descriptions it is clear that youth create sound pieces about a range of topics.

Table 9.

Youth Descriptions of their Sound Pieces

Name	Description of Sound Piece
Alice	So it was basically the song "Powerful" by Alicia Keys mixed in with the chant. The Black Lives Matter Chant. And I wanted to—at the same time I'm just saying this different lives matter. They're saying how powerful we are, how we all matter and how innocent people are [dying] for something they didn't do. (Interview, 7/15/2016)
Alexander	It's a combination of different speakers and motivational speakers….(Interview, 7/15/2016)
Eliza	So my sound piece was supposed to be like a happy city so it was supposed to be little kids playing in the park and a bus going by and you can hear the trees going by and a little bit of construction and it was just the ideal image of the happy city. (Interview, 7/15/2016)
Haider	It's pretty abstract, it's telling a story through a basic thunderstorm lightning because when you first see it, it sounds pretty much like static with cricket noises in the back but when I tell you it's rain and it's during the night time it's a thunderstorm going on you notice the

	thunderstorm lightning electricity going out and all of that. So first it was a pretty simple rain, cricket sound, thunderstorm. (Interview, 7/15/2016)
Mark	Well in my sound piece it like represents my experience with the city. I've been living in the city all my life. So I chose to include sounds like sirens, footsteps, construction, traffic because those are like all the things you hear in the city. (Interview, 7/15/2016)
Talia	Yeah so basically it was made up of like, the entire sound track that I made myself was us walking around the institute like, from the Sports Exhibit, the Electricity Exhibit and Logan Square. So basically I got like, in the beginning its really quiet, I have birds chirping, I have like a buzz, you can hear that too in the background and then I have, I'm counting down from three and then everyone jumping at the electricity exhibit, the one that like, makes a really, that loud noise then I have, what was after that, I'm pretty sure then it was just walking around like, then it's like a little bit of dialogue, and then it's like walking around the museum, so you can like hear a lot of—then I like, it was not a really long piece, it

	was like, I think it was a minute and fifteen seconds by itself, so I like time lapsed it until like about twenty seconds, so like you can hear that air rushing a little bit better plus you can also like, hear it but then I have music in the back and beneath that so then like, that kind of drowns that out a little bit but not so much as that you can't hear it, and I also have the I have water, I was like from Logan Square like, I have the sounds of water and I want to put that because like, water is like very essential, and I feel like it's very, it makes people more like, humble because water is like a necessity for every human like, if you're rich, if you're poor, if you're like—no matter what you are you always need water so I find that really humbling and then towards the end, I basically like I cut off all the audio and I just let the music play up for a couple of seconds just to show how like sometimes music can like, drown out the world per se. (Interview, 7/15/2016)
Yarrow	It was basically me giving someone a letter through sounds describing who I am to them. And so it was like different parts of me and my personality put into one

	piece. (Interview, 7/15/2016)
Lucy	Oh, my sound piece, okay. So I didn't get to finish it on time, but what I was trying to do was create it, when you said it's something like describes us, sort of. So of course, I wanted to have some sort of song so I try to think of songs that are really important in my life. I thought—trying to think of sounds around the museum or outside of that would embody, like my actual life. So first thing I thought was traffic because I used to go to school in suburbs and hearing all the buses and stuff like that, it's not to see the quiet like birds chirping. So hearing the traffic outside is a reminder of how much I have changed personally, how much more I have been exposed to because I live in a school in a city now. So yes, I was gonna do some traffic and stuff, and then I was gonna have somewhat nature that's—I always loved nature and birds and stuff like that is always gonna be important to me. And then lastly, the song that I decided to choose was "Build Me Up, Buttercup," and you've heard it 'cause I played it but that's the song that my mom played on the car right home from the hospital

	where I was born, so that's always been like whenever I hear the song when my mom looks at me like, "Oh, my baby," so that's been like. Ever since then, that's an example of how much I was surrounded by music growing up and now, this is how I turned out. I love music more than anything in the world. So that song definitely that it did a good job describing me. (Interview, 7/15/2016)
Tom	It was completely random, but that's 'cause when I did it. I did it with the idea of random is several thoughts that have been passing through my mind. I just go in quick and write them down and then do a sound piece based off that. (Interview, 7/15/2016)
Sam	Getting two clips of music that describes me a lot. (Interview, 7/15/2016)

To determine if participants felt that they were able to share who they are through their sound pieces, I asked in the semi-structured interviews, "How does your sound piece reflect you?" The majority of the participants felt that their sound piece revealed aspects of themselves. There were two emergent descriptive codes for how their sounds pieces revealed aspects of the youth. The first is that the sound piece showed one

particular trait. The second was that the sound piece was able to explain what may appear to be dueling, incongruent, or multifaceted aspects of their personality.

Four youth expressed how their sound piece revealed one particular trait, for example:

> I am socially conscious. (Alice interview, 7/15/2016)
>
> I am peaceful. (Eliza interview, 7/15/2016)
>
> I am always driving round [*sic*] exploring new things. (Mark interview, 7/15/2016)
>
> [I] always give the best effort to things (Alexander interview, 7/15/2016)

All of these examples are statements about one aspect of an individual that these youth revealed in their sound pieces.

Four youth spoke of how their sound pieces provided an explanation of what may appear to be dueling, incongruent, or multifaceted notions of who they are, for example:

> …what I was aiming for was like I can be quiet but when I need to I can be also loud. (Haider interview, 7/15/2016)
>
> Because it shows that I'm always constantly thinking about different things and how I'm wondering, and being inquisitive. (Tom interview, 7/15/2016)
>
> I feel like that describes me a lot because like at one second I could be like, completely happy and then the next second like, just like I could like, just get upset over something just completely random like, my moods change as fast as like, the audio does. (Talia interview, 7/15/2016)
>
> It was very random and it was different pieces and I think my personalities don't really fit well with each other separately. Well when you put them together they match so yeah that was sort of I was reflecting my personalities and my traits through my music like the sounds. (Yarrow interview, 7/15/2016)

These statements show how youth were attempting to reveal the intricacy of who they are through their sound pieces and not just sharing one particular trait. For example, Yarrow wanted to express the complexity of how each aspect of herself might not "fit" well on its own, but all together she makes sense. She showed the layers of who she is through the random pieces she chose, which she believes work well together, just as her random interests fit together.

There is evidence that the sound pieces have a range of creative solutions. This is seen in the variety of notions of self shared and through revealing different kinds of information. Some of the youth chose to show one aspects of themselves, such as Alice, who says her sound piece shows she is "socially conscious." Others, such as Yarrow, felt her piece explained how her seemingly incongruent personality does work well together, just like her various sound clips work well together.

The role of creating a sound piece on youth learning about sound.

Along with understanding if youth were able to make their sound pieces their own through sharing who they are, I was interested in finding out if creating a sound piece provided a context for learning about the science of sound. To create their sound pieces, individuals spliced together sound clips to make one cohesive piece. This process required youth to manipulate sound that was displayed graphically in the sound editing software. In the post-workshop interviews I asked if creating a sound piece motivated them to learn about the science of sound. Five of the youth said it did not. Three youth were motivated to understand more about sound from creating their sound piece. Two

youth didn't answer this question. Three descriptive codes emerged for why youth found creating a sound piece motivating or not for their learning: 1) primarily focused on creating the sound piece, 2) they found other aspects of the workshop more motivating, and 3) that helped them figure out information.

The sound piece did not motivate youth to learn about sound, in part because they were focused on creating the sound piece, not on learning about sound. As Alice described:

> I mean, no, not really, I'm not really paid [*sic*] attention. Making the piece I just enjoyed making it, putting the music. But how sound moves not really. (Interview, 7/15/2016)

Alice wanted to create a good sound piece and so was paying attention to how it sounded, not really on how sound works. The other reason youth gave for the sound piece not being motivating was that other aspects of the workshop were more motivating, as Yarrow pointed out:

> **Interviewer**: Was creating your sound piece motivation to learn about how sound travels?
>
> **Yarrow**: Not really, the speaker.
>
> **Interviewer**: The speaker did that more?
>
> **Yarrow**: Yeah. (Interview, 7/15/2016)

Making the speaker was more motivating than creating the sound piece for Yarrow.

Three youth did feel motivated by the sound piece to learn about sound because it helped them to figure out information. Tom describes how he was able to experiment with the sounds to get them to play through his speaker:

> Because it shows that when you experiment cause if you have a small sound but it wont you can have a small sound piece but it won't come through what you have created, like speakers we created. So it gives you a chance to experience how maybe you need more bass on one part or something like that. (Interview, 7/15/2016)

It was making a sound piece that had to play through his homemade speaker that motivated Tom to figure out more about sound so his piece could be heard. Mark on the other hand spoke about how it was the actual representation of sound in Audacity that helped him learn:

> I think it did because on the actual program it's not like the sound waves, it was like low pitch and like high pitch and they showed me how like it can get louder or lower. (Interview 7/15/2016).

It was this representation and being able to play around with sound graphically that helped Mark understand louder and softer sounds.

Overall, creating a sound piece did not motivate most of the participants to want to learn more about sound. However, what is important here is that some individuals *did* find the sound piece as both a place to express themselves and to learn about sound.

Evidence of youth agency as seen in their homemade speakers. Along with creating a sound piece, youth built speakers for their sound piece to play through. The speakers in this workshop required four parts: a membrane, a magnet, copper wire, and a headphone jack. There were several choices youth had beyond these four required elements. The first was what material they would make their membrane out of, and there were several materials to choose from: bottles, plastics cups, cardboard, and construction paper. The second decision youth made was the shape of the speaker. Third, they had a

choice on the number of speakers they wanted to create—one or two. All of these design choices left space for youth to potentially come up with a variety of creative solutions for how to build a speaker. Similar to the sound pieces, I wanted to know if youth were able to have agency in making this object. Agency is in part creative self-expression. In investigating the handmade speakers I was looking to determine if youth produced a variety of creative solutions.

There were two overarching styles of speakers built—flat or three dimensional. Two youth built flat speakers while the remaining eight created three-dimensional speakers. Across both the flat and the three-dimensional there were seven distinct shapes of speakers: disc, cross, cone, box and cone, box, dumbbell, and cylinder. Of the three-dimensional shapes, the majority were cone shaped.

Table 10 shows all of the speakers, the materials used to construct the speakers, the number of speakers built, and the shape of the speakers. All of the speakers were built using the following materials: copper wire, headphone jack, magnet, and eletrical tape. Nine of the speakers included cardboard as part of their design. Three speakers used construction paper, two incorporated plastic cups, and three used plastic bottles. In terms of number of speakers built, all but two youth created a single speaker.

Before the art exhibit opened on Thursday afternoon, all of the youth had created at least one functional speaker. Alice was not satisfied with her speaker and so chose not to use it to play her sound piece; however, the remaining nine youth used their own handmade speakers to play their sound pieces for the exhibit visitors. For the most part

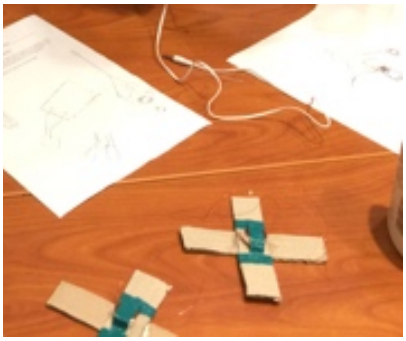
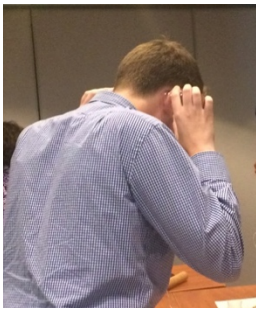
the speakers were very quiet, except for Yarrow's speaker. The loudness of Yarrow's speaker was due in part to the materials she chose and the design she created, and in part due to the fact that she played her sound piece off of a computer and not a low-quality MP3 player like the majority of the cohort used. Tom and Sam were the only youth to successfully create two functioning speakers.

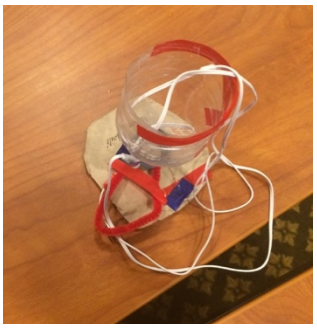
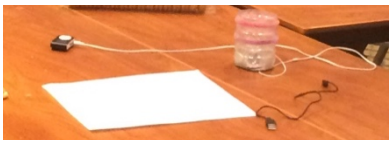
The range of solutions to the instruction to build a functioning speaker demonstrate that youth had space for creative expression in making their speaker.

Table 10.

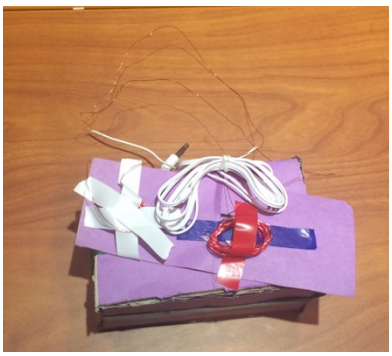
Handmade speakers coded for materials, shape, and number of speakers as evidence for creative self-expression

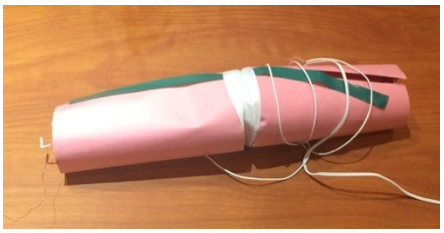
Student Name	Photo of speaker	Description of speaker
Eliza		**Materials**: cardboard, copper wire, headphone jack, magnet, electrical tape **Number of speakers**: one **Shape**: flat disc

Sam		**Materials**: cardboard copper wire, headphone jack, magnet, electrical tape **Number of speakers**: two **Shape**: flat cross
Tom	 Speakers incomplete  speakers in action	**Materials**: cardboard, copper wire, headphone jack, magnet, eletrical tape, plastic cup **Number of speakers**: two **Shape**: 3D cone

Haider		**Materials**: cardboard, copper wire, headphone jack, magnet, eletrical tape, plastic bottle **Number of speakers**: one **Shape**: 3D cone
Lucy	 	**Materials**: cardboard, copper wire, headphone jack, magnet, eletrical tape, plastic bottle **Number of speakers**: one

		Shape: 3D cone
Yarrow	 speaker being built  incomplete speaker	**Materials**: copper wire, headphone jack, magnet, electrical tape, plastic cup **Number of speakers**: one **Shape**: 3D cone
Alexander		**Materials**: cardboard, copper wire, headphone jack, magnet, eletrical tape, plastic bottle, pipe

		cleaner, construction paper **Number of speakers**: one **Shape**: 3D box with a cone
Mark		**Materials**: cardboard, copper wire, headphone jack, magnet, electrical tape, construction paper **Number of speakers**: one **Shape**: 3D box

Alice		**Materials:** cardboard, copper wire, headphone jack, magnet, electrical tape **Number of speakers**: one **Shape**: 3D dumpbell
Talia		**Materials**: cardboard, copper wire, headphone jack, magnet, electrical tape, construction paper **Number of speakers**: one

		Shape: 3D cylinder

The role of deconstruction and construction on youth learning about sound. It is evident from the above section that youth produced a range of creative solutions to the task of making a functioning speaker. This section focuses on whether taking apart and making a speaker were activities that provided for learning. With regard to deconstruction and construction, I asked eight of the youth if taking apart a speaker and building a speaker helped them learn. Half felt that they did not learn what they were supposed to learn while taking apart a speaker. Half of the youth felt that taking apart a speaker did help them learn. All of the youth asked felt they learned through making a functional speaker, and the majority of the youth believed that making a speaker motivated them to learn about sound.

One theme emerged for why youth felt that taking apart a speaker did not help them learn: They spoke of needing more scaffolding. As Yarrow explained:

> When you take them apart you just see someone's example I think, I think we need more instructions. That's what I needed, more instructions because I didn't understand just from seeing someone's speakers. (Interview, 7/15/2016)

In order to understand what she was seeing Yarrow needed more instruction for what to look for in the speaker. Several of the youth felt this sentiment of needing help to understand what to focus on in this activity. As Sam pointed out:

> Since just breaking apart, with my knowledge, I couldn't click on what's doing what. I needed more knowledge to understand. (Interview, 7/15/2016)

These individuals needed more guidance for the activity of taking apart a speaker to be a learning experience. Just taking apart a speaker was too vague a task.

The other four participants believed that taking apart a speaker did help them learn because it revealed the materials and the parts that make up a speaker. As Mark pointed out:

> I think it was because it helped us know what materials we need to create the speaker like copper, magnet because before that I would never know that a magnet was important to the speaker. (Interview, 7/15/2016)

Here Mark stated that he learned that magnets are an integral part of a speaker from taking apart the earbud. Tom noted that if he had not taken apart a speaker he would have gone searching on the internet to figure out what supplies he would need:

> Because before if you had just asked me to build a speaker I would be searching through the internet looking and looking. But when we took apart, and now [I] know all these components and how they working together. I learned that…. (Interview, 7/15/2016)

By taking apart the speaker Tom learned what components make up a speaker, allowing him to more easily make his own functional speaker.

Two descriptive codes emerged for why constructing a speaker helped youth learn. First, several participants claimed that building a speaker let them grapple with

their understanding of how a speaker works. For example, Alice stated that building a speaker:

> …helped me figure out how sound moved and how it worked. (Interview 7/15/2016)

In building a speaker Alice felt she learned how sound moves. Sam mentioned how he had to think about what the copper wire was going to do in order understand how to make his speaker:

> I was really confused on how it's gonna [*sic*] work. I thought about it and realized that how copper sends the signal it vibrates. So that, that way, I think making by myself helped me learn. (Interview, 7/15/2016)

It was by being forced to grapple with his understanding that Sam was able to figure out why the copper wire was important to making his speaker.

The second reason that youth gave for how building a speaker helped them learn was that making their speaker illuminated a concept or showed new information. Haider spoke about how building a speaker helped him learn about engineering and electricity:

> **Haider**: Well I mean it helped me learn about more of engineering stuff, more than sound. I know science is very well connected but it didn't make me feel like I was actually learning about sound and more about engineering and how energy goes through stuff and the miracle of copper wires. That's about, it wasn't much sound in it. I mean there was sound, it was a speaker but I didn't really learn more about sound, more of an engineer kind of electricity works.
>
> **Interviewer**: Do you think you would have learned as much if you hadn't built a speaker?
>
> **Haider**: Definitely not. If I didn't build a speaker I wouldn't really learn much about electricity whatsoever. So I mean building the speaker definitely did help me learn but not about sound, more about engineering

> and how electricity flows, how you make a circuit for sound to travel and stuff. Vibrations to travel and then make sound. (Interview, 7/15/2016)

By making a speaker Haider felt that he learned about other disciplines and not so much about sound. While Mark pointed out how making a speaker helped him learn where sound comes from:

> I think it did because it helped us, showed us where does the sound come from. Because I always thought sound comes out through the air but I learned that it comes from vibrations. (Interview, 7/15/2016)

In making his speaker Mark learned that sound comes from movement and not just magically from the air. Learning that sound is movement was also what Yarrow spoke about:

> I actually felt the vibrations and like how sound moves I saw it through my speaker. (Interview, 7/15/2016)

The act of making the speaker helped Yarrow feel the vibrations and understand further how sound travels through matter.

Not only did building a speaker help youth learn, the making of a speaker was motivating to the majority of the youth in wanting to understand how sound moves. Three youth however did not feel motivated to learn more from building a speaker. These individuals were more focused on just wanting to make a speaker and were not thinking about learning about sound. As Alice stated:

> **Interviewer**: Were you more motivated to understand about sound while you were building your speaker or you were motivated to just make it work?
>
> **Alice**: Yeah just making the speaker, making the speaker work. (Interview, 7/15/2016)

In a similar fashion to Alice, Yarrow said that she liked making the speaker but didn't think it was motivating to learn about sound:

> No, but I did like making the speaker. (Interview, 7/15/2016)

Getting the speaker to function was important but did not motivate all youth to want to learn more about sound.

For the majority of the participants, building a speaker was motivating since making a functional speaker pushed them to gain a deeper understanding. Eliza described how building was compelling:

> **Interviewer**: Do you think that making the speaker motivated you to understand how it works?
>
> **Eliza**: I think it gave me a deeper understanding of it.
>
> **Interviewer**: How did it give you a deeper understanding?
>
> **Eliza**: Of how noise travels from my phone to my speakers but I don't think it's something I do. (Interview, 7/15/2016)

Through making her speaker Eliza began to think about how sound travels from one place to another. Tom mentioned how making a speaker helped him think about how sound is projected:

> …it did force me to look and really think about how the speakers work and how the sound come out *[sic]* and how do you project it." (Interview, 7/15/2016)

Building a speaker helped Eliza and Tom think about how sound travels. Mark claimed that making a speaker motivated him to understand how sound travels through different mediums:

> I think it did because like how sound travels through the air and like travels through the materials we used. (Interview, 7/15/2016)

Building a speaker helped to foster deeper thinking and understanding about different aspects of how sound is able to move from one place to another.

Youth came up with ten different functioning designs for their speakers and, in the process of building their designs, they learned about sound, engineering, and making. The majority of the youth found building a speaker was an invaluable learning experience. For some of the youth, both taking apart *and* making a speaking helped them to learn about sound. Not only did making a speaker provide space for youth agency, but there is evidence that, through both making and breaking, youth learned.

Evidence of youth agency as found in their artist statement. The third and final artifact that youth created were their artist statements. As with the sound pieces and speakers, I investigated the artist statements for evidence of agency. Along with creative self-expression, agency is using the knowledge and practices of a particular context which helps individuals develop their identities and perhaps advance their positions in the world (Barton & Tan, 2010; Basu, Barton, Claremont, & Locke 2009; Hoechsmann & Poyantz, 2012; Sheridan, Clark, & Williams, 2013). In the artist statements, while exploring for youth creative self-expression, I also looked for evidence of youth expressing their identity and/or taking action. Evidence of youth expressing their identity would not only show that youth were developing their understanding of their own identities, but would also show evidence of self-expression. Artistic self-expression,

as defined earlier, is creating an artifact that is expressing personal or internal ideas or notions, rather than just established knowledge (Milbrant & Milbrant, 2011).

In terms of creative expression, I looked at two pieces of evidence in the artist statements: what artifact the youth wrote about and the emotions their artifact elicited. As mentioned earlier, expression of emotion is an integral aspect of creating an art piece (Batsleer, 2011). Youth could choose to write their artist statement about their speaker or their sound piece. Eight youth wrote about their sound piece and two wrote about their speaker. The artist statements covered a range of emotions. On average, a statement mentioned between one and five emotions, with a total of fifteen distinct emotions mentioned across all statements. Happiness was the only repeated emotion, with four individuals writing about how their piece reflected happiness. Two youth did not write about emotions in their artist statements.

The artist statements were also coded for revealing information about the individual's identity and/or an action. Only one artist statement was not codable for either identity or an action being taken. Eight of the youth wrote about how their sound piece or speaker revealed information or notions about themselves. For example, Haider wrote about his sound piece:

> My name is Haider and I created a sound piece entitled The Rain's Thunder Strike. This piece is significant to me because it shows how my personality is like. My piece evokes calmness. I chose to create this piece because it shows how I can both be loud and quiet through a basic story of rain. (Artist Statement, 7/14/2016)

In this statement, Haider revealed how his sound piece disclosed that he is both a quiet and loud individual. This is a particular aspect of Haider's notion of self.

Alexander, on the other hand, wrote about how the shape of his speaker divulged the type of music he enjoys:

> This piece is significant to me because I am inspired by Hip-Hop and my taste of music could originally be heard coming out of a boom box. My piece evokes the following emotions: good vibes, fun times, and originality. I chose to create this piece because of my love for music. (Artist Statement, 7/14/2016)

In this statement, Alexander shared both an aspect of his notion of self in the type of music he loves and the wealth of cultural knowledge he has about this genre of music.

Only one individual wrote an artist statement that could be classified as an action. Alice wrote:

> This piece is significant to me because I am appreciative of the awareness people want to raise for the unnecessary shootings of black men. My piece evokes the following emotions: strong, mighty, powerful, confident, and united. I chose to create this piece because I think that people aren't fully understanding the injustice for fallen, innocent black seat [*sic*]. My goal is to make it fully known that Black Lives Matter. (Artist Statement, 7/14/2016)

In this artist statement Alice wants to make it known that Black Lives Matter — not just that she is a socially conscious individual, but that she wants to spread her message to "…make it fully known that Black Lives Matter." Through this artist statement and her sound piece Alice is taking action to share her political views.

From the youth artist statements, there is evidence that they were able to creatively express themselves as seen in their writing about either their speaker or sound

piece. The range of emotions also speak to youth being able to come up with a variety of creative solutions to the assignment; and there is evidence of youth expressing their identity and, in one case, taking action. All of this highlights that youth were able to have agency in the workshop.

Summary of agency and learning through the maker projects across the cohort. Across the whole cohort of workshop attendees, through the three artifacts (sound pieces, speakers, and artist statements), there is considerable evidence of *all* the youth in the workshop being able to express themselves, find creative solutions, and in one case take action. In the sound pieces, youth were able to express aspects of their identity. They came up with ten unique working designs for speakers. The artist statements show youth expressing their identity and taking action. Provided with making activities placed within an artistic framework, youth were able to have agency in this workshop.

Beyond providing agency, the creation of the sound piece and speaker provided context, connections, and a reason for several of the youth to learn about the science of sound. For a few individuals, creating their sound piece offered a reason for learning about the science of sound. For many participants, both taking apart and making a speaker helped them learn about sound. Youth also spoke about learning about electricity and engineering from making their speaker.

As with the close look at Yarrow's and Tom's workshop experiences, a consideration of the whole cohort's experience shows evidence of multilayered and deep learning due to the activities' intersection of self-expression, science, and making.

In the next section, I move away from the artifacts to explore youths' perceptions of their workshop experience in terms of having space for self-expression and what helped them learn the science of sound.

Youth's Perceptions of Self-Expression and Science Learning within the Workshop

From the two cases earlier, and now from looking across the whole cohort, there is evidence of youth being able to creatively express themselves and also learn from the various maker activities. In this section, I examine whether youth valued having space for self-expression in their workshop experience and what they perceived helped them learn about the science of sound.

Was having room for self-expression important to youth's workshop experience? Interested in what the youth perceived to be significant to their workshop experience, I asked the following questions in their end of workshop interviews: 1) Of all three aspects of this project, learning about how sound moves, building a speaker, and creating a sound piece, which was most important to you and why? And 2) What part of the project are you most proud of and why?

In response to what was most important, five of the youth said creating their sound piece was most important to their experience. Three stated that building their

speaker was most important and two felt that learning the science was most important. When asked why these aspects were significant, three descriptive codes emerged: 1) act of creating, 2) self-expression, and 3) knowledge.

Three youth felt that the sound piece or speaker was important to their workshop experience because they were creating something. For example, Alice stated:

> I like creating things like creating the music. (Interview, 7/15/2016)

It was the making of the sound piece that was important to Alice. For Yarrow and Haider, it was the creation of their speakers that was important to their workshop experience. As Yarrow stated:

> Because I worked hardest on that and I felt like I was giving it a lot more effort into making this speaker because I wanted it to turn out okay and I just had more fun doing it. (Interview, 7/15/2016)

Beyond learning or the struggle to get a functional final product, the act of creating a sound piece or speaker was just plain old fun.

Four youth spoke about ways that the sound piece was important to them because it provided space for self-expression. For example, Tom stated:

> Because it gave me creativity…(Interview, 7/15/2016)

Tom found the most important part of the workshop was creating his sound piece because he believed he could be the most creative in that activity. For Talia it was being able to express herself that made the sound piece most important, as she explained how her sound piece:

> …showed me how you can express yourself through audio….(Interview, 7/15/2016)

Mark had a similar sentiment to Talia in that he believed the sound piece was most important to him because, as he described:

> I think making the sound piece was really important because you had to make something that represents you and put different sounds and make them sound natural. (Interview, 7/15/2016)

The most important part of the workshop for these youth was being able to express themselves, which they believed they were able to do through their sound piece.

Three youth believed that the most important aspect of the workshop was where they gained the most knowledge. For two of the youth, it was in actual science content. As Alexander explained:

> Because without learning about it, we really couldn't do all the other steps. That really gave us our understanding to complete the other steps. So, that was very necessary for us, the whole project. (Interview, 7/15/2016)

Without having the scientific knowledge, Alexander believes he wouldn't have been able to complete the other parts of the workshop. Eliza felt that she gained the most knowledge from making her speaker and therefore this was the most important aspect of the workshop to her.

Even through half of the youth stated that the most important aspect of the workshop was creating their sound piece, when asked what aspect they are most proud of, the majority stated building their speaker. Six youth were proud of their speaker. One individual stated she was proud of her sound piece. One person was proud of learning the

science and building his speaker, and one youth felt most proud of participating in the final exhibit.

There are two emergent descriptive codes for why youth were proud, the first was having a sense of accomplishment. Five of the youth spoke of feeling accomplished. In terms of being proud of his speaker Tom simply stated:

> Because I got them both to work. (Interview, 7/15/2016)

Just the fact that the speakers Tom created were functional was a moment of pride. Sam, in a similar fashion, felt accomplished that he created a speaker that produced sound:

> Since I never made a speaker and it was really cool for me to be able to make something not the best but something that was able to create some kind of voice. (Interview, 715/2016)

While his were not the greatest set of speakers built in the classroom, Sam was still successful in making speakers and was proud of them. Alexander felt both a sense of accomplishment for building his speakers and for learning, as he said:

> Well, building it because I like to see the final product of my work put in. Learning, because I'm happy to learn any day. (Interview, 7/15/2016)

Alexander, like several others, was proud that he was able to have a speaker that functioned.

The other emergent theme was a sense of overcoming a challenge, with four youth speaking about struggling and persevering. As Lucy explained:

> **Lucy**: I'm most proud of my speaker.
>
> **Interviewer**: Why?

> **Lucy**: Because it reflects how much I learned and, because I was very confused at first but then towards the end it was a piece of cake and I remember if I ever needed to just make one myself again, I think it I will be able to. (Interview, 7/15/2016)

Lucy, like many of the other workshop attendees, was proud of overcoming a challenge in order to build her speakers — not just the fact that she built a functioning speaker. Talia also expressed joy in overcoming the challenge and actually making a functioning speaker:

> I'd have to say the speaker, 'cause it was, it was like a struggle, it was like difficult but like I was able to do it and I actually made the speaker and it was actually functional, I really didn't think it was going to work like after, at the end of yesterday, I really didn't think it was going to work, but when it actually worked today, I was just like I felt so relieved that, I thought like happy that I was not like I was like, Oh my God, I actually made this work, like it's working, I did this. (Interview, 7/15/2016)

In working through the confusion and frustration to make a functioning speaker, youth were proud of their speakers.

Yarrow also spoke about overcoming a challenge: She was proud to be able to talk to the public during the art exhibit. As Yarrow explained:

> Me being able to talk to the public because I usually am shy towards people and what I accomplish and stuff so I don't like talking to people much. But I started to get more comfortable and I was like happy that I was able to not be scared to talk to them like I usually am. (Interview, 7/15/2016)

During the art exhibit, Yarrow had to overcome her shyness to be able to speak to the attendees, and was very proud of herself for being able to communicate with these strangers.

From the interviews, there is evidence that youth valued self-expression in their workshop experience, as half of the youth stated that being able to express themselves through their sound piece was the most important part to the workshop. Yet, interestingly, while self-expression through their sound pieces was important, the majority of the youth were most proud of their speakers—artifacts that they did not recognize as a space they got to express themselves.

What aspect of the workshop helped youth learn? When asked, *What aspect of the workshop helped you learn about the science of sound*? youth responded with four different aspects: building a speaker, the animation of sound moving through a medium, the daily discussions, and the lecture/PowerPoint presentation. Half believed they learned about the science of sound from the animation of sound moving through a medium. Three learned from the daily discussion, and one individual felt she learned from building her speaker and one mentioned a specific lecture/PowerPoint presentation. Two themes emerged as to why these aspects of the workshop were helpful for learning: visuals and hearing other peoples' ideas.

The animation of sound moving through a medium was most helpful because the visual gave information not understood in other forms, as Talia stated:

> I learnt a lot, like the animation that we saw really showed me how sound moves and like the red particle things that showed us like, that showed me like, how the particles are like, affected by the sound waves. (Interview, 7/15/2016)

The animation allowed Talia to visually understand how the particles in a medium react to the sound wave traveling through. Haider clarified how the animation allowed him to understand how sound moves like a ripple:

> It showed that the air, the force moving around the red dot, showed how sound expands, how it moves. Like how the sound source stays in a similar spot and everything else moves out. (Interview, 7/15/2016)

The animation helped Haider to understand how sound radiates outward. Others spoke of being "visual leaners" and how the animation allowed them to see how sound moves. For example, Lucy explained:

> I'm a visual person. So, hands-on experiments are cool, discussions are cool but when I see it on the board, like when I saw with the waves and stuff like that, that was like the most, the best demonstration for me personally because of the way I usually learn. (Interview, 7/15/2016)

Here Lucy described how she knew that she learned best by seeing and the animation allowed her to visualize the concept being explained.

Three youth felt that they learned the most from hearing other people's ideas. Yarrow noted that it was through hearing others explain how sound moves and what sound is that she was able to learn:

> Yeah with other people giving me ideas I was able to understand more what it was and other people explaining it like more I was able to understand it. (Interview, 7/15/2016)

Tom felt similarly as he described:

> I really get the idea from it different actually from what people thought about sound…. (Interview, 7/15/2016)

Hearing the other workshop attendees give explanations and share their ideas was helpful.

At the end of the 20-minute interviews I asked more broadly: *What helped you learn the most?* Youth mentioned five aspects of the workshop: daily discussions, building the speaker, other participants, the lectures, and the critique. In looking closely at the reasons why individuals believed these aspects of the workshop helped them learn, three descriptive codes emerged. The first code was the importance of learning from their peers. Four of the youth spoke about this theme. For example, Alice mentioned how critique from her peers and the art exhibit attendees helped her learn:

> Getting critiques from my friends when we did the critiques you know how the papers how they played it out loud helped me really helped me because getting their opinions and suggestions on the song helped me get better and having people come in and give me more suggestions, there's so much that get even better and better I can listen to other peoples' opinions about the sound it can get even better. (Interview, 7/15/2016)

Alice believed she learned the most about how to communicate through sound from her peers. Tom spoke of how he learned the most from hearing his peers talk about understanding the concept of silence in different ways. As Tom described:

> It gave me a different point of view how one person may say silence is absence of a sound or another person may say silence is the background noise you wouldn't notice anymore or another person may say that silence is static on the radio. (Interview, 7/15/2016)

It was from the various ideas his peers had that Tom was able to gain more information and come to his own idea about what silence is. Yarrow spoke of specific help she received from her peers in building her speaker that led to her learn:

> People around me like Haider he helped me with my speaker. So, like the other students they helped me to create the speaker I did so…. (Interview, 7/15/2016)

Yarrow learned the most from getting one-on-one help from her peers to solve a particular challenge.

The second theme was how the actual act of making led to the most learning. Alexander pointed out how the making of the speaker tested his understanding:

> Making the speaker helped me learn the most, I feel, because it really tested what I thought I knew and my understanding for how sound travels and the speaker works. So, that really showed my ability to recreate. (Interview, 7/15/2016)

By building a functional speaker Alexander reinforced his understanding of sound. Haider also believed he learned the most from building his speaker in part because it was fun and in part because he learned about other things besides just sound:

> Well I mean Audacity definitely helped out with pitches and stuff and lowness and high volume. That's something I didn't know before. All I knew was that oh whenever it gets loud it moves, the thing goes up and goes down. Well I guess I would say making the speaker would help me out most. Just learning about electricity and how the magnet needs to vibrate to make noises. But they were pretty much all important but I guess I'm just a little biased towards the making a speaker because it's kind of cool. (Interview, 7/15/2016)

Here Haider mentioned how building the speaker taught him about electricity and not just sound, leading to him learning the most from the actual making. Eliza pointed out how it was both the making and the tinkering that lead to her learning:

> **Eliza**: Probably the speaker part because I learnt most from it.
>
> **Interviewer**: Why do you think you learnt the most from a speaker part?

Eliza: Because I actually got the breakdown of what's happening.

Interviewer: Great. So, what about building the speaker helped you learn do you think? The actual putting it together, was it the taking apart?

Eliza: Putting it together and being able to fix the problems.

Interviewer: Yeah, tinkering with it?

Eliza: Yeah. (Interview, 7/15/2016)

Eliza learned from figuring out how to fix what was impeding her speaker from functioning.

The last code to emerge from what helped one learn the most was how the lectures/PowerPoint presentation led to understanding how and why of the workshop activities. As Mark pointed out:

> I think the presentation because it showed us how to put stuff together and how to add, edit stuff, make the speakers too. (Interview, 7/15/2016)

In this quote, it evident that Mark believed that the explanations and not the act of doing were most helpful to his learning. Meanwhile, Sam felt being able to reread what was in the PowerPoints helped him:

> You were just able to reread it over and over again. It was just easy to understand. (Interview, 7/15/2016)

It was being able to go back and read over and over again certain information that helped Sam learn.

In responding to what helped them learn the science, compared to what helped them learn the most, youth brought up different aspects of the workshop. In terms of science learning, youth tended to focus on more traditional classroom aspects such as

watching an animation. When asked about what helped them learn the most, youth spoke of learning from making their speaker and interacting with their peers.

Summary of youth perceptions of self-expression and science learning. Overall, youth valued having room for self-expression within their workshop experience. The project in which youth felt they could have the most creative expression was their sound piece; yet this was not a project that youth felt led to them learning. Even though they did not presume they learned from creating their sound piece, youth believed that the sound piece was of great value to their workshop experience.

Different aspects of the workshop helped youth learn how sound travels. Many spoke about how watching an animation of sound moving through a medium helped them understand how matter is affected by sound and how sound radiates outward. While most youth did not feel that they learned about sound from creating their sound piece a few did feel that they learned about loud and quiet sounds by playing with the graphs in Audacity. Youth also mentioned how making their speaker was both motivating to learn about how sound moves through materials and also helped them gain knowledge beyond just sound, for example, Hadier spoke of learning about engineering from making his speaker.

Of note here is that youth appreciate and want the space within the workshop to put their own ideas, notions, and creative solutions into the projects. While youth did not always recognize all the ways that maker projects helped them learn, there is evidence of individuals exerting their agency and finding reasons for learning science content through the maker activities. It is in the junction of self-expression and making and, for some

individuals, also the interaction of science that youth experienced the richest learning moments.

In the following section I present the results to the pre/posttest assessment of sound and youth interview answers to how sound travels.

Youth Understanding of Sound as Energy

To determine if youth gained in knowledge of sound as energy, I analyzed youth pre/posttests and interview results.

Comprehension of sound as energy. A Wilcoxon signed rank test run on the pre and posttest scores indicates that youth's knowledge on sound from pre to post test, W=2.5, $p<.01$, $r=0.05$, significantly increased from a mean pre score of 3.7 to a mean post score of 5.1. This is promising evidence that youth were able to gain in knowledge that sound is energy. There is even more promising evidence from the youth interviews. Only one individual remained steadfast with a low level of understanding, having a material view of sound. Two participants had a hybrid understanding of sound as energy. The majority, seven individuals, had a high level of understanding that sound is a process.

Alice is the one individual who remained convinced that sound is matter, as is evident in her interview responses:

> **Interviewer**: So, can you tell me how sound moves?
>
> **Alice**: Like through vibrations—like through vibrations I think. Like when something vibrates it send off a sound. It's like when something vibrates it sends off a sound and then you can hear sound waves travel.

Interviewer: Okay great. So, is sound matter?

Alice: I think everything is matter so we actually – (Interview, 7/15/2016)

Alice believes that vibrations "send off a sound" which suggests vibrations send a physical thing. When asked directly if sound is matter, she responds, "I think everything is matter." These statements indicate that Alice does not understand that sound is energy rather than a thing.

The two participants with the hybrid view of sound revealed a conceptual misunderstanding when they could not explain how to create a louder sound. For example, when asked how to make a loud sound, Alexander responded:

> You would have to vibrate your vocal cords at a higher frequency. (Interview, 7/15/2016)

Frequency is how fast sound is traveling. Sound can travel quickly but still be quiet. To make a louder sound, one needs to put in a greater initial force to create the movement that is sound. Alexander's answer shows that he did not know what frequency is, nor did he understand how more energy needs to be added to the system to create a louder sound.

The remaining seven individuals explained sound as a process and not as something with the properties of matter. For example, Sam explained how to create a loud and quiet sound:

Interviewer: And how do you make a loud sound?

Sam: By putting more force, more vibration into it.

Interviewer: And what about the quiet sound?

Sam: Less force, or less vibration for sound.

> **Interviewer**: And why do you think there's no such thing as true silence on Earth?
>
> **Sam**: Because there's air around us?
>
> **Interviewer**: What does that mean? Why does it not matter?
>
> **Sam**: Since if there's air, there's always move(*sic*) for sound to travel which means that there's no way sound cannot travel or move. (Interview, 7/15/2016)

Sam understood that for there to be a louder sound there needs to be more initial energy in the system. He also knew that sound moves through a medium and because on earth we have air all around us, there will always be a medium for sound to travel through, therefore it is impossible to have complete silence on earth. Another example of an individual expressing her knowledge that sound is energy is seen in Yarrow's explanation of how sound travels:

> So, it's energy that moves, it's like vibrations that move through matter and it needs something to, like, it needs something to move in order for it to move through matter. (Interview, 7/15/2016)

From this answer, it is clear that Yarrow understood that sound is energy, and in order for there to be a noise something had to create the initial movement of energy through the system. Along with sharing how to create loud and quiet sounds, and how an initial movement is needed for sound, Tom explained why you cannot hear in outer space:

> **Interviewer**: So, is sound matter?
>
> **Tom**: I would say no.
>
> **Interviewer**: Can you hear on outer space?
>
> **Tom**: No, because space is a vacuum.
>
> **Interviewer**: What does that mean?

Tom: It means there is no air.

Interviewer: Why does that matter?

Tom: Because air is matter and you need and sound travels through matter. (Interview, 7/15/2016)

Tom stated clearly that sound travels through matter, and that sound is not matter itself. From these answers, as well as the pre/posttest results, it is evident that the majority of the participants by the end of workshop have a sophisticated understanding of sound as a process of energy transfer.

Summary of youth understanding of sound as energy. The results from both the pre/posttest and youth interviews show promising evidence that youth were able to gain in knowledge that sound is energy and therefore not matter.

Chapter Summary

In this chapter I reported the findings from my data analysis which reveal that, through the maker activities within this workshop, youth were able to express themselves, come up with creative solutions, further their notions of self, and in one case take action. Several places within the workshop allowed for youth expression of agency. For many of the youth, being able to creatively express themselves was an important aspect of the workshop. In terms of science learning, there is promising evidence that youth were able to gain in knowledge about a challenging science concept of sound. Various aspects of the workshop helped youth learn, but all youth believed that building a functioning speaker was consequential in their learning.

It was through making, that individuals expressed their agency, and it was through making, that many believe they learned science. In the overlap of self-expression, science, and making, this workshop was able to provide a deep learning experience for the attendees.

In the following chapter, I consider how these findings speak to the design decisions I made in creating this workshop. I focus on two criticisms of the maker movement: who is considered a maker, and what is considered a maker project. I also explore how making can help with youth learning about challenging science content.

Chapter 5: Discussion

This study set out to explore if a novel science and art making workshop focused on sound would provide learners space to exert their own agency while gaining in understanding of challenging science knowledge. From the results, it is clear that the participants of this workshop were able to express themselves creatively, had space to bring in their own identities, and gained in knowledge. In this section, I consider the design choices I made in creating this workshop and how these decisions influenced youth expression of agency and learning from both a making and science education perspective. I begin by focusing on how this workshop might be considered successful for a wide range of diverse youth. I go on to look at why agency and creativity are important to consider for maker activities; and, finally, I explore the design choices that helped or hindered youth science learning.

This chapter goes onto to present suggestions for improving the workshop design, limitations of this study, and places for further research.

Equity Oriented Maker Environment

One of the primary criticisms of the maker movement has been that there is a narrow notion of who is considered to be a maker (Buechley, 2013; Rose, 2014). Makers within popular media tend to be considered white, male adults who have leisure time and disposable income to spend on the hobby of making (Buechley, 2013; Rose, 2014). The dominance of white men and boys on the covers of *Make* magazine presents an image to

the public of who belongs and who is not welcome to the name "maker." This narrow view of who can be a "maker" also leads to an assumed lack of knowledge and skills from individuals who do not have the privilege to have the hobby of making, or whose circumstances *necessitate* that they fix or make instead of purchase new items (Rose, 2014, Vossoughi et al., 2016). As making begins to be found in more and more informal and formal spaces, it is vital that efforts be made to create environments that are welcoming to all, even to those who may not identify as makers or whom society does not initially view as makers.

In creating my workshop I made several choices to help create an inclusive environment. The first choice was to implement this workshop as part of the science outreach program for non-white, non-wealthy youth who achieve in STEM. In terms of the actual design of my workshop, I decided it would be multidisciplinary, hoping that a variety of individuals would be able to find at least some aspect of the workshop that was interesting to them. I also put a strong emphasis on self-expression in order to open up the space for youth to be able to bring their funds of knowledge in to the environment. It has been shown that incorporating funds of knowledge in a learning environment can help non-dominant youth feel a connection to the learning environment and be able to achieve (Basu & Barton, 2007; Basu, Barton, Clairmont, & Locke 2009; Seiler, 2001). In choosing to frame much of the workshop in an arts perspective, I hoped to provide a space for self-expression that did not boil youth culture or experiences into static, banal

notions (Ares, 2006) but would instead allow for a wide range of ideas and notions of self to be expressed.

To begin to understand the wider range of makers, Vossoughi et al., (2016) and Barton et al., (2016) put a call out to the research community to broaden the understanding of how and why maker activities for non-white non-middle class youth are successful. Learning is complex and what constitutes success is complicated. From the youths' perspective, there is a tension between what they believe helped them learn and where they felt they were able to express themselves. The participants understood the more traditional school-like parts of the workshop to be places of learning. For many of the youth, the project where they felt they had the most space for creative expression— their sound piece — was not part of their learning. Yet, according to them, this artifact was vital to the workshop. This highlights a tension between learning and agency, or perhaps between what is privileged to be understood as learning.

Overall this workshop could be understood as successful from both a science education perspective and from an equity standpoint. The majority of the youth left the workshop understanding that sound is energy. All of the youth, no matter their race, ethnicity, gender, or socioeconomic status, were able to have agency in the learning environment as seen through their, sound pieces, speakers, and artist statements. However, a closer look at the individuals' experiences shows a more nuanced story. For example, Alice left the workshop believing sound is a physical object, which is an incorrect scientific understanding. Yet, she was the only participant to push at the

boundaries of her sound piece and to take action. Alice left the workshop without a full understanding of sound but with a greater appreciation of how to communicate through sound. Even after the workshop, she planned on continuing to work on her sound project to improve it based on the suggestions she received during the art exhibit. Alice was also the only participant who managed to hurt herself twice while attempting to build her speaker. So, while she learned and was able to express herself through this workshop, she struggled with both making her speaker and understanding the science of sound. Eliza, on the other hand, did leave the workshop understanding that sound is energy. But unlike Alice, she did not find her sound piece to be a place where she really got to express herself or that was significant to her. Eliza attempted to create a sound piece that would share how peaceful she is, but due to not being as technologically savvy as some of the other participants, she struggled with this task. While Eliza experienced some setbacks when building her speaker, she did not injure herself, and believes she learned through tinkering with her speaker to get it to function. Eliza expressed herself through her solution to building a speaker and learned that sound is energy. These two examples highlight how youth brought with them different skills and knowledge that both helped and hindered their learning experience. When the research community is asked to report on what is successful for non-white non-middle class makers it is important to understand that how one experiences a learning environment is due to more than just race or socioeconomic status, but is due to the funds of knowledge that one has to bring into the environment.

Critiques of the maker movement have pointed out that the education community has a tendency to view "…working-class communities of color…as targets of intervention rather than as sources of deep knowledge, and skill…" while dominant communities are seen as having "something to teach or offer rather than something to learn" (Vossoughi et al., 2016, p. 212). While this may be true, it is also evident that individuals come into learning environments with a variety of skills and knowledge. Alice entered with few skills that would help her to cut cardboard, while Haider was the first to complete his speaker and spent lots of time helping his peers problem-solve for why their speakers were not making noise. Tom loves to make things and was one of the few participants to attempt to build two speakers. Eliza needed a lot of help from Haider to get her speaker to function, but in the end was successful and felt that she learned a lot from building her speaker. All of this is to demonstrate that *all* the individuals in this workshop brought with them varied skills, knowledge and experiences. Just as one should not assume a deficit in ability, one should not assume a plethora of knowledge either.

In creating a learning environment that neither assumes knowledge nor a lack thereof, my workshop suggests that one solution may be a multidisciplinary approach. The diverse youth who participated in my workshop were all able to find different aspects of the workshop engaging and places where they could bring in their own expertise and knowledge. For Alice this was her sound piece, for Haider it was building a speaker, and for Lucy it was learning about the science. Perhaps success for non-white non-middle

class youth means having multiple avenues for them to have agency and ways to connect with the learning.

In the following section, I explore the importance of having an arts framework for understanding the maker activities is for youth creativity and agency.

Art-Forward Maker Activities

Another critique of the maker movement is that, while maker activities often incorporate teaching techniques from studio art classrooms, maker artifacts tend to not include art-forward projects (Buechely, 2013; Vossoughi & Bevan, 2013). By art-forward projects I am referring to projects where the expression of the idea and emotion is central to the project, rather than the technology that helped to create the project. Maker projects tend to be tech-forward, wherein the technology is primary and the expression of the idea or emotion is a secondary consequence. For example, when Buechley (2013) did an audit of the covers of *Make* magazine, they highlighted three types of projects: robots, electronics, and vehicles—all projects that are successful because the technology does something, not because they convey an idea or emotion.

I made several choices in creating my workshop to highlight the artistic side of the maker activities. These choices included critiquing the sound pieces as well as requiring the youth to write artist statements. Another important design choice I made was in what types of sound artists I introduced in the workshop. I did not bring in examples of contemporary popular musicians. Instead I chose an avant-garde composer, John Cage, who is best known for his piece entitled *4'33"* (often called "Four thirty-

three"), in which he sat at a piano onstage for four minutes and thirty-three seconds. The music was the silence of the space. I also brought in recordings by the artist Allen Berliner, who creates sound installations, and Olivia Block, a composer who favors found sounds. I made this choice of sound artists to make it clear to the youth that there is more to sound than just music. I also hoped to show how, in the intentionality of one's choices, sound can be used to share meaning and feeling in more ways than through music. Finally, I wanted to encourage an environment where any individual could create something with sound regardless of musical talent

The following paragraphs focus on how highlighting the artistic side of the maker projects allowed for youth agency. Art is a form of communication (Dewey, 1900/1956), and these youth were able to not only share ideas, but share ideas centered on themselves, their experiences, and their skills through exerting their agency. This study defined art as creative self-expression. In the youth sound pieces, speakers, and artist statements there is evidence of creative solutions and youth self-expression. Beyond just being able to be artistic, these aspects of the workshop allowed youth to express their agency—creative self-expression achieved through using the knowledge and practices of a particular context which helps individuals develop their identities and perhaps advance their positions in the world (Barton & Tan, 2010; Basu, Barton, Claremont, & Locke 2009; Hoechsmann & Poyantz, 2012; Sheridan, Clark, & Williams, 2013).

In creating her sound piece, Alice not only expressed her agency, but was also able to bring in her own knowledge and experience of being a young black female. Alice

spliced together a pop song and a protest chant to create a piece that conveyed to others the importance of understanding that Black Lives Matter. For Alice, her sound piece served as a bridge between her funds of knowledge and the skills and information taught in the workshop. Alice learned how to communicate through sound.

Along with the sound piece, the homemade speakers were also an opportunity for youth to have the freedom to creatively express themselves. The participants built a wide variety of speaker shapes, from Xs to cones to three-dimensional boxes. In their creative expression, youth built bridges between their funds of knowledge and the workshop. Alexander built a speaker that harkened back to the original boom boxes through which hip-hop was traditionally played on the street. In choosing to build such a shape, Alexander communicated his cultural knowledge and enjoyment of a particular genre of music. Talia chose to create a cylinder-shaped speaker to look similar to The Pill, a commercial speaker that she herself owns. Here Talia was able to bring in her knowledge of speakers when choosing how to build her own speaker. In the creative solutions youth came up with in building their speakers, there is evidence of youth bringing in their funds of knowledge.

It is important to point out that these projects are centered within the culture that youth interact within and are members of — for who can make and what is made are culturally situated across time and space (Barton et al., 2016). This is visible in the subject matter Alice tackled (police brutality that directly affects her community) and the cultural history that Alexander referred to regarding why he created a particular shape of

speaker. Youth were able to use these artifacts (sound piece and speaker) as a place to bring in their own knowledge, skills, and identity.

There are several reasons for the importance of why the sound piece and speaker acted as both bridges to youth funds of knowledge and as a place for youth agency. One critique of the funds of knowledge literature is that only a few individuals are able to have their funds of knowledge be honored in the learning environment. We see this through only one minority community group building a house (Hammond, 2001) or only a few students being asked to help co-create a curriculum (Barton & Tan, 2009). In my curriculum, however, there is evidence that *all* of the youth had more than one opportunity to take ownership, express themselves, and be able to bring in their funds of knowledge. In choosing art as a way to connect to youth funds of knowledge and agency, this curriculum does not need to be recreated for a new set of participants as would be true if a few individuals helped to co-create a lesson (Barton & Tan, 2009). By having space for agency and connection to youth through the projects they themselves created, I avoided bringing in a trite connection to youth culture (Ares, 2006). Through a curriculum that was STEAM-focused, youth were able to express themselves, create connections to their funds of knowledge, and learn.

This points to how valuing the arts within a maker project is important for more than just a teaching tool. First, it is clear that youth were able to learn *about* and *through* the arts (Upitis, 2011). Second, the arts are able to create a connection for some youth to their experiences and knowledge. Third, by highlighting the arts in the maker artifacts in

this workshop, there is evidence of the youth being proud of their projects and seeing the artifacts as necessary parts of their learning experiences and not just an odd project an adult made them complete. As maker activities are beginning to enter more formal education spaces, it is important that the maker artifact hold importance to both the learner and the educator. My workshop hints at one possible way to ensure that a maker activity is more than a novel experience.

The next few paragraphs explore the design choices I made in terms of science learning.

Science Learning through Making

For nearly a century, philosophers, educators, and researchers have been writing about the importance of creating connections to learner lives in order to help foster learning (Dewey, 1938/1963; Esach & Schwartz, 2006; Papert, 1980; Sieler, 2000). I made several design choices in creating the curriculum for this workshop that were intended to help create a connection between the learner and the knowledge to be gained. One of the primary choices I made was to include art—a place for creative self-expression—through both the sound piece and speaker. As others have noted, the production of art allows for a rich learning experience (Halverson, 2013; Peppler, 2010; Upitis, 2011).

In the sound pieces created in this workshop, there was evidence of individuals being able to express themselves and, for a few participants, learning about the science of sound through their sound piece. For example, Mark felt that, in manipulating the

graphical representations of sound in Audacity, he was able to learn about pitch and volume. This is notable because Houle and Barnett (2008) found no gains in understanding after their intervention, which had youth interacting with graphical representations of sound. Houle and Barnett express that the lack of understanding could be due in part to the confusion of how sound is graphed. Yet in my workshop, Mark found that manipulating sound graphically helped him gain knowledge about sound. Tom also believed he learned through creating his sound piece. He felt that figuring out how to make sounds loud enough to play through his quiet speaker forced him to think more about sound. Peppler and Glosson (2013) similarly found that, when youth had to use finicky materials, they were forced to gain a better understanding of the science— just as Tom had to figure out more about sound in order for his sound piece to be heard through his quiet speaker. What is notable here is that youth were able to find a context and connection to learning about the challenging concept of sound through creating a sound piece.

Having youth physically build their own functioning speakers was another critical design decision I made in creating the curriculum. Through the act of making their own speaker, individuals learned, for the making illuminated concepts. For example, Yarrow spoke of feeling the vibrations through her speaker which helped her understand how sound travels through a medium. The planning and executing of the project allowed youth to gain knowledge beyond sound; as Haider pointed out, he learned about engineering and electricity from making his speaker. Creating the sound pieces along

with making speakers allowed youth to find relevance for learning that sound is energy while being able to express their own agency within the learning environment.

Understanding that sound is energy is challenging for elementary through college-aged students (Eshach & Schwartz 2006; Houle & Barnett, 2008; Hreptic, Zollman, & Rebello, 2010; Mazens & Lautrey, 2003). Previous curriculums focused on learning sound have not shown if learners felt a connection to learning about sound (Houle & Barnett, 2008; West & Wallin, 2013), yet this is a primary suggesting for improving said learning. Some have suggested that the learner will not learn when there is no connection between the learner and the science being taught (Bouillion & Gomez, 2001; Brickhouse, 1994). In this workshop, there is evidence of youth finding a connection between the science being taught and the maker projects within this workshop. This hints at the maker activities not only allowing for youth to creativity express themselves but also as tools for learning the science of sound.

Even though several participants found a connection between the maker activities and learning about sound, the majority of the youth felt they learned about sound not from creating their sound piece or making their speaker, but from the more scholarly aspect of the workshop. In particular, many spoke of gaining a greater understanding of sound from watching the animated image of sound traveling through a medium. This does not mean that creating a sound piece or building a speaker were not valid learning experiences, but more that there was a missed opportunity for me, as the educator, to highlight the connection between these objects and the science. In terms of science

learning, the valuable takeaway from this workshop is that making can provide a purpose and a connection for some individuals to want to learn about challenging science content.

Summary of Workshop Design Decisions

In designing the curriculum that was multidisciplinary, bringing in studio arts teaching pedagogy (Hetland et al., 2007), engineering design (Tayal, 2013), and constructionism (Papert, 1980) among other teaching tools, I hoped to create a learning environment where a variety of individuals would be able to express themselves and learn. There is evidence of youth finding different aspects of the workshop where they could creatively express their agency along with being able to bring their funds of knowledge into the learning environment—youth had reasons to learn about sound, and places to take ownership of the learning experience. In this workshop, there is evidence of youth learning that sound is energy, a concept which eludes elementary through college-aged students (Eshach & Schwartz 2006; Houle & Barnett, 2008; Hreptic, Zollman, & Rebello, 2010; Mazens & Lautrey, 2003). Perhaps most noteworthy is that, for some youth in this workshop, it was the same project in which they were able to express their agency that they were also able to find a context and connection for learning the science content. For these youth it was in the intersection of self-expression, science, and making that they gained agency and relevance for learning content knowledge.

Improvement to the Design of the Workshop

As this was an exploratory study, there are several places within the workshop which could improve with a few simple changes. I made the choice to provide time for youth to critique and rework their sound pieces, but I did not provide the same opportunity for the designs of their speakers. This was a choice made in part due to the time constraints of the workshop. I believe that if I had given time for each speaker design to be critiqued in terms of volume and ease of listening, along with time to redesign and to rebuild, this could have been a very rich learning opportunity. At the end of the art exhibit, there was a brief discussion about why Yarrow was able to create such a loud speaker compared to the other participants. This discussion suggests that the attendees would appreciate time to think more about their designs and improve upon them. This would provide another opportunity for youth to grapple with their understanding of sound and speakers as well as take ownership of the project while they work to refine their creative solutions.

In order to create time to rework the speakers, I would shorten some of the activities and remove others. I would take away two of the sound audits and just do a sound audit of the classroom to convey the notion of what silence is. It did not seem like doing three different sound audits added enough of an impact to warrant the extra time. Another change I would make would be to provide the requirements for the sound pieces and brainstorm worksheet before we went to collect sounds from the museum and the neighborhood. I believe this would help to focus the sound collection, resulting in less

time wandering around aimlessly. Another place where I could gain time for the speaker reworking is through cutting one of the demonstrations. None of the youth spoke of the sugar dancing activities as something that helped them learn about sound, and for this reason I would not do that demonstration again. The extra time gained from removing and shortening these activities would, I believe, result in a richer making learning experience.

Along with wanting more time for critique of the speakers, several youth spoke of needing more scaffolding or guidance when taking apart a speaker. It would have been interesting to have youth take apart several different-looking speakers to see that there are key parts that all the speakers have in common. This might allow them to begin to understand what parts you need to have to make a speaker. I also would revise the worksheet for this activity to include more guidance over what to be looking for while taking apart the speakers.

Limitations

While the findings show that youth learned and were able to express themselves; this study is not without limitations, which may dampen these positive results. In terms of study design, there are drawbacks to the fact that I had only one small group of participants. For the quantitative data, by not having a comparison group, it is impossible to say that the increase in knowledge is purely from the workshop. For both the qualitative and quantitative data, the small sample size means that it is unreasonable to

make generalizations from the findings. Because of these limitations I used multiple data sources for each of my research questions to bolster the robustness of the results.

A second limitation to the study findings is that the participants were part of an outreach program that specifically recruits individuals with a demonstrated aptitude and interest in STEM fields. Due to the specialized nature of the participants, it is hard to say whether youth who do not do well in school, who may not enjoy STEM content, would learn the science from a short four-day workshop. Along with knowing how to do well in school and liking STEM fields, these youth self-selected to participate in extracurricular STEM enrichment, so it is unclear if less willing participants would find a way to engage with my workshop.

A third major limitation to this study is that I was the curriculum creator, the educator, and the researcher. I came into the workshop with biases and expectations. Just as the youth's learning was influenced by their life experiences, knowledge and skills, so was my teaching, research, and curriculum creation influenced by my background, knowledge, and skills. I do not know, for example, if another educator would get the same results from implementing my curriculum, or if an outside researcher would notice moments and experiences that I missed.

Future Studies

Even with the limitations to this study, the results are encouraging. They suggest that this approach to teaching challenging science content gave space for youth agency and led to learning. I believe the next step for this research would be testing to see if this

curriculum could work with a broader set of participants who do not have both an aptitude for and a love of STEM fields. It would be interesting to implement this curriculum in a studio art classroom and to see if I get similar results or not.

A place of missed opportunity from this study was that the youth were given time to critique and rework their sound pieces, but were not given this opportunity for their speakers. It would be interesting in a future study to have youth critique and rework their speakers. I would want to know if, through a reworking of their speakers, youth would learn more about sound, electricity, and engineering, along with design. Would more youth feel that they were able to express themselves creatively through their speaker designs?

As mentioned above, there were a variety of places within the workshop that allowed for different youth to feel engaged and be motivated. I however did not set out to focus on engagement or motivation in my research questions. In a future study, it would be interesting to investigate why some aspect of this workshop were motivating to some and not to others. This would be important to know in order to improve upon the design of the workshop.

I believe the exhibit at the end of the workshop was an important learning experience. Communication comes in many forms and in this workshop, several of the youth spoke about how learning to create a sound piece broadened the ways they knew how to express themselves. Similarly, several youth mentioned how speaking to the exhibit attendees boosted their confidence and improved their oral communication skills.

In a future study, it would be interesting to explore more fully the role that an authentic audience (the attendees to the art exhibit) played in youth's learning and agency.

Conclusion

This study set out to determine in what ways youth were able to have agency and in what ways youth were able to gain in science knowledge through a multidisciplinary art and science maker workshop. Philosophers, researchers and educators have repeatedly pointed to the power of listening, respecting and giving voice to all learners (Dewey, 1900/1956; Moll et al., 1992; Vossoughi et al., 2016). In this study, youth were able to express themselves in the sound pieces they made, the speakers they created, and the artist statements they wrote. There is evidence of youth being able to bring their funds of knowledge into the learning environment through the production of these artifacts. Through providing space for art and making, youth knowledge, experience, and skills were not boiled down to some banal understanding. A diverse set of non-white non-middle class youth were able to have agency and learn through this workshop.

In terms of the science learning, there is encouraging evidence that, in this workshop, youth learned that sound is energy. This study was able to explore and share what youth perceived helped them learn this challenging content; some youth were able to learn about sound from creating an original sound piece *and* from building a speaker. Overall the majority of the youth grew in their knowledge of sound as energy. This is significant, as sound as energy is a challenging science concept for elementary school through college-age individuals to understand (Asoko, Leach, & Scott, 1991; Esach &

Schwartz, 2006; Houle & Barnett, 2008; Linder, 1992; Pejuan, Bohigas, Jaen, & Periago, 2012; Wittmann, Steinberg, & Redish, 2003).

APPENDIX A

An Exploration of Sound from an Artistic and Scientific Perspective
Theme: Sound tells a story.
Goals: After completing this curriculum youth should be able to:

- Explain that sound is energy
- Give a brief explanation of how a speaker works
- Explain what silence is from both a scientific and artistic perspective
- Explain how the sound piece they created reveals something about themselves

This set of lessons consists of four three-and-half-hour activities. Youth will investigate the notion of sound from both a scientific perspective and an artistic perspective. Youth will record and edit a sound clip that reveals something about themselves. They will build their own speakers from which their sound piece will play. Youth, parents, and the community will be invited to attend an opening of the sound installation exhibit to share the projects the youth have created.

National Standards

Next Generation Science Standards

- **PS4.A: Wave Properties**
  - A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)
  - A sound wave needs a medium through which it is transmitted. (MS-PS4-2)
- **Structure and Function**
  - Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS4-2)
  - Structures can be designed to serve particular functions. (MS-PS4-3)

Common Core Standards

- **CCSS.ELA-LITERACY.W.6.2**
  - Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.
- **CCSS.ELA-LITERACY.W.6.2.D**
  - Use precise language and domain-specific vocabulary to inform about or explain the topic.
- **CCSS.ELA-LITERACY.SL.6.1**
  - Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

- **CCSS.ELA-LITERACY.SL.6.2**
  - Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study.
- **CCSS.ELA-LITERACY.SL.6.5**
  - Include multimedia components (e.g., graphics, images, music, sound) and visual displays in presentations to clarify information.

National Art Standards

- **Anchor Standard #1**.
  - Generate and conceptualize artistic ideas and work.
- **Anchor Standard #2**.
  - Organize and develop artistic ideas and work.
- **Anchor Standard #3.**
  - Refine and complete artistic work.
- **Anchor Standard #4.**
  - Analyze, interpret, and select artistic work for presentation.
- **Anchor Standard #5.**
  - Develop and refine artistic work for presentation.
- **Anchor Standard #6.**
  - Convey meaning through the presentation of artistic work.
- **Anchor Standard #10.**
  - Synthesize and relate knowledge and personal experiences to make art.

Day 1: An exploration of silence.

Materials

- Paper
- Pencils
- Projector
- Speakers
- Sound clips of silence: John Cage, New York Times Architecture
- Computer
- iPads

Agenda

- Introduction (2 Min)
- Paper work (10 Min)
- What is silence? (45 Min)
- Break (15 Min)
- Sound Scavenger hunt (45 Min)

- Sound piece brainstorm and beginning (45 Min)
- Exit ticket (5 Min)

Introduction to the project
- Introduce myself
- Explain how we will be working, over the next week, to make a community art project about sound
- Answer any questions the participants have

Do Now (5-10 minutes)
- Hand out pretest for students to complete. Explain how this is "just so I know what you already know, so we don't relearn information you already know."

What is Silence? (45-60 minutes)
- Hand each person worksheet *What is Silence?* Ask students to define silence.
- Ask for makers to share some of their answers to the question: What is silence?
  - Why do you describe it that way?
  - Is it really just the absence of sound or is it the absence of certain sounds?
  - Do we ever actually experience silence? Why?
  - What prevents us from experiencing silence?
- Discuss John Cage, an influential composter of the 20th century.
  - He is known for his piece called 4'33", in which a musician sits on the stage for four minutes and thirty-three seconds in front of a piano and does not play anything. It is the sound of the space that is being performed.
  - Let's see what Cage thinks of idea of silence: https://www.youtube.com/watch?v=pcHnL7aS64Y
  - What are your thoughts on what John Cage has said about sound, silence and music? Do you agree or disagree and why?
- How a space is formed affects what silence is. This is something that architects have to take into account when building spaces—that the materials and space together create a certain sound.
  - http://www.nytimes.com/interactive/2015/12/29/arts/design/sound-architecture.html?smid=tw-share&_r=1
  - Scroll through the different spaces and play what they sound like. Before playing them, ask the makers what they predict. Will it be silent or not, and why?
  - We are going to go do a sound analysis of the library. We will walk to different areas of the library and each of you will find a

spot to sit or stand quietly. For two minutes (I will set my phone timer) you are going to write down every sound you hear. When the timer goes off, we will move to our second location and write down what we hear there for two minutes. We will then come back to our classroom and think more about this notion of silence.

- Ask the makers to list some of the sounds they heard in each location.

Sound Scavenger Hunt (45-50 minutes)

- What is the silence of the museum and the surrounding neighborhood?
- Working with a partner and using a smartphone you will collect sound from one of the museum exhibit halls. As a group, we will vote on which exhibit to go collect sound from.
- We will also go for a walk around the neighborhood around the museum to collect sounds as well.
- Think about the sound inventory you did earlier. Which of those sounds do you want to capture?
- Make sure all the youth know how to record on their phones. As a group, go collect sounds.

Sound Piece

- Once everyone is back from collecting their sounds, explain the requirements for the sound piece and hand out the brainstorm sheet.
- Sound Piece: 1 min in length, conveys something about yourself, uses at least 20 seconds of found sounds you just recorded, and you can use additional sounds you find or create.
- After youth have completed their brainstorm worksheets, go over how sound is graphically represented and how to import and edit sounds in Audacity.
- Let youth start to work on their sound pieces.

Day 2: Sound Movement and Layering Complexity.

Materials

- Projector
- Speakers
- Computer
- Colored sugar
- Empty yogurt container, plastic wrap, rubber band, (drum)
- Critique worksheet

Agenda

- Review last class (5 Min)

- How does sound propagate? (25 Min)
- Layering and building sound (20 Min)
- Editing your project (35 min)
- Break (5 Min)
- Sound Critique (~5 Min per piece = 50 Min)
- Break (5 Min)
- Rework sound piece (30 Min)
- Exit ticket (5 Min)

Introduction to the Day

- What did we do yesterday?
- What is silence?
- Why can't we experience true silence?

Science Activity (45 minutes)

- The reason we are learning about how sound moves or propagates is because understanding how sound travels will help you understand how an acoustic speaker functions and is able to make noise. This may help you be able to build a speaker.
- So what is sound? Sound is energy. In particular, sound is mechanical energy.
    - Energy is the ability to do work, which means that it does something to something else. In this case, sound moves particles closer or farther apart. This pattern of more dense and less dense particles is what becomes sound. Sound is the energy that creates these packets of varying density.
- Show the simulation of a compression wave (http://www.acs.psu.edu/drussell/Demos/waves/wavemotion.html).
    - Ask the students to trace the path of the red particle. How is the particle moving?
        - Point out how the particle bunches and moves down.
            - Sound is a compression wave. This means it does not move up and down but instead sound propagates from one place to another through a compression of molecules. It is a vibration of molecules.
            - The wave travels in a constant direction and speed through the medium.
            - The particles in the medium through which the wave travels DO NOT move along with the wave.
            - In each case, focus your eye for about ten seconds on a single particle.

        - Note how it moves back and forth, while staying in the same neighborhood.
        - The wave carries energy through the medium.
    - Sprinkle colored sugar on the top of the drum you created out of the yogurt quart container, rubber band, and plastic wrap. Place a speaker on either side of the drum. Attach the speakers to a phone or other device that can play music. Ask the students, "Why does the sugar dance?" and then play a song.
        - Why does the sugar stop moving when I stop the music?
        - Make sure the students understand that the sugar can dance because sound is a mechanical wave that is the vibration going through the drum from the speakers.

Art Activity (40 minutes)

- Changing gears, we are going to spend the rest of class thinking about and starting to create your sound pieces. Last week we collected different sounds from around the library. Today we will think and explore how sound creates moods.
- Show a picture of a rainy day. Play the first sound effect and the last sound effect (found on the website below) and ask "What kind of storm are the picture and sound conveying? What mood do these different sounds of rain suggest?"
    - http://soundbible.com/suggest.php?q=rain+storm&x=0&y=0
- As we listen to this next piece, note how the mood changes as more sound is introduced:
    - http://www.alanberliner.com/installations.php?pag_id=142
    - Layering sound shifts the story being told, as does what is making the sound
- What mood is being portrayed in the next sound piece?
    - http://www.slate.com/blogs/wild_things/2014/04/10/bird_guitar_art_exhibit_c_leste_boursier_mougenot_zebra_finch_guitar_installation.html
- Hand out the brainstorm worksheet from yesterday.
- Today we will be continuing to create the sound piece you started yesterday.
- Work for about half an hour then we will stop and do a critique.
- We are going critique the sound stories you made.
    - Ask if they have ever done a critique in art class.
    - Explain the purpose of a critique.
- Hand out critique worksheets and go over what each section is asking of the makers.

- As a whole class, play each sound piece and have a productive discussion/brainstorm on how to improve each piece.
    - Hand out critique worksheets and go over what each section is asking of the makers.
        - Why do you like this piece?
        - What can be done to make this piece better?
        - Are more sounds needed?
        - Should the sounds be layered more or less?
        - Should certain sounds be louder than others?
- Now that we have gone over each sound piece, you will have the rest of this workshop time to improve your sound piece.
    - Show different places that students can find sound pieces on the internet and add them to their own project.
- Spend the rest of class reworking sound pieces.

Day 3: Deconstruction and Construction

Materials

- Computers
- Earbuds
- Materials for creating speakers: magnets, cardboard, construction paper, copper wire, plastic bottles, plastic cups, felt, electrical tape, scissors, X-Acto knives, etc.
- Smashing speakers worksheet
- Speaker Design worksheet
- Exit ticket

Agenda

- Complete working on your sound piece (40 Min)
- Sound is Energy (10 Min)
- Deconstruction (20 Min)
- How does a speaker make sound? (20 Min)
- Construction (70 Min)
- Break (5 Min)
- Exit ticket (5 Min)

Introduction to the Day

- What did we learn yesterday?
    - What is sound?
    - How does sound propagate?
    - Review any confusion from last class on sound or how it travels.

- Who can remember why the sugar danced? (If necessary, run the demonstration again.)
    - Use the homemade drum (yogurt container, plastic wrap, rubber bands) and sprinkle colored sugar on the drum top. Place a set of speakers on either side of the drum. Connect the speakers to a device that can play music and play a song.
        - Why does the sugar dance?
        - Why does the sugar stop moving when I stop the music?

Smashing Speakers

- Before building a speaker, we are going to each take apart an earbud so that we can figure out what materials we would need to create a speaker, and perhaps even what those different parts might do.
- Hand out a worksheet for the makers to write down their findings while taking apart the earbud.
- Hand each maker an earbud with the instruction to take it apart and record each of the parts of the speaker.
- Once the whole class has completed taking apart the earbud, ask for a list of the parts found.
    - What do you think these things do?
    - What do we remember about how sound travels?
    - What materials do we need to build a speaker?

Construction Activity

- How would you make a speaker? What materials would you need?
    - Since sound is a vibration, a speaker has to be able to create a vibration of more and less dense air.
    - Explain how a simple circuit works.
    - Show diagram of how to create a speaker.
    - Give a list of ways to troubleshoot if their speaker doesn't work initially
    - Provide different plastic bottles for the youth to choose from.
    - Hand out the supplies needed for the speaker: bottles, magnet, electrical tape and copper wire.
    - Using the wire from a pair of headphones, connect and check that your speaker works.
    - If a student asks how to make the speaker louder see if they can give an ideas of how to make it louder (there will be time next class to play around with modifying the speakers;

two main ways to make the sound louder are to have either a stronger magnet or more swirls)

Day 4: Art Exhibit

Materials

- Artist statement worksheet
- MP3 players, SD cards
- Posttest
- Exit ticket

Agenda

- Review last class (3 Min)
- Artist statement (30 Min)
- Complete speakers (30 Min)
- Sound transfer (10 Min)
- Set up art show (15 Min)
- Art Show (45 Min)

Intro to the Day

- Review last class
  - How does a speaker create sound?
  - What is sound?

Artist Statement (15-20 minutes)

- Explain what an artist statement is.
- Hand out worksheet for makers to create their own artist statements.

Complete Speakers

  - Troubleshoot any speakers that aren't working.
  - Give time for youth to complete making their speaker
- How can you make your speaker louder or more functional?
  - Provide various materials (more magnets, more copper wire, different materials to make the cone).
- Hand out MP3 players and SD cards have youth learn how to use their MP3 player and transfer their sounds off of the computer they have been working with

Posttest (20 minutes)

- Hand out posttest for students to take.
- Final exit ticket.

Art Exhibit

- Set up for exhibit.
- Have visitors come through.

Worksheets: Day 1

Silence

1. What is silence?

2. Can one ever experience silence? Why or why not?

Sound Exploration

Imagine yourself as sound explorers discovering the noise of different places. We will walk to several spaces both within the Franklin and in the surrounding neighborhood to discover the silence around us. What is the background "silence" of the Franklin? What is the "silence" of the neighborhood we are in? As you write down the noise around you think about how do these sounds make you feel?

Location 1:

Location 2:

Sound Artist Brainstorm

Each of you will be a sound artist creating your own sound piece that reveals something about yourself. Take the next several minutes to brainstorm what kind of sound piece you want to create.

1. What sounds did you collect during the sound scavenger hunt? (example: the honking of a car horn, a person coughing, the sound of feet on the ground, etc.).

2. Take a few minutes and jot down aspects of yourself that define who you are.

3. What kinds of sounds would you need to convey these aspects of yourself?

Exit Ticket Day 1

*= Required

(This sheet has a front and back, please fill out both sides)

Name * _____ Date * _____

1. Today I learned… *

Tell me in a sentence or two what you learned today.

2. True or False: I consider myself to be a maker of things. *

   ○ True

   ○ False

3. What kind of things do you enjoy making and why? If you don't make things, why not? *

4. True or False: I consider myself an artistic person. *

   ○ True

   ○ False

5. What kind(s) of art do you enjoy and why? *

6. True or False: I consider myself a scientific person. *

   ○ True

   ○ False

7. What kind of science do you enjoy and why? If you don't like science, why don't you?

How many high fives  of fun did you have today? *

1 (not much fun at all)	2 (some fun)	3 (fun)	4 (lots of fun!)	5 (tons of fun!)

Worksheets: Day 2

Artist Critique

Name of Artist	Name of Critic
What mood(s) or story is this piece conveying?	What do you like about this piece and why? (Be specific)
What would you change about this piece to make it better? (Be specific)	What did you learn about the artist from this sound piece?

Exit Ticket Day 2

* = Required

Name * _____ Date* _____

1. Today I learned... *

Write a sentence or two telling me what you learned.

_____

_____

_____

For the following questions circle the best answer:

2. A man is drilling a hole in the ground at the center of a large, empty park. Imagine that you are so far way from the man that you can barely hear the drill. Now, imagine that you are placing one of your ears to the ground, and close the other one. The sound of drilling: *
    a. Will not sound because the ground particles rub against the sound and "disrupt" its ability to pass.
    b. Will be heard, because the change in density caused by the drill travels through the ground.

3. We can hear sounds at different volumes: shouts and whispers. The reason for this is: *
    a. When we speak loudly we release more sound particles which also hurt our throat.
    b. When we speak loudly we release bigger sound particles, which also hurt our throats.
    c. When we speak loudly the air's pressure levels generated near our mouth are greater.
    d. When we speak loudly we push the sound particles faster.
    e. When we speak loudly we push the air with more force. The air pushes the sound particles faster.

4. How does your sound piece relate to your life?

    _____

    _____

5. What did you learn from the critique of your sound piece?

    _____

    _____

6. What did you change in your sound piece to make it better? If you chose to not change your sound piece, please explain why.

How many high fives  of fun did you have today? *

1 (not much fun at all)	2 (some fun)	3 (fun)	4 (lots of fun!)	5 (tons of fun!)

Worksheets: Day 3

Smashing Speakers!

Inventors, tinkers, and makers take things apart to figure out how they work. Take the next several minutes to completely deconstruct the speaker in front of you. Make sure you draw and identify all of the parts you find as you take it apart.
As you take apart your speaker draw all the of the parts that you find in the boxes below. If you can identify what the parts are.

Designing Your Speaker(s)

How will the visitors to the exhibit listen to your sound? Will there be one or two speakers? Will they hold something to their ear? Will they wear a hat-like object? Will they lean towards your speaker? How will the electricity flow from the MP3 player to your speaker?
Take a few minutes to plan out and draw your design.

Exit Ticket Day 3
Required *

Today I learned…. *
Write a sentence or two telling me what you learned.

How does a speaker make sound? *

Why did you decide to make the speaker(s) you made? *

Was it challenging to make your speakers? If so, why? If not, why not? *

How many high fives  of fun did you have today? *

1 (not much fun at all)	2 (some fun)	3 (fun)	4 (lots of fun!)	5 (tons of fun!)

Worksheets: Day 4

An artist statement is a where an artist shares with the public their reflections and hopes for the art piece that has been created. It is a space to communicate with the public and help them understand where your art piece is coming from.
As a sound artist please take the next several minutes to think about the piece you created and complete the paragraph below. If you do not like the prompts you can also turn the paper over and write your own paragraph without the prompts. But make sure to reflect on why the piece is important to you and what you want the audience to get out of listening to the piece.

Artist Statement
My name is _____ and I created a sound piece entitled_____.
This piece is significant to me because_____. My piece evokes the following emotions:_____. I chose to create this piece because_____.

Exit Ticket Day 4
Required *

Name * _____ Date* _____

Today I learned…. *
Write a sentence or two telling me what you learned over the last week.

True or False: I often take apart things to figure out how they work. *
True
False

Did taking apart a speaker help you learn how a speaker works? If so, how? If not, why not?*

True or False: I often make things in my spare time. *
True
False

Did making the speaker help you understand how sound travels? Why or why not? *

APPENDIX B

Sound Information (PRETEST)

This is just a short exercise to figure out what you know about sound.
The questions are a bit tricky so take a moment and read them over carefully. Some of the questions might have more than one correct answer.

1. True or False: Sound is NOT matter.

   (a) True

   (b) False

2. When we strum a guitar string, we hear a sound because:
   Circle the best explanation below. There may be more than one correct answer.

   (a) The vibrating string releases sound particles and pushes them outward so they reach our ears.

   (b) Each string releases and pushes outward sound particles of different sizes, and that is why they make different sounds.

   (c) The sound particles are actually in the air. The vibrating string pushes them. Because they are pushed with varying force, we hear different sounds

   (d) A vibrating string causes changes in the density and pressure of the air around it. This change in density and pressures travels to our ears and enables us to hear.

3. True or False: Sound moves because the air pushes it.

   (a) True

   (b) False

4. True or False: Sound can travel through a vacuum (a place without matter).

   (a) True

   (b) False

5. True or False: Sound is invisible matter.

(a) True

(b) False

6. True or False: Sound is created by the density of the matter that fills a space (medium). The change in the medium's density (compactness) propagates (moves) through it creating sound. *

   (a) True

   (b) False

7. When we speak:
   Circle the correct explanation below. There may be more than one correct explanation.
   (a) Our body releases sound particles that are pushed out by the vocal cords.

   (b) The size of the particles released is the reason for the difference between sounds.

   (c) When we shout, our throats hurts because more sound particles come out and rub against the sound of our throat.

   (d) We shake the air in our throats using our vocal cords. This shaken air makes a change in pressure that can travel distances. These pressures changes are, in effect, sound.

   (e) The speed at which the chords shake the air and cause changes in air's movement is related somehow to the different sound created by them.

   (f) The sound coming out of our mouths is carried in invisible bubbles. These bubbles are pushed by the air, and when they reach the hearer's ears, the sound exits the bubbles and enters the ears.

Please circle your appropriate descriptors:

Sex:

(a) Female

(b) Male

Race:

(a) White

(b) Black

(c) Asian

(d) Hispanic

(e) Native American

(f) Other _____

Age: _____

Sound Information (POSTTEST)

This is just a short exercise to figure out what you learned about sound.
The questions are a bit tricky so take a moment and read them over carefully. Some of the questions might have more than one correct answer.

8. True or False: Sound moves because the air pushes it.

   (a) True

   (b) False

9. True or False: Sound is NOT matter

   (a) True

   (b) False

10. When we strum a guitar string, we hear a sound because:
    Circle the best explanation below. There may be more than one correct answer.

    (a) The vibrating string releases sound particles and pushes them outward so they reach our ears.

    (b) Each string releases and pushes outward sound particles of different sizes, and that is why they make different sounds.

    (c) The sound particles are actually in the air. The vibrating string pushes them. Because they are pushed with varying force, we hear different sounds.

(d) A vibrating string causes changes in the density and pressure of the air around it. This change in density and pressures travels to our ears and enables us to hear.

11. True or False: Sound can travel through a vacuum (a place without matter).

(a) True

(b) False

12. True or False: Sound is invisible matter.

(a) True

(b) False

13. When we speak:
Circle the correct explanation below. There may be more than one correct explanation.
(a) Our body releases sound particles that are pushed out by the vocal cords.

(b) The size of the particles released is the reason for the difference between sounds.

(c) When we shout, our throats hurts because more sound particles come out and rub against the sound of our throat.

(d) We shake the air in our throats using our vocal chords. This shaken air makes a change in pressure that can travel distances. These pressures changes are, in effect, sound.

(e) The speed at which the cords shake the air and cause changes in air's movement is related somehow to the different sound created by them.

(f) The sound coming out of our mouths is carried in invisible bubbles. These bubbles are pushed by the air, and when they reach the hearer's ears, the sound exits the bubbles and enters the ears.

14. True or False: Sound is created by the density of the matter that fills a space (medium). The change in the medium's density (compactness) propagates (moves) through it creating sound. *

(a) True

(b) False

APPENDIX C
Semi Structured Interview Protocol

Preamble and consent

Thank you for participating in this interview. The purpose of the interview is to get your perceptions about your experience participating in this workshop, and what you think you learned as a result of participating in this project. The interview is about 20-30 minutes long and broken up into three sections: one focusing on science, one on making, and one on art. If I ask a question that you do not wish to answer, let me know and we will skip it. If you would like to stop the interview for any reason, let me know and we will stop it.

The first set of questions are about science.

1. Do you enjoy science? Why? Or Why not?
    a. What about science do you like and why? Or what do you not like about science and why?
    b. Do you mainly learn science in school or out of school?
    c. What is the primary source of your science knowledge?
        1. Where else do you learn science?
2. Is anyone in your family or community a scientist?
    a. What kind of scientist?
    b. Do you talk about science with this person?
    c. If not does your family encourage you to pursue science? How or how not?
        1. If your family doesn't encourage you, what motivated you to join STEM scholars?
3. Had you ever learned about sound before this workshop?
    a. If so how was sound taught you?
4. Can you explain to me how sound moves?
    a. Is sound matter? Why or why not?
    b. Can you hear sound in space? Why or why not?
    c. How do you make a loud or quiet noise?
    d. Why is there no such thing as true silence on earth?
5. What helped you learn how sound moves? (i.e. daily discussions, a particular demonstration, building the speaker)
    a. How did this help you learn?
    b. What about this helped you?

This next set of questions focus on the sound piece that you made.

1. Do you consider yourself to be an artistic person? Why or why not?
2. Is art a subject that you take in school?

    a. What is this experience like?
    b. Do you enjoy it? Why or why not?
3. Do you do art outside of school? For example, do you keep a sketch pad to draw in, or do you make your own music, or have you ever tried out for a play?
    c. Does your family or community encourage you to do art? How or how not?
4. Is anyone in your family or community an artist?
    d. Do you talk to this person about art?
    e. Does your family consume art? For example, do you go to the art museums, or to concerts, or do take books on art out of the library.
        1. Can you tell me more about this like what kind of art is valued in your family and why?
        2. Do you value art and why?
    f. Is there anything else you think I should know about how art influences your life in or outside of school?
5. Think back to the sound piece that you made. Can you please describe the piece?
    g. How does your sound piece reflect you?
    h. Why did you choose to make the piece you made?
    i. Does the piece hold significance for you? If so, what is the significance?
    j. Are you proud of the piece you made? Why or why not?
6. Was creating your sound piece motivation to learn about how sound travels and to create your speaker to play your sound? If so, why? If not, why not?
7. Was having an outlet for you to create something of your own important to you? Why or why not?
    k. Would this project been just as good if you didn't have to make your own sound piece?
    l. Do you think making your sound piece helped you learn about sound? If so, what did it help you learn? If not, why do you think it didn't help?
8. What was it like to have the public listen to your art piece?
    a. Did you enjoy having your art work in an art show? Why or why not?
    b. Did this change the way you viewed your piece?
    c. Did having the public interact with your art piece make you want to change any parts of your project? If so, what would you change and why? If not, why not?

This set of questions focus on the making of the speaker.

1. Do you ever make things on your own?
    a. What do you make?
    b. Do you ever tinker with things?
    c. Have you ever participated in any of the makerspace around town, for example the Maker Jawn at the free library or hacktory?
2. Does anyone in your family make things? For example, fix cars, knit, or sew.
    d. What do they make?

    e. Do you talk to this person about making things?
    f. Do you ever make things with this person? What kind of things?
    g. Are you encouraged to make things?
3. How does a speaker create sound?
    h. What helped you learn this?
    i. What are the parts of a speaker and what do they do?
4. Did building a speaker help you learn about sound? If so how? If not, why not?
5. Did taking apart a speaker help you learn? How? Or why not?
6. Did building a speaker give a purpose to understanding how sound moves? Why or why not?
    j. Do you think you would have learned as much if you had not built a speaker?
    k. Do you think it was integral to take apart the speaker? If so why? If not why not?
7. Did you choose to take your speaker and sound piece home? Why or why not?

This final set of questions asks about the whole project.

1. Of all three aspects of this project learning about how sound moves, building a speaker, and creating a sound piece, which was the most important to you and why?
2. Which helped you learn the most and why?
3. Which part of the project are you most proud of and why?
4. Was any aspect particularly challenging and why do you believe this aspect was so challenging?
5. Is there anything else you would like me to know about your experience in this workshop?

Thank you so much for your time.

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