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A Teacher's Adoption of Maker-Centered Learning: A Phenomenological Case Study

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A Teacher's Adoption of Maker-Centered Learning: A Phenomenological Case Study

A dissertation submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy in Education at Virginia Commonwealth University.

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The maker movement is a social movement which espouses the importance of artifact creation through physical and digital tools. As the maker movement moves into educational spaces, researchers and educators are exploring ways to integrate it alongside current classroom practices. A prevalent framework for maker integration is the maker-centered learning framework, which was used as part of the conceptual framework. Currently, more research is needed which justifies and analyzes maker-centered learning in an educational environment. This study aimed to use phenomenological methods to capture the lived experience of chemistry teacher as she integrated the maker-centered learning framework into her chemistry classroom.

Chapter 1: Introduction

Prologue: Philosophy of Making

Aristotle wrote of the term techne, one of three categories through which he explains the different forms of knowledge. Techne is defined as the set of principles, or rational method, involved in the production of an object or the accomplishment of an end (Flyvbjerg, 2001). This does not mean there is not thought, or understanding which exists in the idea of techne; it only implies the knowledge found in techne is for the purpose of creating an actual object. This definition of thinking and being in the world is juxtaposed with the other two forms of knowledge: episteme, theoretical know why; and phronesis, practical wisdom (Flyvbjerg, 2001). The categories try to encapsulate human knowledge in order to offer an accessible way to debate matters of the mind. The three categories were not hierarchical in nature, but merely a classification. Aristotle did not hold one above the other, but gave each its due credit, which allows for a complete picture of knowledge. Unfortunately, modernity has altered the value of the levels of classical categories of knowledge.

The emphasis of educational institutions is on episteme, theoretical know why. The overvaluation of theoretical know why disrupts the balance and creates an alienation from concrete knowledge. Jackson (1971) states, "Adaptation to school life requires the student to become used to living under the constant condition of having his words and deeds evaluated by others" (p. 122). The acquiring of abstract thoughts is a daily necessity. Most schools are designed this way. Moreover, they are not preparing students for actual jobs which require thinking, but merely indoctrinating them into the world of abstractedness. There is the objectification of knowledge to the point where knowledge becomes the commodity, or ultimate goal; the abstractness in turn creates an alienation from the ideas themselves and it creates a

disconcerting feeling in the student (Anyon, 2011). So much so, the person must push out away from abstractedness towards the fully realized tangible work where knowledge is not commodified, and there is a freedom of thought tied together with action. Creating a factory line of thought creates a feeling of alienation and separateness. Similarly, Jackson (1971) states, "Adaptation to school life requires the student to become used to living under the constant condition of having his words and deeds evaluated by others" (p. 122). Students are discouraged from original thought. They are taught knowledge is measurable through standardized testing, and the only worthwhile information is that which will be tested (Apple, 2005).

The importance of artifacts as the answer to the abstractedness which has overwhelmed modernity is as Crawford (2009) states, "The disappearance of tools from our common education is the first step toward a wider ignorance of the world of artifacts we inhabit" (p. 1). Crawford's perspective focuses on the larger subject of work. He compares the intellectual knowledge acquired through a book and the knowledge acquired through hands-on work. Crawford decries the educational system for upholding a fallible philosophy behind education while pointing to examples from his own life which reinforce his arguments against abstract knowledge. He goes so far as to undercut predictors of a knowledge based world in the statement, "What is new is the wedding of futurism to what might be called 'virtualism': a vision of the future in which we somehow take leave of material reality and glide about in a pure information economy" (p. 3). Crawford is concerned with the senseless uplifting of "pure knowledge" versus physical knowledge (p.3). Deriving one's knowledge from only the abstract thoughts confined in the mind can create a skewed idea about the surrounding world. Crawford demonstrates this through a story about his father, a physics professor, in a conversation about the electrical components on a Volkswagen Beetle. The takeaway from this brief interaction is simple: the professor could

intellectually explain the reason for the issue with the vehicle, but lacked the real-world knowledge to help his son figure out how to fix the issue. This story is related not to depict Crawford's father as an imbecile, but rather to show how knowledge based in the theoretical cannot withstand practical application. If and when, Crawford's father had issues with his own automobile he would simply take it to an auto-mechanic to fix it, not knowing what exactly is wrong with it. This is not because his father was not smart enough, but because somewhere in his education he left mastering hands-on knowledge for intellectual knowledge.

The 'knowledge economy' depends on human capital and not industrial production to propel its growth. The advent of the global economy has broken down borders and has allowed for the inclusion of many different people groups to participate in the knowledge factory. This factor allows for cheaper knowledge labor, as was and is with physical labor, and devalues the work done by the knowledge worker (this of course takes place in America). But as Crawford (2009) so eloquently points out, "Yet trafficking in abstractions is not the same as thinking" (p. 44).

Rose (2004) states in regards to what was thought of as the traditional role of schools, "that the task of the efficient school system is to guide people into their likely place in the social order" (p. 178). The maker movement honors the hand and brain trying to bridge the gap between academic and vocational education. Through this bridge building, it leaves opportunity to connect between classes in school and help develop conversation with the hope of eliminating the stigma associated with vocational education programs. Maybe, the vocational education program will no longer be regulated to a lower perception by society as society sees the benefits of hybrid learning like the maker movement instills.

To live in an egalitarian society, schools need to prepare people for work. Not just a specific type of work based on their class, but for work in general. This would be a truly great contribution to the ideal of the democratic society. John Dewey states it more clearly in "My Pedagogic Creed" (1929), "To prepare him[the student] for the future life means to give him command of himself; it means so to train him that he will have the full and ready use of all his capacities that his eye and ear and hand may be tools ready to command" (p. 34). This statement embodies the maker movement because it compels us to think of technology as a tool in which to educate and push forward the wholeness of a person over simply looking at the academic or vocational aspects.

Dewey (1929) is a strong advocate for education through vocational education. The importance of vocational education to Dewey is as a functional tool to enable students to become fully realized people (Dewey, 1929). It supports the democratic principles he eschews throughout his philosophy on education. And, it puts credence to the idea of the student as the important part of the learning equation, which is encapsulated in the statement, "The child's own instincts and powers furnish the material and give the starting-point for all education" (Dewey, p. 33).

Furthermore, since the maker movement encourages social interaction among creators there is a social constructivist bent to the movement which aligns with the principles Dewey wrote about. This is clearly demonstrated in a writing by Dewey, "I believe all education proceeds by the participation of the individual in the social consciousness of the race" (p. 33). Learning is not an isolated affair, but requires the interaction of people within a community to foster learning. Even though there is not the necessity for community in creating something; it is

for the benefit of the learner to invite others into the process of making. This is exemplified in the importance the maker movement places on hands-on learning and the creation of artifacts.

Context of the Study

The maker movement is a moniker for a community of skilled members who are committed to creating physical and digital objects for both play and utility (Martin, 2015). From the surface, it appears as if this is not different from anyone who may consider themselves a tinkerer or a handyman, but through the advent of digital fabrication and online networks which have created an online community it has become entirely reinvented (Martin, 2015). Dale Dougherty, the Founder and Director of Maker Media, Inc which publishes *Maker Magazine* and helps organize Maker Faires around the world, is the progenitor of the maker movement and its associated meaning. Dougherty (2012) states, "The maker movement has come about in part because of people's need to engage passionately with objects in ways that make them more than just consumers" (p. 12). The maker movement has sparked interest from stakeholders in educational institutions based on its emphasis on science, technology, engineering, and math (STEM; Oliver, 2016). The possibilities of the maker movement to inspire creative exploration through digital and physical forms has captured the imagination of many people. This includes educational researchers who are interested in finding the potential benefits of this movement on educational institutions (Peppler & Bender, 2013).

The desire to build physical objects individually while having a supportive community of like-minded individuals is attractive to many. As Halverson and Sheridan (2014) state, "The maker movement refers broadly to the growing number of people who are engaged in the creative production of artifacts in their daily lives and who find physical and digital forums to share their processes and products with others" (p. 496). The maker movement has strong ties to

constructivism and constructionism (Ackermann, 2001). The focus of constructionism is on the benefit of the physical object creation to the learners' conceptual understanding; it adds another layer to the theory of constructivism whereby the object functions as an "evolving representation of the learner's thinking" (Sheridan, Halverson, Litts, Brahms, Jacobs-Priebe, & Owens, 2014, p. 507). The layer of interpretation occurs as the learner negotiates to interpret the artifacts' importance and meaning (Sheridan et al., 2014). The connection between the mind and body are important to comprehend as the maker movement sees the benefit of their interrelatedness (Rose, 2004). This connectivity allows for the exploration of the importance of the mind and body in competent STEM learning and other subject matter as well.

Research Background

Researchers involved in the analysis of the impact of the maker movement on educational institutions suggest maker-centered learning activities may attract greater numbers of students to pursue opportunities in STEM content areas (Bevan, Petrich, & Wilkinson, 2014; Hsu, Baldwin, & Ching, 2017; Martin, 2015). The connection between STEM and the maker movement manifests itself in the informal learning space, and the tools and technical knowledge required to apply them in order to create artifacts, nominally titled makerspace (Martin, 2015). These makerspaces are spaces whereby learners actively engage in the physical creation of objects through the assistance and support of digital technology. The spaces thereby become the embodiment of the maker movement principles; they reflect the desired and preferred learning environment. As the ideal learning environment for the maker movement resides in an informal space surrounded by the tools necessary to create the desired artifacts.

As the maker movement has garnered more interest from educational institutions there has become a need to integrate maker-centered learning in educational institutions (Clapp, Ross,

Ryan, & Tishman, 2016). However, before teachers can skillfully integrate maker-centered learning into their existing curriculum they must be educated on maker-centered learning strategies (Cohen, Jones, Smith & Calandra, 2017). Professional development experiences whereby teachers not only learn about the maker movement, but also, engage in making activities needs to be developed (Paganelli, Cribbs, Huang, Pereira, Huss, Chandler, & Paganelli, 2017). Teachers are on the frontline of the maker movement in education and they need to have experiences which ingrain maker-centered learning practices (Clapp et al., 2016). Empowering teachers to gain the knowledge to conceptualize the maker movement and the makerspace itself will allow its acceptance in the classroom culture (Oliver, 2016). It has the potential to strengthen learning in STEM subject matter as making can reinvigorate both the teacher and learner (Berry, Bull, Browning, Thomas, Starkweather, & Aylor, 2010).

Purpose of the Study

The purpose of this study is to examine the experience of a female high school chemistry teacher as she incorporates maker-centered learning in her science classroom. Using a phenomenological lens as a filter to guide this case study, I aim to capture an in-depth understanding of the lived experience of a chemistry teacher as she attempts to create affordances which adhere to maker-centered learning framework (Clapp et al., 2016; Dougherty, 2016; Hatch, 2013; Thomas, 2014). Utilizing phenomenological methods, the study hopes to reveal the pre-predicated consciousness the teacher endures as she both incorporates the maker-centered learning framework and struggles with her established classroom norms. The documentation of a teacher integrating a maker-centered learning framework will contribute to the assessment of the impact of the maker movement in educational institutions. It will allow for

arguments which support the development of maker-centered learning in schools to be validated through the examination of a teacher interacting with maker-centered learning.

Many articles and books cite the importance of the maker movement amongst current educational trends (Dougherty, 2016; Hatch, 2013; Thomas, 2014). However, there are few empirical studies which showcase the effects of the maker movement in a K12 classrooms. Even though most studies on the maker movement occur in one of the STEM subjects there are few empirical studies which show significant learning gains through the implementation of a makerspace. The connection between the maker movement and STEM subjects seems like a foregone conclusion, but there are assumptions about best practices associated with STEM learning and the learning which occurs in makerspaces. Makerspaces could be more interesting to students than the traditional STEM classroom, but this does not indicate the revelation the maker movement is impacting learning in an innovative manner. By focusing on one teacher's integration of a maker-centered curriculum, I hope to go "back to the 'things themselves'" (Husserl 2001, p.168), looking at the experience itself. Not for the sake of mere generalizability of the experience, but to communicate the complexities found in the pre-reflective and reflective moments given to a teacher incorporating maker-centered learning into her praxis. The observation and documentation of a chemistry teacher will inform currently held assumptions about the maker movement in educational institutions, and highlight the struggles and successes of an individual teacher.

Theoretical Framework

Maker-Centered Learning

The theoretical framework which informs my study was created by a three-year research project called Agency by Design. Their work focused on three strands of research which is

influencing the curriculum associated with the maker movement. The following outlines their work:

> 1. A review of literature associated with maker-centered learning.
>
> 2. A series of site visits to a variety of maker-centered learning environment paired with formal interviews conducted with maker educators and thought leaders at the forefront of this emergent domain.
>
> 3. A program of participatory research carried out first with a group of educators in Oakland, California, and later with a national learning community consisting of individuals representing maker-centered learning environments throughout the United States. (Clapp, et al., 2016, p. 4)

From this research came the book *Maker-Centered Learning: Empowering Young People to Shape Their Worlds* which articulates what people learn by engaging in maker-centered learning. Clapp et al. (2016) see the harm standardized testing and learning measurements have brought to education, and they have created a maker-centered curriculum to educate using a constructivist lens. Clapp et al. (2016) offer "Thinking Routines" to the maker movement conversation which focus on ways to empower students through focused inquiry, design, and construction (p. 175). The different Thinking Routines allow students to focus on an object, issue, or idea to analyze and alter their perceptions while trying to create a different way to solve the problem posed. Clapp et al. (2016) are creating a way for students to construct a different ontological and epistemological perspective through the deconstruction and construction of objects within the physical world.

The organization which Clapp et al. (2016) are associated with and helped perform the research which supported the development of the book *Maker-Centered Learning: Empowering*

Young People to Shape Their Worlds has developed the concepts formulated in the book into a succinct framework which will be used to inform the study. *Figure 1* visually expresses the macro framework created by the researchers at *Agency by Design:*

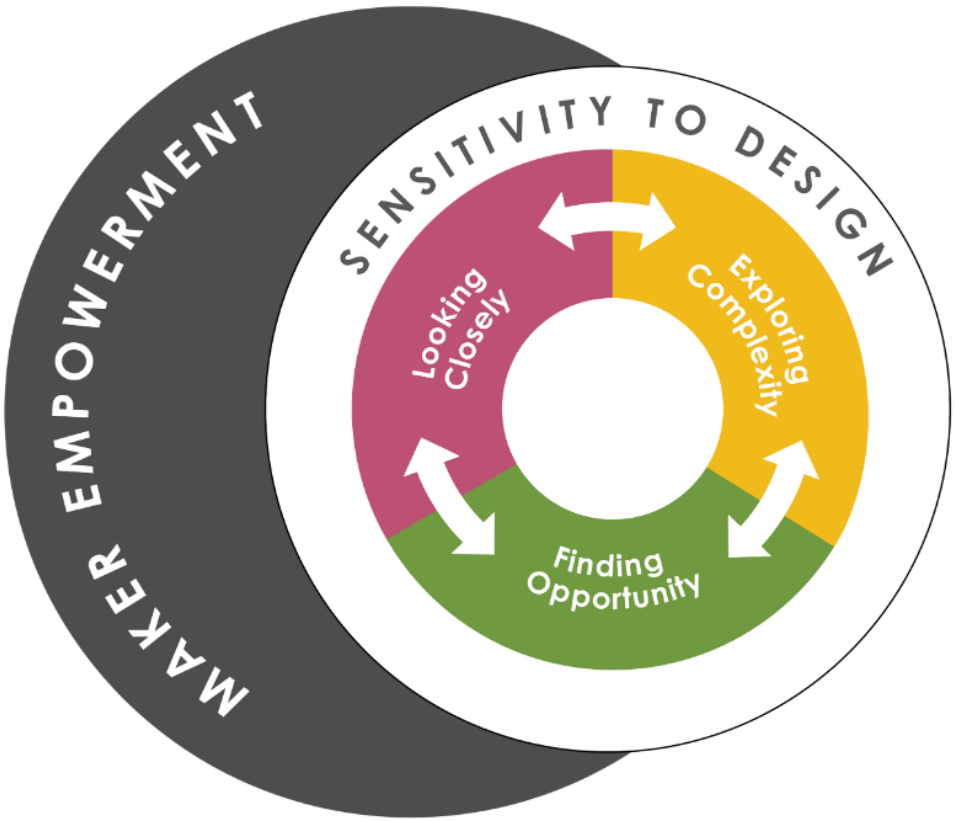

Figure 1. The Framework for Maker-Centered Learning

Clapp et al.'s work and description of sensitivity to design, which is summarized as the ability to "look closely and reflect on the design of objects and systems, explore the complexity of design, and understand themselves as designers of their worlds" (Agency by Design, 2018) is used by the Agency by Design research group in order to create the following definitions found in Table 1:

Table 1.

Agency by Design Definitions

1. Looking Closely	Looking carefully at objects and systems in order to notice their intricacies, nuances, and details
2. Exploring Complexity	Building on close observations and explorations of complexity to see the potential for building, tinkering, re/designing, or hacking objects and systems
3. Finding Opportunity	Finding Opportunity: Investigating the interactions between the various parts and people associated with objects and systems, including the range of values, motivations, and priorities held by the individuals who engage with particular objects and systems

The definitions given to the terms allow for the operationalization of the terms, which is outlined in Table 2:

Operationalization of Terms

1. Looking Closely	Notice everything: Cast a wide net to capture all that you can observe. Revisit: Look/listen/touch again, and see if you can find something new. Use categories: Look for different kinds of features or components.

	Juxtapose: Look at things side by side; compare, observe relationships. Physically change perspectives: Look from high, low, far away, close up.
2. Exploring Complexity	Explore inner workings: Explore how things, ideas and systems work—what are their parts and interactions? Explore points of view: Consider and take different perspectives: What different ways can you look at this? Probe your own perspective: Examine your own assumptions and beliefs. Look back and forward: Explore the histories and possible futures: How did this come to be? Where might it be going? Tinker to explore: Take things apart, put things together, play around with how things work.
3. Finding Opportunity	Envision: Imagine what could be invented, or how things could be changed. Reframe: Rethink, refocus, or re-define a problem, opportunity, or procedure; hack or repurpose how things work. Source resources: Be proactive and creative about finding information, advice, and instruction. Prototype and test: Make models and run tests; try things out to see what works.

	Make (and draw) plans: Identify steps; sketch what things could look like and how they could work; illustrate ideas & processes.

The definitions offered by the Agency by Design work stems from design thinking which center around affording the opportunity to students to creatively engage in artifact creation (Clapp et al., 2016). Much of the work performed by the Agency by Design research groups builds on previous research which has connections with constructivism and constructionism.

Constructivism

Constructivism is a learning theory which posits the learner in the center of the knowledge creation (Ackermann, 2001). It is through the learner's experience and interaction which should impact how the knowledge creation, and not the curriculum, the teacher, or the learning environment. Learner-centered environments are seen as the future of education, but as of yet they have not found a way to incorporate teacher learning which will educate teachers on best practices to fully support learners (Bobst, Mangum, & Wolf, 2017).

While John Dewey is usually associated with the philosophical undertones of the constructivist perspective, Jerome Bruner and Jean Piaget are contributors to the constructivist perspective as it is currently held. Piaget helped establish the learning theory as a credible way to engage learning in the classroom from a cognitivist perspective. Bruner saw learning as an active engagement whereby the learner created meaning that built upon past experiences and knowledge. In addition, Lev Vygotsky's contribution was looking at the interaction of the learner through his social development theory, which proposes social interaction precedes development (Vygotsky, 1978). Vygotsky's ideas not only support the learner as the knowledge

creator, but also suggests cognition and learning come from social interaction. The collective contribution to the field of education encouraged educational theorists away from behaviorist tendencies towards the idea that learners construct knowledge and increase cognition with their own personal background knowledge, as well as, with others. Learning takes place within a social atmosphere and deep cognitive understanding is not solely acquired through behavioral principles, which emphasize rote memorization.

Much of the literature surrounding the maker movement cites constructivism as an appropriate theory to attach to the types of learning within a makerspace whereby maker-centered learning most often occurs. It places the learner as the center of the knowledge creation which is one of the key components associated with the maker-centered learning framework. The benefits seen from engaging the learner align with "maker empowerment" which is used to get stakeholders excited about the adoption of the maker movement into their classroom (Agency by Design, 2018).

Constructionism

Seymour Papert (1991) developed the theory of constructionism out of his experience with constructivism. Papert's work takes the ideals of constructivism and implements a concrete experience alongside the ideals of learning through the process eschewed through constructivism (Papert, 1991). While the form of engaging students Papert took occurred through the computer programming language named Logo, he still acknowledged the larger ethos found in the constructivist theory, which aligns with the maker movement in form of learning through making. This singular idea is at the center of the maker movement, but much like constructionism is entangled with other theories which eschew the agency of the student over the teacher.

The abstract concept found in much of school learning is taken out of the teacher and student exchange and replaced with concrete learning through action. This exchange was seen by Papert (1991) as a purposeful manner by which to gauge student learning. The contrast, in Papert's (1991) opinion, was placing the teaching at the center of the classroom, which seemed contrary to the point of schools. The student is active in the knowledge creation, and the teacher is empowered to become a knowledge facilitator rather than a didactic dictator found in traditional classrooms. These ideals again align with the maker movement and the maker-centered curriculum because they encourage the engaging type of learning which occurs through the conceptualization and creation of a physical artifact. More importantly, the student learned through doing, the object is a manifestation of the doing, but it is not a clear representation of what the child has learned. Constructionism, like constructivism, is concerned with the process and how a student migrates towards their goal, rather than an end goal, or product.

Conceptual Framework

Returning briefly to Aristotle's three types of knowledge and the overvaluing of episteme, the conceptual aspect of this paper relies on the rejection of the traditional scientific methods offered by natural sciences. Instead, the author has tried to align with the Flyvbjergian interpretation of rigorous social science research, which focuses on capturing experiences which are relevant and powerful (Flyvbjerg, 2001). Thus, the focus switches away from proving a specific observable assumption to capturing the experience itself and allowing it to speak to the practical concerns surrounding the experience. This type of thinking aligns with phenomenological research whereby the researcher acknowledges his role and bias in order to bracket his own experience and capture the lifeworld of the participants (Dahlberg, Dahlberg, & Nyström, 2008). The researcher does not come to the study unattached, and during the

documentation of the experience the researcher brings certain bias which hinders an objective perspective. In order to capture the preconscious and conscious decisions made by the participant, the researcher must bracket/bridle his bias (Merriam & Tisdell, 2016).

As the researcher aims to observe the preconscious movements of the participant as she engages in creating meaning from the maker-centered learning framework within the chemistry curriculum, both for herself and her students, there is also participants intentionality which needs to be unraveled. The intentionality of participants cannot be captured in the moment, but occurs upon reflection (van Manen, 2015). However, the focus will be on gaining insight into the participant's interior consciousness in relation to the exterior and back again, so that there is a recording of tacking back and forth while still being enmeshed with the present. The interaction between the researcher and participant will be part epistemological construction (as a way of knowing about the maker-centered learning experience), and part ontological construction (as a way of being a teacher within the maker-centered learning experience) of the experience of a chemistry teacher with maker-centered learning. While the theoretical framework informs the larger impetus guiding and forming the researcher's perspective for understanding the experience, the philosophical aperture of phenomenology has guided the study to consider the lived intentional moments of the participant.

Research Questions

1. What is the lived classroom experience of a chemistry teacher with maker movement knowledge?
2. How are the three components (looking closely, exploring complexity, finding opportunity) of maker-centered learning present in the teacher's praxis?

Methods

The study will record the experience of a high school chemistry teacher's incorporation of the maker-centered learning framework into the chemistry curriculum through phenomenological methods. While the methods employed will be grounded in phenomenology, the larger mode or research method will be classified as a case study. The context of the research falls within the parameters of a case study as the researcher aims to capture "an in-depth description and analysis of a bounded system" (Merriam, & Tisdell, 2016). A case study is defined by the unit of analysis, and not the topic of investigation. The research will focus on one high school chemistry teacher operating within a bounded system as she begins to develop and implement maker-centered learning lesson plans. Creswell (as cited in Merriam & Tisdell, 2016) offers a more detailed description of a case study, "case study research is a qualitative approach in which the investigator explores a bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information (e.g., observations, interviews, audiovisual material, and documents and reports), and reports a case description and case-based themes" (p.40).

The researcher will try to capture the lived experience of a chemistry teacher integrating maker-centered learning techniques into her classroom through understanding and interacting with the teacher's epistemological and ontological creation attached to maker-centered learning. In order to capture the lived experience, the researcher will conduct interviews as well as analyze her curriculum, the science curriculum and the larger school curriculum, and observe her interactions in class. Once multiple interviews have been conducted over the course of the term, the interviews will be transcribed and read. After reading through the transcribed interviews meaning units will be assigned to specific ideas expressed in the interviews (van Manen, 2015).

The meaning units created by the participant are compared with the theoretical and conceptual framework for comparison and alignment which will allow for an epistemology to develop which acknowledges the teacher's experience with maker-centered learning (van Manen, 2015). The interpretation of this data will be done alongside the acknowledgement of the researchers own positionality, as the researcher will try to be bracketing his own intentionality and perspective through a reflective journal and memos after each interaction with the teacher. This will allow for the teacher's experience to be at the forefront of the study, while also accounting for the researcher's biases and positionality.

Summary

This chapter established the philosophical context behind the maker movement, gave credence to the current contextual state of the maker movement, and illustrated the importance of the proposed research. In many ways, the maker movement is a vehicle for a larger progressive movement which idolizes the making of artifacts as a way to transfer meaningful learning. However, there has been little empirical research which captures the lived experience of a teacher changing her curriculum to align with maker-centered learning techniques. Therefore, the aim of this study is to capture the lived experience of a teacher integrating maker-centered learning.

Definition of Terms

The following section provides a list of definitions for words used in this study which might otherwise be misinterpreted or might not be known to the reader.

Epoché (reduction proper). The bridling and bracketing of the researchers own judgments and prejudgments for the sake of observing the participants natural attitude.

Hermeneutic circle. The idea that one separate life experiences create a collective understanding communicated through our being.

Lifeworld. Being in the natural attitude, not consciously analyzing the situations occurring, but the preconscious understanding which culminates in expanding our knowledge of human beings lived experience.

Maker-centered learning. Maker-centered learning is a learning framework which has been created by Agency by Design (AbD), which is an ongoing research initiate support through Project Zero at Harvard University.

Makerspace. Makerspace is defined as an informal learning environment which has tools used for the creation of digital or physical artifacts.

Natural attitude. The lived experience unattached to judgements expressed by the participant.

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Chapter 2: Review of the Literature

Introduction

The purpose of this study is to examine the experience of a high school chemistry teacher as she incorporates maker-centered learning into the science curriculum used in her classroom. Using phenomenological methods, the study aimed to capture an in-depth understanding of the lived experience of a chemistry teacher as she attempted to create patterns and affordances which adhered to maker-centered learning framework (Clapp et al., 2016; Dougherty, 2016; Hatch, 2013; Thomas, 2014). The documentation of a teacher integrating a maker-centered learning framework will contribute to the assessment of the impact of the maker movement in educational institutions. As such, the review of the literature focuses on previous studies centered on K12 classrooms and teacher professional development with maker-centered learning. All of the literature chosen offered a fuller picture of previous studies in order to support the research performed for the current study.

Overview

This review of literature presents the research to date associated with the maker movement in education, specifically K12. The first section outlines the methods employed to search and retrieve the literature applicable to the maker movement and k12 education. The literature review was organized through themes which were formed during the progression of the review. Gaps were identified and described at the conclusion of the literature review.

Methods

Academic Search Complete, Education Research Complete, and Education Resources Information Center (ERIC) databases were utilized to search for literature published about the maker movement in education between the years 2000 until 2018. The initial search was

conducted on September 24, 2018. The following terms were used in the search: (Maker Movement) AND (Education). The outline of the process review is as follows:

Table 3.

Process of Review

1. Aim	To determine empirical research performed on the maker movement in K12 institutions.
2. Search Strategy	Boolean search using: Maker movement AND education
3. Inclusion Criteria	Research focused on analysis of the maker movement on educational institutions. Full text, peer-reviewed, scholarly articles, empirical research.
4. Exclusion Criteria	Conceptual or theoretical studies on the maker movement and education, collegiate or non K12 learning environments
5. Data Extraction	Read studies and collect relevant information.
6. Synthesis of Data	Identifying themes within population categories in order to create across study connections.
7. Report	Results analyzed and summarized to demonstrate the empirical research performed on the maker movement and education.

The search procedures were conducted as follows: an initial search with terms, duplicates were removed, reading of each article title, a reading of article abstract (if the title seems applicable), and a reading of the entire article (if the abstract seems applicable). These procedures were developed in order to include as many studies as possible and reduce the risk of excluding relevant articles. The initial search revealed 1,120 results. After eliminating duplicates, 599

studies remained. All 599 studies were aggregated into Microsoft Excel through the reference management software Zotero for readability whereby the researcher manually read each title and subsequent abstract if title was applicable. Through the reading of the abstracts, the researcher retained any study with the terms Maker, Maker-Movement, Maker Movement, and Education which left 105 studies for further review. Before further study analysis was conducted, duplicates were deleted in Excel as for some reason they were retained in the transfer from Zotero to Excel, which left 78 peer reviewed journal articles. The journal articles eliminated had connections to policy makers and making, movement in class, and many different forms of makers that were not directly associated to the inclusion criteria detailed in Table 3.

Once the 78 studies had been aggregated into an Excel document the researcher developed and used the following categories: Population, Content Area, and Research Design to help organize the articles found. These categories were in addition to the categories created by Zotero when the files were exported to Excel: Item Type, Publication Year, Author, Title, Publication Title, Url, Abstract, Date, and Pages. The researcher analyzed each study looking at the created categories: Population, Content Area, and Design.

From the 78 studies focused on the maker movement, the researcher identified 15 studies whose population was K12 students and which were empirical (either Qualitative or Quantitative) in the study design. In addition, 10 studies were identified whose population was K12 teachers which fit into the inclusion criteria of empirical studies which focused on K12 teachers. Twenty-five journal articles inform the review of the literature and inform the proposed study.

Table 4.

Articles Reviewed

Authors	Year	Population	Area	Area of Impact
1. Bers, Strawhacker, and Vizner	2018	K12	Makerspaces	Makerspaces
2. Blikstein, Kabayadondo, Martin, and Fields	2017	K12	Makerspace	Instrument Design
3. Bull, Schmidt-Crawford, McKenna, and Cohoon	2017	K12	English	English; STEM
4. Burton, Ogden, Walker, Bledsoe, and Hardage	2018	K12	Science	STEM
5. Craddock	2015	K12	Library Studies	Makerspaces
6. Kafai, Fields, and Searle	2014	K12	Workshops	STEM
7. Litts, Kafai, Lui, Walker, and Widman	2017	K12	Computer Science	STEM
8. Martin, Dixon, Betser	2018	K12	Makerspace	Equity
9. Nemorin	2017	K12	Wood Shop	Maker Technologies
10. Parekh and Elisabeth	2018	K12	Library Studies	STEM

11. Smith and Smith	2016	K12	Science	STEM
12. Stornaiuolo and Nichols	2018	K12	Media Studies	Media Studies
13. Stroud and Wesley	2018	K12	Biology	Science
14. Tofel-Grehl, Fields, Searle, Maahs-Fladung, Feldon, Gu, and Sun	2017	K12	Science	STEM
15. Wright, Shaw, Gaidos, Lyman, and Sorey	2018	K12	Science	STEM
16. Bullock and Sator	2018	Teachers	Teacher Education	Maker Pedagogy
17. Cohen	2017	Teachers	Teacher Education	Maker Principles and Technologies
18. Crichton	2014	Teachers	Teacher Education	Innovative Learning Centers
19. Fields, Kafai, Nakajima, Goode, and Margolis	2018	Teachers	Teacher Education	E-textile Integration
20. Harlow and Hansen	2018	Teachers	Teacher Education	Maker Integration
21. Julian and Parrott	2017	Teachers	Teacher Education	Makerspaces
22. Kjällander, Åkerfeldt, Mannila, and Parnes	2018	Teachers	Education Programming	Makerspaces

23. May and Clapp	2017	Teachers	Art	Maker-Centered Learning
24/25. Oliver (Two Separate Articles)	2016	Teachers	Teacher Education	Best Practices

Results

The review is broken up into themes which were formed during the progression of the literature search. The researcher initially broke the study into two categories based on dominant populations from existing studies: K12 Students and K12 Teachers. The following themes emerged from the K12 Students studies: STEM learning, Types of Learning Encouraged by the Maker Movement, Makerspaces, Maker Narratives, and Maker Equity. These themes were used to synthesize the studies as they informed the search parameters and helped to organize the research associated with the maker movement and education. The following themes emerged from K12 Teacher studies: Teacher Professional Development, Teacher Experience, and Preservice Education.

K12 Students Studies

STEM learning. Teachers and researchers alike see the maker movement as a vehicle to carry STEM learning into the classroom. Eight journal articles out of the fifteen identified in the literature point to the positive impact of the maker movement on STEM subject matter (Bull, Schmidt-Crawford, McKenna, & Cohoon, 2017; Burton, Ogden, Walker, Bledsoe, & Hardage, 2018; Kafai, Fields, & Searle, 2014; Litts, Kafai, Lui, Walker, & Widman, 2017; Parekh, & Elisabeth, 2018; Smith, & Smith, 2016; Tofel-Grehl, Fields, Searle, Maahs-Fladung, Feldon, Gu., & Sun, 2017; Wright, Shaw, Gaidos, Lyman, & Sorey, 2018). Stroud (2018) described the experience with creating a fairly innocuous classroom experience centered around aquariums.

Through the implementation of maker movement principles Stroud created a classroom environment which placed the learner at the center of the knowledge creations instead of the teacher. This classroom shift is similar to principles Dewey (1929) discussed, related to training the student to have full command of their potential capabilities. This led to a science classroom design which Stroud (2018) described as encouraging students to develop projects which "combine arts, crafts, engineering, science, and technology," through the use of "technology by designing, building, modifying, and/or repurposing material objects with the guiding principle of freestyle innovation" (as cited by Stroud, 2018, p.65). Furthermore, Stroud (2018) relayed the impact of the surrounding community as the creation of the aquaponic system dreamt up by the student would not come to fruition without the support of the surrounding community for necessary supplies. Stroud used a descriptive methodology to reflect upon the principles of the maker movement found in a science classroom. The students utilized digital technology to create an object while operating within a defined community structure of their classroom and relying on the local community for supplies, and researching information from the larger world to help in the creation of an aquaponic system they were proud to call their own. Because the project was student-led there seemed to be a heightened interest which motivated students to not only create environments for fish to live in, but also to ask questions about ecological factors, and how to create a system with as little water waste as possible. Stroud did not explicitly state connections to the maker-centered learning; however, implicitly he captured the students exuding agency during their hands-on learning which aligns with maker-centered learning principles (Clapp et al., 2016). In addition, none of the experiences of either the students or teachers were document as the activity unfolded.

Similarly to Stroud's (2018) article, Wright, Shaw, Gaidos, Lyman, and Sorey (2018) wrote about an experience incorporating a National Science Resource Center (NSRC) curriculum on motion and design with engineering design principles. A structured hands-on activity centered on the creation of a propeller powered car was utilized to "illustrate engineering design cycle: (1) define a problem using criteria for success and constraints or limits of possible solutions, (2) research and consider multiple possible solutions to the defined problem, and (3) rigorously generate, test, and optimize solutions to the defined problem for the best possible Design" (Wright et al., 2018, p.57). The researchers used the construction of a propeller car with a 3D printed propeller as a competition between students to assess how the 5th grade student groups went about creating and solving the problem of moving their cars while getting them to understand the principles of motion. Professionals who studied making and tinkering and its integration in engineering were elicited from colleges and universities to assist in the curriculum design.

The possibility to attract more students to the STEM fields through the maker movement was captured by Tofel-Grehl et al. (2017). Their research used a quasi-experimental research design to assess 155 eighth grade students' motivation and learning outcomes in their science class. In addition to motivation and learning outcomes, the researchers explored the students' change in attitude towards science over time and if their interest in a scientific career increased. In order to assess the student learning and perceptions, the researcher used an e-textile unit and a traditional unit with the eighth-grade students, but both had the same content. Their research based on the concern with attracting students to the STEM fields, especially nondominant groups (Lindstrom, Thompson, & Schmidt-Crawford, 2017; Vossoughi, Hooper, & Escudé, 2016). The

use of e-textiles could translate to getting students motivated and interested in sticking with STEM subjects from middle to high school (Tofel-Grehl et al., 2017).

While Tofel-Grehl et al. (2017) used e-textiles in a makerspace to examine the effects on students' perceptions and interests, Litts, Kafai, Lui, Walker, and Widman (2017) examined the understanding of functional circuitry and software design on high school students through e-textiles. They used a pre/post experimental design to analyze students' abilities to read codeable circuit designs and design and remix functional code for controlling circuits. The researchers looked at a class of 23 high school juniors (4 boys, 19 girls, 16–17 years old) enrolled in a STEM elective class. In order to gather an understanding of the students' learning during the course of the class, the students were given three different circuit and coding tasks; two were given prior and one after the experience. The findings supported a substantial increase in the knowledge and design of circuitry, which indicated the students were able to interpret and grasp an understanding of the interconnectedness of circuit design and coding. The application of e-textiles as a learning tool can enable students to begin to understand the connection between engineering, computing, and design. While Litts et al. do not exhaustively state the connection the maker movement; they cited recent studies which support their research and included references to other studies which incorporated e-textile learning (i.e. Buechley, 2006; Buechley & Hill, 2019; Tofel-Grehl et al., 2017).

Smith and Smith (2016) described an experience whereby students were exposed to LED lights and other tinker centric devices (Makey Makey, Hummingbird Robotics kits, etc.) to help students understand electricity. Once students had achieved an adequate understanding of the principles behind the transference and transformation of electricity, they were allowed to create an object of their interest to showcase what they have learned at the fourth-grade Maker

Showcase. Smith and Smith presented an example of maker-centered learning occurring in action, but they failed to depict a complete picture. They did present exact student numbers or acknowledge the students' socio-economic status. While they do point to a reflective measure being implemented to the students, there is no inclusion of the measurement in the paper. A more systematic method of measuring student achievement and cognitive growth would be beneficial for understanding the benefit of the Maker Showcase. The researchers need to acknowledge the student context and population while looking at their lived experiences. Learning does not occur in a vacuum and the principles of the maker movement encourages students to engage with many different tools to acquire knowledge. It would behoove researchers to understand and capture in what direction the maker movement is guiding students as they learn.

Focus of learning encouraged by the maker movement. As the maker movement becomes a part of educational institutions around the world, it is important to know what is being learned. Blikstein, Kabayadondo, Martin, and Fields (2017) separated information and communication technology (ICT) from exploration and fabrication technologies (EFT) in order to better classify what type of learning occurs in the maker movement. The EFT instrument identified new technology literacies which arise from students' abilities to create artifacts in makerspaces. They purported the instrument they had created could measure students' experience level on a particular tool while also taking into consideration critical thinking skills. The EFT instrument was created in an iterative cycle between fall 2012 and spring 2014; during this time, students were asked to self-report on their confidence and performance levels on specific EFT and ICT. Overall, results indicated students were more confident in their abilities with ICT than EFT. The EFT instrument did not show the distinct technological literacies

involved in a makerspace; however, it did not take into consideration the community which is created in a makerspace (Bers, Strawhacker, & Vizner, 2018).

Whereas Stornaiuolo and Nichols (2018), focused on one specific school community,"45 high school freshmen in the Collaborative Design School's media makerspace" (Stornaiuolo & Nichols, 2018, p.1), Stornaiuolo and Nichols (2018) desired not just to capture the learning occurring in makerspace environments, but understand how students operating in the Media Production Makerspaces create new forms of meaning which inform their understanding of the surrounding world. Subsuming Halverson and Sheridan's (2014) broad definition of making, "creative production of artifacts", Stornaiuolo and Nichols tried to substantiate their claims through a social design experiment. This led to the desire of the researchers to capture how students were making meaning through the creation of media artifacts and to capture the process of the students and the "opportunities and tensions that emerged when new literacies were mapped onto schooling practices…, particularly for students from non-dominant communities who often have experienced forms of marginalization or oppression in schools" (Stornaiuolo & Nichols, 2018, p. 9). The term they used to reflect the theoretical framework of new literacy and the connotation implied by the term maker movement is "making public", which highlighted their concern about how students are engaging with the larger world as they endeavor to create in an informal educational space (p.3).

Stornaiuolo and Nichols (2018) used participant-observers to collect both observational data and artifactual data through field notes, reflections, analytic memos, audio recording, video recording, photos of artifacts, informal conversations, survey data, and semi-structured interviews. Engaging in grounded theory all of the qualitative data was analyzed to understand the students' perspectives on the projects they created. The study cited the work of Vossoughi

and Bevan (2014) to support their research done with non-dominant population, and argued for taking into account the multitude of perspectives found in an educational institution invested in a maker curriculum. Vossoughi and Bevan performed a literature review which specifically looked at the known factors associated with making in classrooms, emerging design principles and pedagogies which are associated with making, and possibilities for equity-oriented teaching and learning. What Stornaiuolo and Nichols (2018) and Blikstein et al. (2017) failed to recognize was how the space itself encourages a focus on different types of learning. These spaces, aptly named makerspaces, disrupt traditional modes of education and allow for student-driven learning.

Makerspaces. The spaces in which the maker movement occurs is an important component to its integration in educational institutions. Without the growth of makerspaces, the maker movement would be seen as another conceptual idea with little weight in the impact (Halverson & Sheridan, 2014). Researchers like, Craddock (2015) highlighted the importance of the maker movement engaging in creative ways to have students experience making (i.e., a mobile makerspace). The space offered students opportunities to be exposed to hands-on learning in a school environment whereby the school building could not physically contain such a place. Finding creative ways to expose students to makerspace principles is a common when trying to bring maker-centered learning into schools. Co-opting the definition of "tinkering" implied by Bevan, Petrich, and Wilkinson (2015), Smith and Smith (2016) described the experience of performing a traditional unit on electrical circuitry infused with an informal twist. While they saw the need to familiarize the students with the basics behind electrical circuits, they also saw the need to allow students to tinker with circuitry through the incorporation of different materials. The traditional manner used to teach how electrical energy can transfer and transform

is through the manipulation of batteries and wires in a structured class. By contrast, the maker-centered classroom allowed the students to explore different materials and electrical kits with the goal of creating a project which exemplified the important electrical concepts from the unit.

The creative use of a makerspace for third grade science learning is aptly described in an article by Burton, Ogden, Walker, Bledsoe, and Hardage (2018) on a project-based learning experience centered around the creation of a rocket. The project itself relied on a mission to Mars narrative which forced the students to actualize conceptual mathematical principles in the production of a rocket. The rocket design needed to carry a payload of materials to help support life for a group of humans who would be living on the planet. This project asked students to create a persuasive essay arguing for the increase of food units or decrease of food units in order to offer greater food variety. Students were asked to vocalize empathetic markers as they were asked to plan for food alternatives for family members. This activity showcased the power and learning potential the maker movement has to offer schools. It also supports the theory that the makerspace in the school becomes a tool for learning as teachers used the space to facilitate a hands-on project which could have easily been performed in their classroom, which is supported by Bers, Strawhacker, and Vizner's (2018) research. They presented two case studies of two makerspaces: "the Kindergarten Creator Space at the International School of Billund (ISB) in Denmark; and the ECMS at Tufts University in Medford, MA in the USA" (p.80). Loris Malaguzzi, "the founder of the influential Reggio Emilia approach, a pedagogical framework for municipal preschools" (p.76), created the idea that the physical environment is students' "third teacher" (p.76). Bers et al. saw makerspaces as places where the environment holds significant weight in the development of the childhood cognition. Not only did they integrate the Reggio Emilia approach and the maker movement into their analysis of the makerspaces, but the

researchers also used concepts from Bers' (2012) Positive Technological Development (PTD), which looked at ways to design a learning environment to promote positive behaviors through the use of technology. Their theoretical work identified opportunities for researchers to analyze how important space design is to student learning. Although the two spaces were designed to be shared open-learning spaces, Ber et al. used the connections to the makerspace through PTD which are as follows: Content Creation, Creativity, Communication, Choices of Conduct, and Community Building. These defined terms helped formalize the researchers' focus as they analyzed how the design of the space worked to facilitate learning. The method employed to analyze these was a co-participatory design process with semi-structured interviews, making sessions, and collaborative design experiences with teachers and children. Looking at the educational spaces, supported the researchers' assumptions about the impact of design on an informal space designed for younger students. The focus on learning through doing reflected itself in the overall design and availability of tools in the space. They astutely raised the likelihood of increased availability of 3D printers and other tools commonly found in makerspace, as they become cheaper and easier to use, they will likely be enfolded into a 'regular' classroom. A future they suggested is that the regular classrooms start to look like makerspaces, similarly like what happened to computers as they moved from a designated computer room into every classroom. In summary, research has been done on the educational potential of makerspaces; however, it is limited in sample size, subjective interpretations, and systematic analysis. A thorough study which describes and highlights specific tools used to create a unique learning environment is an important contribution to the literature. It would also be beneficial to capture the stories which arise as students interact in a space which looks

different than other classrooms and to begin to understand how teachers create engaging curriculum.

Maker narratives. Narratives are often used to help create interest in the maker activity employed for learning, like in the case of Burton et al. (2018) and Wright et al. (2018). In these articles, the narrative behind the project is separate from the actual construction of the object. Although there is still a narrative attached to the maker project, it comes across as an afterthought rather than a part of the project's construction. A 2017 study by Bull, Schmidt-Crawford, McKenna, and Cohoon focused on the story making which occur in project-based learning. Combining both making and storytelling, Bull et al. (2017) connected with a deeply ingrained desire for humans to share stories. Whereas Burton et al. (2018) and Wright et al. (2018) placed science and technology integration at the forefront of their project to inform, Bull et al. (2017) focused on creating an activity which uses technology to create a story. They had two different student groups in an elementary (*n=4*) and middle school (*n=2*), create stories using the programming language 'Scratch' to pilot a microcontroller which operated dioramas to tell a story. In addition to scratch, the students used Audacity, a free recording and editing software, to create recordings which told the story as the dioramas moved. This study is very different in that they set out from the start not to reinforce, or attract students to the STEM field, but rather to ensure to build an appreciation and understanding of how STEM is interwoven into to all aspects of their students' lives. Their exploratory study examined the benefits of intermingling literacy and engineering in order to acquire learning in both fields. Limitations of their study included a small sample size which doesn't account for socio-economic diversity within the school district. This is an interesting point as there are recent articles published which detail the maker movement as place for equitable exchange. Students often underrepresented in

the STEM fields are said to have experiences within the maker movement which encourage their continual learning in those subjects.

Maker equity. The maker movement is touted as a way to create equity in the STEM fields as it supplants traditional pedagogical methods for hands-on inquiry-based practices (Bilkstein, 2013). The innovative manner of presenting STEM subjects allowed for a fresh look at equitable measures in the STEM field where there is an apparent lack of diversity. There was also concern over creating makerspaces that are equitable places of learning (Vossoughi, Hooper, & Escudé, 2016). Using design-based research, Martin, Dixon, and Betser (2018) examined ways equity is affected in a high school makerspace. They utilized the repertoires of practice from Gutiérrez and Rogoff (2003) as a lens to analyze ways to create an equitable makerspace. Although Martin, Dixon, and Betser (2018) spent two years looking at and defining ways to improve equity, they only focus on two students' experiences in the makerspace. Focusing on one project per term did not allow for a multitude of opportunities to explore different tools and relied on strengths which not everyone had obtained. Through the design-based research, they were able to change the makerspace in order to adequately challenge students to highlight their strengths; the longitudinal design of their study also provided opportunity for these research expansions. Furthermore, the questions, "What counts as making?" and "Who has authority to define making?" (Vossoughi et al., 2016, p.44) became apparent as observational data was collected on students in the makerspace. Overall, the design-based research paired with repertoires of practices allowed the researchers to create a space which acknowledged student differences in order to promote student-motivated learning, which contributed to the creation of equitable space.

The maker movement is seen as a tangible way to teach STEM subjects in a new and exciting manner which motivates students to become lifelong lovers of STEM subjects. Kafai, Fields, and Searle (2014) explored e-textiles as a way to "disrupt" traditional modes of learning in the classroom (p.535). While the idea of "disruption" in schools is a term coined by Christensen, Horn, and Johnson (2010) in their argument for school reform, Kafai, Fields, and Searle described two ways the maker movement can disrupt established conventions in schools: students' concept of what, how and who can participate in technology fields and the passive mindset established by being a passive consumer. Kafai, Fields and Searle used three, eight-hour workshops to teach ninth graders (n=18) over the course of a school year the intricacies of e-textiles to produce a physical artifact. They discussed the difficulties of introducing a new instructional model into a structured curriculum where there is little room for additional curriculum. As Halverson and Sheridan (2014) suggested, this is one of the biggest arguments for the integration of the maker movement: hands-on, active-learning allows students to connect abstract learning in a concrete method. Kafai et al. also described the impact e-textiles could have on attracting a diverse population, especially as e-textiles combines traditionally female practices of sewing and aesthetic appeal. Disrupting traditional pedagogy allows for student-centered learning which enables a diversity of learning to occur.

K12 Teacher Studies

Teacher professional development. The interest of the impact of the maker movement has grown over the years, and its presence is being seen in K12 institutions across the globe. In order to assess its continuing impact in K12 environments, teachers have to be taught how to utilize the new tools and principles fostered by the maker movement. Cohen (2017) began the assessment of teacher education programs' incorporation of maker movement principles through

a survey sent to 123 member institutions of the American Association of Colleges for Teacher Education (AACTE; *n* = 811). This survey data was used to answer two impactful questions Cohen developed associated with the maker movement and teacher education:

> 1. To what extent are teacher education programs integrating maker principles and technologies into their programs?
> 2. What factors are impacting teacher education programs' intent either to include or not include maker technologies and principles into their programs? (p.2)

The overall findings from Cohen's study indicated about half of the institutions with teacher education programs that responded to the survey have participated in maker-centered learning or technologies associated with the maker movement. According to survey results, major factors contributed to the lack of maker-centered learning in teacher programs are cited as lack of interest from education professors and lack of funding for both a makerspace and implementation of a curriculum aligning with maker technologies. A strength of this survey was its large sample size (*n*=811); however, all participants were teachers. This research design excluded input from students in their classrooms. Another limitation of the survey is that it is a subjective report from teachers, not objective data gathered from their classrooms. Currently, there is a profound amount of literature and research on the efficacy of teachers' learning and integration of technology in their praxis; however, there is a scant amount of literature which supports, outlines, or relates to the integration of maker principles into the teacher's praxis.

Teacher experience. Allowing teachers to gain experience with the maker movement and maker-centered learning is important for the incorporation of maker movement principles into their existing praxis. Writing with place and experience in mind, Julian and Parrott (2017) wrote impactfully about how makerspaces in libraries can create opportunities for educational

institutions to expose students to critical thinking skills. They focused on the implications for learning, but approached the maker movement's impact on physical space, more so than a learning environment. As one of the authors is an associate professor of Architecture, the article's attention to the impact of a collaborative space, like a makerspace is seen as a benefit for science educators, administrators, and librarians. Makerspaces facilitated learning outside of the teacher-centered model is an important contribution as Julian and Parrott note, and it is an additional opportunity for students to access makerspaces outside of classroom usage.

Potentially, the maker movement can be used to change educational institutions in empowering ways for teachers and students, and Crichton (2014) is concerned about teacher empowerment. Through the Innovative Learning Centre (ILC) which encouraged students, teachers, administrators, and policymakers to create new pedagogical approaches. The ILC is connected to the University of British Columbia, and they hope by looking at deficits in teacher support located in East Africa to affect change. Ultimately the article's purpose is to explore how a change in pedagogy could help educators in East Africa deal with contextual challenges found in their teaching environments. Crichton (2014) observed that the traditional pedagogical method employed is rote memorization. However, the ILC felt the best way to foster student engagement is not through rote memorization, but through supporting changes in teacher pedagogy which will lead to impactful change in teacher praxis. One of the most prevalent ways is by utilizing the maker movement principles to create an informal learning environment leading toward an innovative, student-centered learning space. These desires and benefits were identified as Crichton (2014) solidified ways to approach change to offer more ways to support teachers under difficult pedagogical positions. Crichton's (2014) article aligned with an article by Oliver (2015) on teacher professional development with the maker movement. Moreover,

Oliver (2015) claimed teachers need to gain the knowledge to conceptualize the maker movement and the makerspace itself to allow its acceptance in the classroom culture. Both saw the potential benefits of this social movement in an educational realm and struggled to find ways to impart maker movement principles into teachers' pedagogy. In addition, Lindstrom, Thompson, and Schmidt-Crawford (2017) spoke to the dominance of pedagogies and curriculum that are based on standardized testing. These pervasively established perspectives are in direct opposition to maker-centered learning. Lindstrom et al. (2017) communicated the realization that makerspaces are designed for peer teaching, mentoring, and coaching.

Researchers who actively sought and engaged with teachers using maker movement principles through e-textile projects included a collaborative work by Fields, Kafai, Nakajima, Goode, and Margolis (2018). They specifically investigated two high school teachers' approach to implementing an eight-week e-textile unit with the Exploring Computer Science (ECS) curriculum. The students were tasked with designing their own wearable electronic textile projects. Fields et al. (2018) were concerned with creating a dialogue to start focusing on ways teachers can foster a peer pedagogy where students were empowered to teach one another. Additionally, the intention of the article also circles around themes of equity in the maker movement, specifically: "broadening access, diversifying representation (by privileging nondominant makers, techniques, and artifacts), and deepening participation" (p.22). These three issues helped the researchers focus on ways in which the two teachers interacted and taught their students during the course of the eight weeks. The student population consisted of two groups (n=32 and n= 21) from different schools in California. The teachers had both taught for seven years and had finished the ECS training required to teach the computer class. During the course of the study, the researchers made observations and collected data which corresponded to

the three issues identified above before the study commenced. The study demonstrated that a large number of students could participate in maker activities with less than 1 to 1 student adult ratio. The implementation allowed for a diverse population of students to create a project they each personally decided on, and the students attained a high-level of content proficiency with rigorous learning of programming, circuitry design, and problem solving. These concepts were reinforced through the legitimization of student knowledge and allowing students to peer teach. This qualitative study supports the proposal for more studies on teachers utilizing making in their classrooms as it begins the conversation surrounding teacher education in the maker movement. There does need to be more attention paid to the supportive network needed to provide a rich experience for the teachers to fully integrate maker principles in the classroom. The researchers did not go into detail about the teachers' practical integration of maker movement principles into the classroom.

An in depth look at how teachers are integrating maker-centered learning activities into their classroom curriculum is presented by Nemorin (2017). Nemorin used an autoethnographic research design to explore the realities of making in schools. In order to gather the research necessary to be classified as ethnographic research, Nemorin embedded herself in an Australian high school woodworking class for 25 months. The project she engaged in creating was the ninth-grade year end project, constructing a race car using a 3D printer which can go approximately 25 miles per year. The project allowed Nemorin to engage in using design software, interact with students for help/advice, and create a physical project. In her research paper, she highlighted three key issues which surfaced from her research: lack of pragmatic engagement, affective labor of failing, and mediated alienation. In Nemorin's opinion the lack of pragmatic experience was grounded in the process of making itself. She states, "Making

privileges a theoretical understanding of the artefact (as an object of substance consisting of mathematical and scientific properties) above 'doing' with one's hands" (p.532). In addition, she lamented the affective labor of failing, which was observed and experienced in the woodworking classroom. Despite the maker movement's appreciation of failure as a gateway to the creation of a growth mindset (Dougherty, 2016), there was only little acknowledgment of the student's resourcefulness in overcoming failure, and the students were still graded on what they created, not where they failed. This demonstrated the existing ambiguity in the research about failure as an active learning component in the classroom. Finally, the mediated alienation Nemorin felt took the form of not being at the center of the knowledge creation, but rather limited by the 3D software and by the constraints of the project assigned by the teacher. It is unfounded to generalize her experience to that of other students in the classroom; she did not interview or gather data on their experiences, but merely observed. It is evident that more empirical research is needed in order to highlight what making looks like in the different formal education environments in order to understand the benefits and limitations of the maker movement in K12 environments.

Maker-centered learning is often presented as something new, or separate from other subjects already established in K12 school. May and Clapp (2017) brought this issue up as their research looked at the language of aesthetics, usually used by art educators, in makerspaces and maker educators. They conducted content analysis on 16 transcribed interviews of maker educators in the eight formal school settings, seven informal school settings, and one professional organization. They desired to gain deeper insight into their perceptions of aesthetics and maker-centered learning. The findings showed maker educators did not seemingly use language with aesthetic appeal, but did describe at times the finished objects in an aesthetically

pleasing manner. The experiences teachers need in the classroom would be better situated for success if there were some teacher education associated with their training as educators

Preservice education. Preservice elementary teachers were exposed to a purposeful introduction to maker principles through the teaching of science curriculum as described by Harlow and Hansen (2018). During the 13-month program preservice teachers participated in, future teachers were taught about the realities of integrating maker principles through a Maker Faire, which are organized celebrations and showcases of maker culture (Dougherty, 2016). During the second semester, as teachers began to learn about science education, they were taught about maker movement principles. In addition, the teachers were expected to create a maker-centered learning area for visiting elementary school students. Each activity they created had to be based off of the Next Generation Science Standards (NGSS), which is described as "a vision of science in which children learn science through the practices of science and engineering" (Harlow & Hansen, 2018, p.33). The preservice teachers were split into pairs and allowed to co-create an activity which they thought best exemplified the NGSS standards and could be accomplished by visiting elementary school students. On the day of the maker faire, approximately 300 students came to the faire and experienced the inservice teachers' maker-based learning modules which were spread out on the campus. After the event, teachers turned in reflections from the experience and the key takeaways they had expressed were observing students perform tasks at a higher-level than anticipated, the elimination of fear from not having 'expert' knowledge on the specific activity, realizing they were learning alongside the students, and learning to adjust the activity for various ages. This article described a creative way to introduce maker movement principles to preservice teachers while getting them to create and make age appropriate activities for students. It also illustrated the viability of being able to

create an activity which aligned with standards while still using maker movement principles. However, a significant limitation of this study is the short-term nature of the educational experience, with it lasting only one day; additionally, data was not collected on what the elementary students learned from their making.

Although there has been some research on how to educate preservice teachers in maker-centered principles, additional research has indicated about how professors educate the future teachers in maker-centered principles. Bullock and Sator (2018) performed a collaborative self-study to understand how their interpretation of the maker movement affected their praxis. They have identified four maker pedagogical principles: hack, adapt, design, and create. These four principles form the basis for the term Maker Pedagogy which was created from principles found in the larger maker movement (Halverson & Sheridan, 2016) and clearly defined in previous work (Bullock & Sator, 2015); however, in this article they failed to clearly define the terms which left room for numerous interpretations. They utilized their Maker Pedagogy Lab as the space where the study occurred while they interviewed four preservice teachers and examined their understanding of the maker pedagogy. The two researchers also acted as critical friends to one another in order to question and assert their own understanding of the maker pedagogy, and its function in the teacher education program. A dialogue was created between the researchers and four teacher candidate participants which defined the maker pedagogy as a way to come to terms with the intermingling of the maker movement and their existing teacher praxis. This article contained a reflective practice which helped unravel what it means to the education professors as they begin to change the curriculum to meet the needs expressed through the maker movement. Limitations of this article include the small amount of participants' perspectives and lack of formalized terms/measurements. Again, research by Bullock and Sator (2018) continued

to demonstrate the lack of empirical principles regarding the equipping and training of teachers in maker principles.

Kjällander, Åkerfeldt, Mannila, and Parnes (2018) looked at the possibilities the maker movement might offer teacher education programs in trying to create opportunities for students to engage in computational thinking. The researchers approached the integration of maker principles by comparing three specific makerspaces in order to determine best practices. The article illustrated how makerspaces located in teaching schools can be collaborative spaces for education professors and preservice teachers as they begin to learn best practices associated with computational thinking. Nordic countries, including Finland and Sweden, are trying to find creative ways to teach future educators to incorporate computational thinking into their future curriculum. They drew a strong connection between design thinking and the possibilities exhumed from the makerspaces. In summary, trying to create opportunities for teachers to engage in maker movement principles is important for their praxis, and finding connections of maker movement principles to established learning methods is important as teachers begin to develop their own teaching habits.

Gaps in the Literature

Not only has the maker movement been touted as a way to bolster educational institutions (Halverson & Sheridan, 2014), but also as a mechanism for changing the way corporate industries operate (Anderson, 2014). However, there is a significant lack of empirical data that explores and defines the ways the maker movement practically goes about changing educational culture (Oliver, 2015). The maker movement is multifaceted and affects many different levels of American society; yet there has not been any conclusive empirical evidence to show how it has

or can affect K12 education. Studies involving students do not conclusively show evidence the maker movement fulfills its claims to drastically change educational results and culture.

Many of the articles reviewed showcase the maker movement as a way to merely transmit STEM subject matters. They are using the maker movement as a learning technique, or merely another hands-on learning activity without understanding the implications of the maker movement. Stroud (2018) describes allowing the students to create an experience where they are at the center of the creation, but he still has structured the class around specific topics of interests. The confines added by the teachers, while they may be necessary in the context of the classroom, were not a huge consideration in the inception of the maker movement (Dougherty, 2016). While Tofel-Grehl et al. (2017) suggest that integration of maker movement principles will increase students' interest in the STEM fields; yet, there is no guarantee or causal evidence of student success or a future of STEM careers simply by becoming involved in the maker movement. Their research contained a large student population (n=155), but there was no indication maker principles were being put in place for the benefit of the students' cognitive growth.

Smith and Smith (2016) balanced the need of formal learning to gain an understanding of the subject matter with the allowance of tinkering. This type of learning allows teachers to build a base of knowledge and then give students freedom to create and tinker with their newfound knowledge. However, the focus on seeing what maker movement factors go into the creation of knowledge in the classroom disallowed the ability to truly embrace student-led learning which is touted in the maker movement. Additional observational studies would provide evidence to support students fully immersed in making; however, this may be difficult because of the informal nature implied by the maker movement.

In order for formal educational institutions to incorporate the maker movement, educational opportunities must be afforded to pedagogical leaders. The maker movement is a term many use without understanding its implications. Teachers need to understand how to implement principles of the maker movement in the classroom, as much as, administrators need to understand how to properly support teachers, schools, and students in its most effective utilization. Nemorin (2017) embedding herself in an autoethnographic study allowed the exposure of maker principles and rigorous examination of what was already occurring in the shop class. Turning a critical eye to programs that tout maker movement principles, as well as classes which may contain them will be important to afford teachers a better understanding of the maker movement. With Nemorin (2017) in mind, further research should be conducted on the teacher experience with maker-centered learning. While much of the current literature describes the conceptual knowledge appropriated by the teachers, few look at the actual incorporation of maker-centered learning in a classroom, which is a hindrance to its mainstream acceptance and incorporation in educational institutions. This gap in the literature has encouraged the researcher to focus on the lived experience of a teacher incorporating maker-centered learning into her praxis.

The current literature review captures the results from the search terms “Maker” and “Education”, but by no means is this literature an exhaustive list of all terms associated with the maker movement. The maker movement is a relatively new term established in 2006 through Dale Dougherty’s (2016) work. Prior to Dougherty’s description and naming of this social occurrence iterations with similar principles but different names existed (e.g. digital fabrication, rapid prototyping etc.). While these terms are still prevalent in certain fields, they have slowly been phased out of use in regards to applying to the definitions offered previously for the maker

movement. These terms were not used in the literature search though, as the researcher was interested in procuring literature reflective on the defined search terms. Furthermore, the researcher acknowledges studies were omitted which might have fit the search criteria, but however did not show during the literature search. The researcher believes the current literature accurately depicts the search performed and presents an accurate picture of the current research concerning the maker movement and education.

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Chapter 3: Methodology

Purpose

The purpose of this single-subject case study is to document the experience of a female chemistry teacher integrating maker-centered learning techniques into her classroom. Current research has not sufficiently documented a teacher's perceptions, nor the lived experience surrounding the integration of maker movement principles. While Nemorin's (2017) work, depicted a classroom-centered around maker-centered learning; it failed to capture the teacher's lived experience with maker-centered learning in the classroom. More research which qualifies its benefit to educational critics must be produced. The lack of literature (n=10) capturing the perceptions and lived experience of teachers in the classroom is apparent from the review of literature. This supports the need for in-depth research concerning teachers and maker movement principles.

As elements of the maker movement are being integrated into schools around the country and its benefits have been touted (Halverson & Sheridan, 2014; Martin, 2015), there is a need to more fully understand the specifics associated with the integration of maker-centered learning in a science classroom. Many suppositions have been made about best practices associated with creating a maker environment, but there is a lack of critical data which illustrates the lived experience a science teacher has with maker-centered learning or the larger maker movement. This study aims to understand the lived experience of a teacher integrating maker-centered learning into her classroom.

Research Questions

1. What is the lived classroom experience of a chemistry teacher with maker movement knowledge?
2. How are the three components (looking closely, exploring complexity, finding opportunity) of maker-centered learning present in the teacher's praxis?

Study Design

A single-case study will be used to examine a chemistry teacher's experience with maker-centered learning in a chemistry classroom. The study will employ qualitative research methods in order to ascertain the meanings brought forth by the lived experience which the chemistry teacher undergoes with maker-centered learning. Case studies are used when researchers want to comprehend real-world phenomenon in deep impactful ways within context (Yin, 2018). Using a phenomenological approach, the hope is to gain insight of the lived experience surrounding the induction of a new praxis, maker-centered learning, with a chemistry teacher.

The rationale behind using a single-case study is to look deeply at one participant and the context in order to gain a deeper understanding of maker-centered learning. This particular single-case study falls under a critical case study as the focus is on analyzing a case which is important to the growth of maker movement in education (Yin, 2018). While the study falls under the larger definition of a single-case study, phenomenological methods were employed to fully capture the lived experience of the teacher. The researcher's overall objective is to capture the lived experience of a chemistry teacher struggling with the incorporation of the maker-centered learning framework. This required the bracketing and bridling of my own perceptions and bias (van Manen, 2015). As I limited my own cognitive dissonance through bracketing and

bridling, the findings and givings were examined through two different approaches: empirical inquiry and reflective inquiry. The Lived Experience Description (LED), a term coined by van Manen (2017) is the empirical approach which uses activities aimed to explore the range and varieties of pre-predicated experiences that help to reveal the teacher's lived experience in the classroom. The reflective activities are aimed to interpret the structures of the phenomenon (van Manen, 2017).

The researcher looked to observe and assess the pre-predicated conscious moments of the teacher in the classroom. There were moments during the research where I became aware of the teacher's reflection on her experience with the maker-centered learning framework. While these moments were valid and informative, it was even more valuable to capture the LEDs, both through observations and interviews, in order to evaluate the lived experience of the teacher. I was mining the LEDs for "meaning units", the lived structures of meaning created by the teacher, once the interviews had been transcribed and read multiple times (van Manen, 2015). This helped in understanding how the theoretical framework found in maker-centered learning applied to a chemistry teacher's praxis. Even though the researcher analyzed the text and curriculum from the larger school system and subject curriculum, the focus was on a single teacher and the meaning from the lived experience with maker-centered learning in her chemistry class.

Case

For this research study a chemistry teacher was chosen as a participant for the single-case study. The participant is a thirty-seven-year teaching veteran who has been employed by an all-girls independent private school located in the Southeastern part of the United States. The majority of her teaching experience has occurred at her current school with short stints at the

collegiate level. She has a Bachelor and Master degree in chemistry and worked in industry for a short period while she taught part time before she started teaching at her current school. The participant did participate in a maker movement professional development class in the Spring of 2018. The professional development experience took place in a commercial makerspace with seven other teachers from her school. She also was the teaching advisor for a Makerspace 2018 Summer Enrichment program that was organized through the school and which occurred at the commercial makerspace. The participant was still a member of the commercial makerspace and is a proponent of the ideas surrounding its integration into schools. During the research study, she taught four different sections of 10th grade chemistry at the high school. Her background knowledge and experience helped in the formation of the maker-centered curriculum.

Positionality

Throughout the experience the researcher tried to bracket his own personal judgements with a reflective journal and memos after each interaction with the teacher (Merriam & Tisdell, 2016). This allowed for the teacher's experience to be at the forefront of the study, while also accounted for the researcher's biases and judgements. The acknowledgement must be made that the researcher values the maker movement and believes in the benefits of the maker movement in the schools. Therefore, the desire to want the maker movement to grow might have influenced the interactions and analysis of the interview data. Furthermore, the researcher is not a content expert in regards to chemistry and does not have a deep understanding of the pedagogical approaches associated with it. While the researcher has been a teacher, he has never taught chemistry and would not be considered an expert in science education. The researcher's personal experience with chemistry in high school was not an encouraging experience, and if anything served to distance him from science in general, and gave a dislike for chemistry. As the

researcher has had time and perspective, the dislike for chemistry has waned, but the memories of the high school chemistry class persist and influence perceptions about chemistry classes. Finally, as a white male entering an all-girls school and studying a female chemistry teacher it is imperative to state the researcher's understanding and perspective will be limited. The researcher did attend a private school, but it was a coed institution. The experience went beyond much of the researcher's embodied experience as his experience has been informed by being white and male.

Procedures

Data Collection

Artifacts. In order to build a historical curricular context in which the participant is operating within, an analysis of curriculum materials was gleaned. Prior to observations and interviews, the school curriculum, science curriculum, and chemistry curriculum were collected and analyzed using the framework for maker-centered learning (see Appendix A) which was designed by researchers at Agency by Design (2018); it is a continuation of the work done prior by Clapp et al. (2016). The procedures used to construct knowledge were a content and heuristic analysis to gain a deeper understanding of the importance of the curriculum within the school and in the teacher's classroom. The content analysis broke the curriculum into themes and categories to help understand how the school structured the curriculum of the school and whether or not the themes or categories fit into the maker-centered framework. Furthermore, the chemistry curriculum used by the teacher was not only analyzed using a content analysis, but also analyzed using heuristic analysis to assess the teacher's interpretation of the curriculum.

This data helped in the analysis of the teacher's acceptance of the maker movement principles into their classroom curriculum as it provided insight into the bounded system the

teacher experienced. The artifacts that gave credence to the phenomenological methods were employed as meaning was aimed to be found through looking to the things themselves. By looking at the things which conceptually define the pedagogical space the teacher inhabits; it allowed for a fuller contextual understanding of the teacher's experience, and helped the researcher understand how the teacher created curricular meaning.

Preliminary Interviews. Once the larger curricular context had been established, the researcher conducted a biographical interview which was one of two preliminary interviews. The interview helped in establishing a historical understanding of the teacher's present state. The interview was open-ended to allow the teacher to communicate her educational lived experiences as well as her work experiences. The brief biographical sketch looked at the participant's educational background, both as a student and educator, and allowed for insights into her experiences with the maker-centered learning framework. The interview was conducted in a phenomenological manner whereby the researcher bracketed his own perceptions in order to allow the teacher's pre-predicated conscious thoughts to come forth and capture LEDs.

The second interview focused on the professional development experience the teacher had in a makerspace in the Spring of 2018. The open-ended questions were aimed at capturing LEDs of the teacher's experience with maker-centered learning while looking at the arrivals and departures of the specific moments associated with maker-centered learning. I was looking to record the participant's experience with the maker-centered learning experience and the anecdotes which occurred while in the makerspaces. Once transcriptions had been completed and read, meaning units were explored using the conceptual framework as a lens to assist in understanding how the teacher's pre-conscious interacts with the way she creates meaning.

Observations. I observed the teacher during the course of the third and fourth quarter of her school year. Using the maker-centered learning framework (see Appendix B) to influence the contact summary form (see Appendix C) I documented the teacher as the meanings found in the maker-centered learning framework arrived and departed. In addition to following the researcher-created contact summary form, anecdotes were recorded by me during the classroom activity. These anecdotes informed the debriefing interviews which occurred directly after the teacher's instruction.

Debriefing Interviews. After the in-class observations, the teacher was interviewed nineteen times in order to debrief and record the teacher's experience with the maker-centered learning principles. The debriefing interview aimed to capture the moments where the teacher may have exhibited pre-predicated movements which would show a connection to maker-centered learning. These interviews were transcribed and meaning units were attached to them to help in creating a complete picture of the teacher's arrivals and departures of meanings associated with maker-centered learning.

Concluding Interview. At the end of the study, the participant was interviewed for concluding remarks and final thoughts on maker-centered learning. The interview was a time to capture anecdotes which may have been missed during the initial interview, or the debriefing interviews. It was an open-ended interview in order to allow for the observations and previous interview material to inform the questions.

Memorandums. During the process the researcher memoed after the interviews as well as after the observations in order to establish a reflective component to the research study. The memos helped me bracket and bridle my positionality. It allowed me to see the type of questions to ask during the debriefing and exit interviews.

Table 4.

Data Collection

Method	Procedure	Materials
1. Artifact Collection	Content and Hermeneutic analysis	School Curriculum, Science Curriculum, Chemistry Curriculum
2. Preliminary Interviews	Open-ended interviews	Semi-structured interview questions (see Appendix D)
3. Observations	In class observations of the case	Contact Summary Form (see Appendix C)
4. Debriefing Interviews	Open-ended interview with the teacher directly after class	Maker-centered learning: looking closely, exploring complexity, and finding opportunity
5. Exit Interview	Open-ended interview	Will be created during the initial analysis process

Data Analysis

In order to arrive at a deep understanding of the lived experience of the teacher's integration of this new curriculum, "examples", or anecdotes, were used (van Manen, 2015, p.815) to capture deep introspective moments. These examples came from the interviews where I bracketed my own positionality and looking at the participants' pre-predicated epistemological and ontological arrivals and departures. The anecdotes assisted in the creation of meaning structures during the reflective analysis of the study. The empirical analysis concerns itself with the preconscious space the participant finds herself as she struggled with the maker-centered

learning curriculum (van Manen, 2015). The focus of the empirical analysis examined the preconscious anecdotes. The participant stayed in the presence of the moment while also acknowledging the reflective side to the calling forth of the memory. It is in capturing the uncertainty and humanity of the experience where the researcher can begin to see how the participant is epistemologically constructing meaning through the experiences associated with the maker movement while still looking towards the ontological meanings also at play from the experience. In order for this to occur the researcher had to bracket and bridle his own position and come to the experience believing his positionality can and is controlled.

The reflective component of the study utilized reflective moments in order to create further meaning units which could be recorded and realized. This occurred after the interviews had been transcribed through meaning units which came directly from the participant's interviews. The meaning units created by the researcher after careful reading and re-reading of the transcribed interviews are compared with the theoretical and conceptual framework for comparison and alignment. These meaning units allowed for the formation of epistemological and ontological interpretation of the participant's experience with maker-centered learning in the classroom. Furthermore, as stated by Freeman (2011), "When we learn about others, we learn about ourselves, not for the purpose of verifying or solidifying what that means but to enrich the possibilities of living our lives well" (p.549). Through the analysis of the data the researcher built a hermeneutic understanding of the experience as the participant struggled with the whole and parts of maker-centered learning.

Artifacts. The analysis of the identified artifacts (school curriculum, science curriculum, and chemistry curriculum) assisted the researcher to conceptualize the overall curriculum design in regards to maker-centered learning. The analysis of these documents was informed by the

maker-centered framework (see Appendix A/B). These juxtapositions and textual constructions guided the researcher's analysis as they informed the bounded system in which the single-case study was performed. The system in which the participant operated influenced the epistemological and ontological construction of maker-centered learning. It did not detail the entire construction of the participant's epistemological and ontological presence, but allowed for a piece of the larger whole to be analyzed and considered. Ultimately, the researcher aimed to allow for a fuller contextual understanding of the teacher's experience, and it helped to understand how the teacher created curricular meaning.

Preliminary interviews. The researcher used semi-structured interview questions (see Appendix D) whereby the preliminary interview questions aligned with the research questions and conceptual framework. These questions captured anecdotal evidence to support the participants epistemological and ontological experience with maker-centered learning. The questions were divided into two interviews: the first set of questions captured a biographical sketch of the participant, the second focused on the makerspace professional development experience and general knowledge about the maker movement. In order to systematically attach meaning units, the researcher used NVivo 11, a software program used to assist in the analysis of unstructured text, the researcher utilized this software to assist in organizing the transcribed interviews and observational data. As the focus is to capture the teacher's experience with the maker movement and experiences pertaining to maker-centered learning, the preliminary interview was conducted to capture moments of uncertainty whereby the participant pre-consciously experienced maker-centered learning while also reflecting on it as an object in the present moment.

Observations. In class observations were conducted during the course of the third and fourth semester of the school year. Using the maker-centered observation worksheet as a guide (see Appendix A) (Agency by Design, 2018), the researcher created a contact summary form (see Appendix C) to help guide the salient data observed during observations. The form allowed the observer to focus on the important features during observation time while still being able to collect a narrative description of the teacher's actions during the course of a class period.

Dasein. Analysis of the teacher's way of "Being-in-the-world" stemmed from the belief "We [humans] are not, and never can be, radically detached from the world" (Polt, 1999, p. 46). Performing observations served to understand the teacher as she was "Being-in-the-world" which indicated the teacher's involvement in a contextual environment in a meaningful whole while dealing with separate things and people (Polt, 1999). The idea encapsulated with Heidegger's notion of Dasein is that it is an active engagement where humans are constantly moving between their whole world being experience and the smaller environmental changes. Her world is defined by the things in her world, but also the context in which she finds herself takes precedence in different instances. She had concern of things in her world. This idea is preceded by the assumption found in Heidegger's intention behind Dasein, which is that ontology precedes epistemology. The acceptance of this presupposition leaves room for the construction of descriptors which can be used during the course of observational study.

An important tool to reveal one's being in a research context is what is called epoché, which allowed for the reduction proper, or the peeling back of preconscious judgements. Many things in the world, separate from the mind, influence the way in which humans understand what is occurring. The challenge then becomes to get at the Dasein, the thing which is a part of the being and is what I, as a researcher and most curious, but in order to see the complexities implied

by Dasein, there must be a removal of factors which do not contribute to it. This is where playing close attention to what the participant said, and removing my own per-conscious/conscious bias became imperative.

Pedagogical movements. Physical movements signal "being"; therefore, it becomes important to capture the movements found in the contextual space in order to accurately represent the "worldhood" of the teacher (Polt, 1999, p.49). By observing the physical movements attached to the teachers' pedagogy, I looked at the parts of the teacher's pedagogy which signify her being. This was especially useful as the teacher moved from the concrete to the abstract during her teaching lesson. The aim was to capture and realize what her bodily movements could tell me about her pre-consciousness. The body and consciousness are not mutually exclusive. Observing her comportment as a teacher led me to understanding how her body interacted with her unconscious and conscious thoughts. The accumulation of this knowledge offered insight into her complete "Being-in-the-world" while moving between her whole worldhood and the partial worldhood captured during my observational time.

Maker-centered learning. The framework provided by the *Agency by Design* research consortium defines specific attributes of maker-centered learning: Looking Closely, Exploring Complexity, and Finding Opportunity. The framework supposes that through designing curriculum around the three base principles a movement towards Sensitivity to Design occurs, which will empower the students to be engaged in the overall learning process. This framework parallels the "Being-in-the-world" mindset explored by phenomenologists who are interested in capturing the lived experience. My interest is in understanding how the teacher developed her lifeworld with the information gathered from her own lived experience in a makerspace and the intellectual knowledge developed from learning about the maker-centered framework (Baldwin,

2004). The observations and the way the teacher interacted with students and curriculum were influenced by maker-centered framework.

Debriefing interviews. After each class where observations occurred, the researcher and teacher met shortly to debrief on the lesson. The interview was audio-recorded for later transcription and meaning unit assignment, but was conducted in an open format with open-ended questions which revolved around the maker-centered learning terms: Looking Closely, Exploring Complexity, and Finding Opportunity. The interviews were also informed by the observations prior to the interview. These observations allowed the researcher to capture the experience of the teacher as they became enmeshed with maker-centered learning. The debriefing interviews captured the meaning created from the teacher's experiences during class.

Concluding interview. The concluding interview with the participant occurred at the conclusion of the study with emphasis on capturing missed moments from prior reflections, or asking other questions which might have emerged during the course of the study. The focus of the final interview was to allow the participant to relay any anecdotal stories which might show the participants' epistemological and ontological creation.

Reflexivity. I embed myself in the classroom as a non-participant observer to gain a better understanding of the lived experience of maker-centered learning. In order to acknowledge my own bias and knowledge which I brought to the interpretation of the meaning I created reflective journal entries. These journal entries allowed me to bracket and bridle my own bias during the course of the study and helped to inform the final study of where bias might exist. Even though I identified and bracketed my own position during the course of the study, it needed to be reassessed during the research process. This occurred through reflective journals and

memos which allowed me to bracket and bridle my own experience away in order to capture the participant's experience.

Findings and Givings. In order to maintain a rigorous interpretation of the collected data multiple sources of data had to be collected (Yin, 2018). This study sought to meet this requirement and triangulate data collection through a preliminary interview and document analysis, exit interviews, debriefing interviews after observation data, observations, field notes, and reflective journaling. As this study aimed to incorporate phenomenological methods to understand the teacher's lived experience; it aligns as Freeman (2011) states, "with Heidegger's notion of truth as 'unconcealment' invites researchers to conduct and present their work in such a way as to open up experience and dialogue with a subject matter" (p.544). The study is less about capturing and presenting results which are generalizable, and more about delving into understanding the interconnectedness between being and understanding (Freeman, 2011). In the instance of this research study, the hope was to understand a teacher's being and understanding of maker-centered learning. Trying to find the ontological truth while acknowledging the epistemological truth gave voice to the teacher's experience. Through this research process the researcher had to remember to stay close to the things themselves in order to establish a hermeneutic circle of whole to parts in the creation of meaning.

Limitations

This study is unique, and not easily repeatable. The context of the study alone raises questions of generalizability and whether the study adds significantly to the maker movement literature. Ensuring there is rigor in the study assured validity, but researcher bias and the teacher's social desirability were difficult to control. Making sure the researcher is bracketing his own perceptions and interpretations was important in order to have an accurate depiction of

the teacher's lived experience with the maker-centered curriculum. Furthermore, the researcher had to be wary of the teacher's position as a leader in her school which might have led her to answer questions less than truthfully. Through full rich description and a thorough anecdotal investigation the author gathered an accurate picture of what the experience is like for a secondary chemistry teacher experiencing maker-centered learning.

Chapter 4: Findings and Givings

Temporality is part of existence. The notion associated with phenomenological research is the person along with the researcher produce a glimpse of the person's experiential life. The research participant, through observation and interviews, offered a deeper understanding of her personal life as a chemistry teacher, yet my presence as the researcher was also felt. Janice is more complex than even her responses can communicate or her observations might reveal. As a researcher I am trying to gain a glimpse into Janice's lifeworld as "research does not occur in a vacuum but in a world vibrating with meaning" (Dahlberg, p.234). Through observation and interviews I hoped to begin to unravel my views on Janice's understanding of maker-centered learning through a hermeneutic circle which relies on a tripartite structure (whole-part-whole). The whole being the teacher's current classroom lifeworld, and the part being past experiences with maker-centered learning and then back to Janice's lifeworld. The hermeneutic circle not only allowed me, the researcher, to look at how Janice created meaning, but also as I looked at the "things themselves" and bridled my own meaning could I begin to understand the teacher's intentionality associated with the anecdotal moments shared in the interviews.

As I sought to bridal my own introspections as well to understand the teacher's lived experience with maker-centered learning, it became apparent to me the importance of Janice's constructed history. Heidegger states, "As soon as we try to think of the essence of constructive

building in terms of a letting-dwell, we come to know more clearly what that process of making consists in by which building is accomplished" (Basic Writings, Building, Dwelling, p. 337). In connection to humans, we see that to understand the whole, we must understand the parts. I am trying to understand the teacher as a whole pedagogical moment, which is defined by van Manen (2015) as, "A pedagogical moment is that instant of a pedagogical situation or relation when a pedagogical action is required" (p. 35). This moment occurs simultaneously as smaller pedagogical moments take place within Janice's defined lifeworld, her school, which is defined by Dahlberg, Dahlberg, and Nyström (2008) as "a necessary condition for knowledge" (p.37) because it attaches the person to the world itself through the actualization and reconceptualization of Janice's phenomenon.

The first interviews I conducted focused on the teacher's historical being, which in this case refers to both the lived experiential moments she regaled while participating in a professional development experience and the summer enrichment program she helped lead. There were reflective moments which arose both surrounding her experiences in the professional development and summer enrichment program, and extending to her personal life experiences. The anecdotes presented by Janice during this interview time allowed me to gain insight into her experiences in the makerspaces and in her past educational experiences. The makerspace and stories and past educational experience helped me to understand her current pedagogical presence.

Her answers allowed me to grasp the different pedagogical moments she moved to and from in thinking about, building, and dwelling within her lifeworld, which makes accommodations for tacking back and forth from her historical experiences to her past professional development experiences, and her present teaching experiences. Temporality is an

important piece when looking at the lifeworld presence of Janice's experience with maker-centered learning, and one of the areas which was intriguing to come back to during analysis. Janice's interviews while maintaining a present outlook, moved to the present to the past to the future often to construct meaning. Janice was both attached and detached from time, in a sense her current being was intertwined with her navigation of the her temporal experiences. The questions about Janice's historical background were the first interview questions, which gave me an insight into what kind of learning experiences she had in the past. And it was her past experience we would often come back to, which intersected with my own experiences. The very first question I asked centered around her educational background; she explicitly stated her undergraduate degree, which showed a mindset focused on her collegiate education, and thus excluded other interests outside of an academic environment. The following exchange highlights this tension:

> Janice: In the middle of a sorority hall, I said you could not pay me to teach. When I made that statement I lived in the middle of a bunch of elementary ed majors who were making file boxes of index cards with nursery rhymes and I was a chemistry major. So, nothing is ever anything I ever expected it to be.

She jumped from stating her undergraduate major to her collegiate experience in a sorority hall where she made a promise to herself that she would not teach. This promise was made in response to observing elementary ed majors "making file boxes of index cards with nursery rhymes". But concluded with the obvious statement, as she is now a teacher, supporting her current occupation as unexpected. I was caught off guard by the fact she had not planned a career as a teacher and intrigued as to why she became something which she obviously did not set out to become, but in the end I reflected on my own life and how I too had never planned to become a teacher.

Janice's response towards teaching made me curious as to why chemistry, and biology, or other science; in reflecting, I think it was my own distaste for chemistry which led to this intrigue. Janice led the conversation to positive personal experiences in educational environments whereby her love and interest of chemistry was reinforced. Overall, the conversation allowed for me to see an aspect of her experience as a learner and someone who loves science. In the following quote Janice expresses her uncertainty behind her interest in science, but knew she loved it:

> Janice: I don't know. I was always interested in science, I mean, I really thought I was going to be a biology major. And um, through the professors I interacted with in the beginning, I really never intended to be a chemistry major, I still find biology more interesting than chemistry, but um.
> Interviewer: Can you recall a specific moment and story, where you were just like...
> Janice: Well, when we were in high school, we didn't have AP classes, but I lived in Catonsville, Maryland, which is right next door to UMBC (University of Maryland - Baltimore Campus) and so we went there and took college biology… And I always said I was going to go to graduate school from the beginning and when it came time to go, I didn't want to go, but I was afraid not to do what I said I was going to do. And um, I always thought I wanted to do research and I hate doing research…And I don't have that, and so what I found later, and if I had to do it over again there are the two things I experience in professional development opportunities is nuclear engineering, and I spent a week at UVA they used to have, before they shut down their reactor, their research reactor they had a week for nuclear, nuclear science for teachers, and we spent a week doing stuff.

Janice goes into great detail to regale her past experience with science. As a point of reference, she started with an experience she had in high school attending a university for advanced studies in biology, which led her to taking chemistry in college. She talked about her professional development experience prior to the makerspace professional development experience, and I saw a connection between those experiences. The same excitement which pervaded her language in talking about the makerspace experience was contained when she referenced the professional development experience with the nuclear reactor. All of these moments seem to reinforce and provide clarity in her mind about how she has maintained an interest in chemistry and charted

her experience as she has grown her knowledge in chemistry, which led her to her teaching career. The following quotes provided insight into Janice's previous professional development experience:

> And then I got to apply it there. Because being here, being in an independent school you get to do whatever you want to do, you have autonomy so we did a whole unit on nuclear stuff, and the second thing was material, and I went through, I guessed they used to be called the metallurgist but now they are called the material science, engineering group, professional group. And they had a week long workshops for teachers, I went to Albuquerque, New Mexico and spent a week playing with all this stuff, we sand-casted jewelry, we did raku pottery with, you used metals in it they have metallic glazes in it. We messed around with glass, we built concrete blocks to see how much weight it could stand; it was all, it was a whole those activities and so much you could bring directly back. We went visited a blacksmith and did some blacksmithing, and then I did it, I actually got to send a couple of my students to the student version, and then we did stuff together and then two or three years later I went back and did it again. And so, and it had direct things you could do, professional development where you had something you did and you could take it and put it right into your classroom. This was the next thing, this makerspace thing that was like this is really cool. What I have found, I had a hard time, I understand how to do the kinds of things we did, or even the things we did this summer with the kids, I had a hard time figuring out how you did that within a chemistry class. I think the issued is you have to do enough reading on it to, like this design theory thing, to understand you are doing that, I am already doing that. I just haven't, initially attached these words or categories to it, and I think the key for getting making in the teaching curriculum is getting teachers to make that connection.

The jump from her own schooling to professional development to the maker professional development experience she had through her school shows how her past experiences informed her present state as a teacher. Especially when she switched to talking about what she got to use in her classroom, and the "design theory thing", which she feels she is already doing. The reflective knowledge Janice presents in relation to the makerspace professional development learning experience reinforced her perception that she is "already doing that".

Coming back to her lack of desire to become a teacher from an early age, she states the following:

> Actually, in undergrad I TA'd for a couple of labs. But when I went to graduate school, I went under a teaching assistant. So, it paid for all my tuition, and I could take classes anywhere I wanted within the campus. And I taught labs, and one of the programs they had was a masters themed community college teaching… I wanted a degree in chemistry, so I took those classes and then I was setup to do an internship at Thomas Nelson Community College in Newport News and I went home for Christmas and I got a call and they had been contacted by Thomas Nelson…I ended up teaching full-time. Being the only full-time person with three adjuncts that were all older than I was.
> Interviewer: Wow!
> Janice: So, it was an interesting experience and it was 50 miles from where I lived.
> Interviewer: From William and Mary?
> Janice: From where I lived. So, it was 50 miles door to door, and so that semester I taught and juggled these three people and I can still remember going to my chemistry professor saying, ok, here is the book, what part do you cover? And they said all of it, which I knew in retrospect couldn't have been true, but I shudder to think what I made my first classes do because that is what they told me what I needed to do… And when he was six weeks old I went back to work, and when I was at work I was perfectly happy and when I was home I was perfectly happy, and I felt like a schizophrenic trying to make a decision. Whether to stay, and nobody would help me make that decision. So, I finally decided this is what I said I was going to do. And I quit and I taught, I ended up for twenty years teaching between VCU and J. Sarge and the University of Richmond part-time. Probably a full load sometimes between them, but it was at night or in the summers and my husband we were just interchangeable, so I kind of got to have my cake and eat it too. And I never ever intended to teach in a high school.

She shares the development of her teaching praxis which she first engaged in as an undergrad and then further developed her praxis in graduate school where she ended up in charge of the chemistry department at a local community college. This is all while being married and commuting to the campus; however, once she had completed her degree in chemistry, she took a job at Phillip Morris performing research. Her teaching career did not end during her time at Phillip Morris, as she continued to teach night classes at community and local colleges. She stopped teaching when she and her husband decided to have children, but before that she continued to teach as to have something to do as her husband was talking night classes for his MBA. The story of how she became a full-time teacher at the small private school is quite remarkable because she never intended to become a high school teacher, as she states, but found she actually enjoyed the work.

Janice aligned her career path with the teaching as she reflected in the current moment, but also, I would argue this is not the first she time she had reflected on her career trajectory. Yet, there was still the shock at coming to a high school as a chemistry teacher. She further explained how she moved from the corporate world to teaching at the collegiate level, and then eventually at a high school in the following quote:

> Janice: One of the people at Phillip Morris, his name was John Dillywn [pseudonym], he is the brother of the Benedictine sister who is prioress of this community and owns this school. And I had been working at Reynolds, he was finishing his PhD at VCU, he told me about an opening. I kind of followed him, you know, and that is how I got my jobs, how I knew him, and I had had a baby in February and have given up all my classes and Sister Carmelia [pseudonym] who was the head of school here, called me and said they needed a six week sub for the permanent chemistry teacher for the last six weeks of school, and I thought maybe I am supposed to go do this. And so, I did and I went around with my mouth hanging open most of the time because I hadn't been around adolescents' girls since I was one, and you know it was an interesting experience and kind of ok fine, and went back to summer.

Relationships are at the center of Janice's career development, and not only does she earn a job through a friendship with Dillywn, but also when she meets Sister Carmelia for the substitute position. These relationships inform her career decisions and brought her to the tenure chemistry teaching position at the high school. An anecdotal moment which illustrated a relationship Janice esteemed is captured in the following quote:

> Janice: And she called me the first day of school in the fall and said the chemistry teacher had come back in the fall and walked out on her and so she needed somebody, and I had already made my comments for the year, so I said sorry I couldn't. And then she called me in May when she said she decided not to rehire the person that had been there a year, would I come by to talk to her? That is when I thought, well maybe I am supposed to go do this… And I walked in and in her indelible way, she didn't talk to me about a job, she just started introducing me as the new chemistry teacher, which was kind of her style. I can remember going home and saying to my husband I think I got a job today, but I am not really sure. And so, I came and I taught part-time here in the mornings… And I have never left. And I cannot imagine not being around 15 to 24-year old.

Janice did not plan to become a high school teacher, but in fact became one because she found herself in the right place at the right time. Moreover, she trusted others, Dillywn and Sister Carmelia, to help navigate her career with her. The most impactful statements came in the form of time, Janice started teaching at the school in 1991 and chose to stay, she could have done something else, but as she states, "I cannot imagine not being around 15 to 24-year olds". I do not think it is because she cannot envision a life outside "being around 15 to 24", but that she does not want. To put it plainly, she likes the population she has spent the majority of her life engaging alongside, and found worth. Moreover, she could not see herself separate from this age group because over the course of her career part of her being has become entangled with this population. When she leaves, she will not just leave behind a dwelling place, but she will be leaving behind a part of being. Often times the static nature of a job is seen as a justifier for staying at a job, but this does not seem true with Janice. Even though the lack of formality in which she was hired resonates as something which allowed her to accept the thought "well, maybe I am supposed to go do this". The job as a high school chemistry teacher was not something she sought directly, but wound up in the position by circumstances and through the suggestion of Sister Carmelia. The reason she stayed though was of her own making as she experienced a high school environment through the lens of a high school chemistry teacher.

Janice's position as a female chemistry teacher is significant as many women do not pursue the field of chemistry. Not only does she have B.S. in chemistry, but also, she has obtained her masters' degree in the field, and even performed research at a corporate level. I was curious as to understand why she chose chemistry as her field of study. She could not place her original interest in science, but I did get a response to why chemistry, which was due to the professor's influence at her small liberal arts university. It was interesting that Janice is still

more interested in biology than chemistry and may have pursued that major if it hadn't been for the fact, she had inspirational chemistry professors.

The calling forth of specific memories from her high school experience, collegiate experience, and career experience allowed me to understand the development of where she is now, which is a chemistry teacher in a private school. She acknowledges her identity as a chemistry teacher and made statements about her distaste for chemistry research when she had had the opportunity, and clearly stated her own perception about her abilities. The most powerful aspect of this study was her final ideas of the maker movement, which is found in the statement, "This was the next thing, this makerspace thing that was like this is really cool". Her statements kind of outline her progression of professional development and why there was interest from her and support from her school to invest in the makerspace professional development experience. Furthermore, her willingness to unravel what maker-centered learning appears in the following statement:

> I think the issue is you have to do enough reading on it to, like this design theory thing, to understand you are doing that, I am already doing that. I just haven't, initially attached these words or categories to it, and I think the key for getting making in the teaching curriculum is getting teachers to make that connection.

I was surprised to hear her say she had not attached specific words from the maker-centered framework to what she was doing in the classroom. And yet she states, teachers are the key to getting maker-centered learning integrated into classrooms. I was taken aback by her comparing design theory and maker-centered learning, but only later did I realize she was merely equating one with the other as both are hot topics in current educational spheres.

As the larger conversation circled around her work and her personal educational experiences, I became curious to hear about her parents' occupation as I thought it would give

direct insight into why she chose her profession. The following statements offer insight and hint at her choice of profession:

> Interviewer: … What did your parents do?
> Janice: My mother was a nurse, she never worked as a nurse, she went to Emory, and she was the first person in her family to go to college, wow. My dad was at Georgia Tech, that is how they met… Yeah when we were teenagers. My dad was an electrical engineer, actually he was an agricultural engineer from the University of Georgia, and then he got a job at Westinghouse, um, that is what took him to Baltimore, and he worked in agricultural engineering for the government and then went to Westinghouse and that was his career.
> Interviewer: That is cool.
> Janice: Very different than today.
> Interviewer: Yes, Westinghouse is, um.
> Janice: People don't get to do that anymore.
> Interviewer: No, my dad worked for 30 years for the Long Island Railroad and retired.
> Janice: And my father-in-law worked for Reynolds.
> Interviewer: It is just what you did.
> Janice: That is right, and you were well taken care of too.
> Interviewer: Oh yeah, my dad retired when he was 52, full pension.
> Janice: And they embraced that. And I am here thinking what am I going to do? What I find more people now are not done, they don't feel like they are done.
> Interviewer: I was reading an article in the New York Times about people who just keep on working, they interviewed a 76-year-old florist and a 60 something elevator mechanic who don't want to quit. Just keep on working.
> Janice: They are happy.
> Interviewer: The coolest one was this 92-year-old primary physician, I just really love it. I don't want to stop it. I really like the puzzles.
> Janice: I can identify with that. Yeah.

I was very much hoping she would attach the fact she became a chemistry major and eventually a chemistry because of her mom and dad's influence so I could correlate her career choices to her parents, but she never references it. Where she finds meaning, or importance is in her father spending his entirety of his career at Westinghouse, and how that is not the case anymore. This moment drew me into direct connection with her perspective, as I expressed my own father had worked at the same institution for the entirety of his career and then retired at age 52. Furthermore, I referenced an article I had read the day before on older people working past retirement age and its perceived mental health benefits. Janice stated she identified with the

sentiment of working after retirement age, and not wanting to give up a working life. Prior to my referencing the articles came a moment where Janice expressed her own predicament as a 67-year-old chemistry teacher in comparison to her father. The idea of embracing retirement came from her father's generation to which she states, "And I am here thinking what am I going to do? What I find more people now are not done, they don't feel like they are done." This kind of thought would become even more important, which was unbeknownst to me at the time, because this would be her last year teaching chemistry at the school. It was curious to be a part of a conversation which focused on the inevitability of retirement, but for her I think that present moment was closer, possibly because her age and the time she spent teaching.

The final thing we discussed was her work at the school, and her work creating the science curriculum during her tenure as a chemistry teacher and the head of the science department. In the following exchange I learned that she worked full-time starting in '93, but was part-time prior:

> Interviewer: Yeah. So, what else. You came here, you worked. How long have you been working here?
> Janice: Since '93 full-time, and from that time I worked part time and then Mistress Charlotte asked me to come full-time and redo the program. And so, you know in a small school you learn how to do a lot of things because there is nobody above you to do it. And so, I put the first fume hood in downstairs and we build this addition, you design the chemistry department and the labs and all of that. I have learned to do a lot of things that I wouldn't have had the opportunity. And in an independent school you have autonomy. I get to do what I want to do within my classes. I mean, I look at where the state standards are, but we still get to do our own thing.
> Interviewer: So, you pretty much created the curriculum from '93 until now it's pretty
> Janice: I mean with help

The nonchalant manner she goes about sharing her experience as the creator of the science curriculum is quite remarkable, up until this point I hadn't realized she was the progenitor of the entire science program and how much she had contributed to the curriculum.

The quotes and conversations show a teacher who has committed herself to a specific place and time, which is the school. At least this is what I consider during the conversation and also with the reading and re-reading of the interview. I am very privileged to be interviewing a teacher who has taught so long because she has so much lived experience in teaching and those experiences relate to different life experiences, she is willing to share.

Maker-Centered Teacher Professional Development

The first point of contact I had with Janice was through a professional development experience my adviser setup to immerse teachers in a makerspace so we could observe their learning. This experience was the first Janice had with the maker movement and a makerspace, and of course it was something I desperately wanted her to share, hence the following exchange:

> Interviewer: Um, how did you enjoy your professional development in the makerspace experience?
> Janice: It was fantastic. That is all I thought about, I mean it consumed my thoughts. I would wake up at night I would be thinking about it, I would get up in the morning I would. Meghan and I were talking about it, we just never stopped thinking about what we could do and how it worked and what else could we make.

Janice effusively describes her emotional context during the course of the experience, and goes on to talk about the community which was found in the commercial makerspace where the professional development took place:

> I mean I finished from my teaching that, so now it is like oh, there's people here who will show me; it was the space and the people because they were more than willing to help you and answer your questions because that was when Jonathon was still there, and they were wonderful, and I never felt like I was interrupting him or bugging him, so it gave me the safety net to try to do something so.

Finally, after she describes two separate moments, she details a moment while working on a bed frame when she could not arrange the parts of lumber sufficiently, and then delves into another experience of seeing all the different types of people sitting around a table and the general feelings she associated with the environment:

> I still remember I was there one day and I couldn't get it to be plumb. And this guy walked in and he spent two hours helping me, and that certainly wasn't on his list of things to do, so part of it was the experience there, you walked in some days, and you felt like you were in the middle of the big bang theory.

In this last exert Janice is communicating a sort of blended moment, or tacking back and forth from the lived experience to her reflective reality and it is in these types of moments where we see the lived experience transmit itself (van Manan, 2016). Janice's state of being, or being in her classroom and understanding of the maker-centered learning framework is attached to the moments she has described and experienced. This phenomenological idea is encapsulated in the phrase "big bang theory" which is the idea of chaotic cohesion whereby Janice feels understanding is being accomplished in what on first blush is a chaotic environment.

Janice struggles with the integration of the maker ideas, but in the following anecdote she describes a moment where she solidifies the abstract ideas found in the maker-centered framework into a concrete example for another teacher:

> I got, I see the benefit of what I did this summer, the maker things, I am not exactly sure how to do that in chemistry, I see parts of it, and I guess the whole idea of making, it is allowing your brain to expand it to what it means to make, and I think that is a stumbling block for this movement that teachers are doing things that are making, but they don't see them as making, an example was one of our world language teachers said, yeah that isn't applicable to anything in our class, and Celine [pseudonym] said well wait a minute you have them make food. You have them research recipes and they bring in dishes that are from France or whatever, that is making and that kind of concept, that low level idea of making because so much of what is out there when you read about it is like let's go build this and let's design this thing, that is a stumbling block. I think sometimes in the academic classrooms because you really are doing that you just don't recognize it as such. And getting people to believe that it does have that application and some of it they are already doing. Making in a science lab is labs. I mean it is all the lab work. Now is it, is it original design? No, but there are purposes behind it. Maybe learning a laboratory technique, it may be exploring well I do this, and this, and this. Well, what do you see that happens, and what do you think that means? So, in a way, in science we have been doing the maker movement from its inception.

Janice explains how another subject area might include maker-centered learning through cooking a French meal which serves as an example of her creative vision for maker-centered learning.

However, Janice's perceptions about her own subject matter is that science has already been "doing the maker movement". She does admit that labs are not "original design", but that there is a "purpose" behind them. The "purpose" supersedes "original design", which does not align with the maker movement's ideals, student-centered learning through hands-on creation. What is also important from Janice's quote is that teachers from her school are thinking about ways to include the types of thinking encouraged by the maker movement. She even goes so far to state, building and designing for the sake of it is a "stumbling block" and should be avoided, but learning how current classroom practices align with the maker movement can be helpful. Again, as Janice states, "Making in a science as is labs." The classroom has intuitive classroom procedures which embody principles, but it takes a little work to align a class not necessarily seen as a class that makes stuff. In a follow up question, I captured her thoughts about the maker movement's benefits:

> Interviewer: You would say the differences from the maker movement to the, I guess some of the things you do in the chemistry class on labs specifically are very similar. What do you think the maker movement has to offer?
> Janice: I think it has, this whole framework, I think gives you the opportunity to really think about the connections, real world connections. Like how does it apply. Why does it matter. How can it make a difference somewhere? I think it sets the stage for that next connection to be made which sometimes in trying to get through material that gets lost, so applications, the application piece. How can I apply this? I can see keeping this framework in mind that it would spur you to do, have kids do more of that.

Janice states her appreciation of the framework as a whole, as a tool which allows students to see how they can apply their learning in the classroom to the context of the world. This is one of the underlying values found in the maker movement, and an ideal which was ingrained in the maker-centered learning framework.

Gentle Exactness

Phenomenology asks to consider the ontological presence of a being before considering the epistemological presence. Keeping this in mind, I am utilizing epoché and reduction proper to distill Janice's ontological being. The epoché aims to bridle my own perspective as a researcher and to become aware of them, and the way I "give" to the meanings that emerge from Janice's lived experience, while the reduction proper aims to allow for an openness to Janice's existential being-teacher, which should not be undersold. I am looking at one specific attribute, maker-centered learning, but I must also be aware that Janice's being as a teacher will bring forth meaningful moments outside the bounds of my proposed study.

The epoché and reduction proper operate within the confines of time as it helps establish the boundaries of a person's being (Heidegger, 1996). This can be seen in singular moments in time where Janice's being is called forth which come through her reflective anecdotes. Ultimately, I hope to answer the question: who is Janice as a teacher? Specifically, what is her being as a high school chemistry teacher who has had an experience in a makerspace, and who has learned the maker-centered learning framework. As I look for, bridle, and highlight different moments where Janice's being is pronounced and unattached to situational moments in her everyday life as a chemistry teacher involved in the creation meaning. Furthermore, I also tried to pay attention to how Janice is creating meaning as she tacks from her lifeworld as a chemistry teacher to past anecdotal maker-centered learning moments.

Attuning to moments during the interviews where Janice's being seemed to be called forth, I try to highlight unattached moments either to my own leanings and my own pre-understandings. A moment which presented itself occurred as we talked about Janice's father, which led her to highlight the care and precision he had doing things around the house. During

the short excerpt that follows she repeats the word care, and only through my own attachment of the word thoughtfulness did I begin to understand. As I tried to understand her perspective, what she was referencing, I focused more on the word care than other words because of the repetition. But I think the key to understanding the moment occurs at the end with the word precision, or rather the word care and precision functioned as a unit to create a specific meaning. Furthermore, this moment relies or juxtaposes her father and his carefulness and precision with tools against what you don't see today, which in my mind is clumsiness and imprecision. The following excerpt captures this moment:

> Interviewer: Yeah, yup. I wanted to ask about your dad you talked a little bit about your father as an engineer and his care with his tools
> Janice: Yeah, he was very careful about everything.
> Interviewer: What did he like to make, what did he.
> Janice: Well, he was more than anything, I can't say he made a lot of stuff.
> Interviewer: Was he like a fix it guy at home?
> Janice: No, well he could do things, but it took him forever, forever. But I mean, he was curious, he um, decided to grind a lens for a telescope, I have, he never finished it, he never finished anything. I have this lens it is about this big that he was hand grinding like you walk in a circle around it, you know, you know it is about that deep. He was curious and he tried stuff, he was an amateur photographer for a while, he had a black, a darkroom... But whether he was going to set a post in the ground for the mailbox, he was just very careful about everything he did. You just see that, and that is not what you see today.
> Interviewer: I understand, I hear what you are saying.
> Janice: I mean that is the only way I can describe it. Is he could, he did everything himself, but when you watched him worked it was always with care and precision.
> Interviewer: Thoughtfulness.
> Janice: Thoughtfulness, that is a good word.

During the exchange, there was a moment where Janice's gesture was a calling forward of a memory; it took place as she spoke about her father creating a telescope lens. Janice's hands made these circular motions to show how her father would go about grinding the lens in order to create the thickness. It was just a moment, but the motions of her hands mixed with the emphasis she placed on her words in this moment made it feel like a special moment to me, I was

imagining a younger Janice observing her father creating a lens. Janice was speaking about a significant person in her life; it was tangible both in the moment for me, and in the calling forth of the memory preserved by Janice's being. It also was partially tactile as the memory elicited a movement which mirrored her father's movement which was done to create the telescope lens.

The personal background experience is embodied in the idealized depiction of her father both in the care and precision which is juxtaposed with the current student mindset she sees in class. There is also this idea of thoughtfulness, which was presented by me and then agreed upon by Janice, but before even offering the word to describe the mindset she had observed a certain difference in the way her father thought and acted and in the way her students currently go about interacting with knowledge creation. Janice moved from memories of the past about her father to her present interaction with students in order to create meaning. This was the second time Janice and I talked about this type of mindset pertaining to her father, and I offered up my own perceptions and anecdote, which upon reflecting helped me understand her, but also provided a moment of commonality. The following excerpt shows the back and forth movement of Janice's thought, where the original question asked focused on an interaction about the students' difficulties reading a glass thermometer and the discomfort I saw and then also the students' desire to simply move to a digital thermometer. Janice described her interpretation of the students' cognition and then pivots to her father and back to her present understanding in the following exchange:

> Interviewer: Yes, yes, they want to be right, this is, when you were talking about the digital thermometer, versus the glass thermometer, you know seeing some of the stuff you are doing in here it seems like, I think that you are right, and I don't
> Janice: Well, they want to be right, and society has kind of changed so we are, we are not very exacting.
> Interviewer: Yeah.
> Janice: When I watched my father and his generation work on something, even if it was working out in the yard or whatever, I don't know how to describe it, it was like they had

a certain gentleness to how they, they didn't go up and shake something, they want up, they had a gentle way, I mean you watch the guys at build, i mean they are, it is the only way I can describe it, it is a carefulness that they have, about what they are doing and how they approached things. Now, my dad was an engineer so maybe that was part of it, but, but it was a generation where physically you had to do things, you used calipers, you used, you wanted just measurement, and now everything is just kind of, if it is 80 percent ok, it is ok.
Interviewer: I would agree with that, but I would also say that, there is something about that my dad and my grandfather there were all these procedures, so they had their tools setup because they knew, you know, they knew what steps,
Janice: What steps and it made sense. It was linear.
Interviewer: Yeah, exactly
Janice: It was linear.
Interviewer: It was linear, and there was a respect for that versus just getting it right and done with it.
Janice: Yeah, they may have done it three times. They may have done more iterations to get to that point, maybe there wasn't much of expectation that it was going to be right the first time. I don't know.
Interviewer: I was going to mention iterations, I am glad you brought that up. Because what do you think that does for iterations like, if they cannot get the answer right, what occurs, what do you think occurs.
Janice: And that is part of some of the process I have put in place because, I can see exactly where it is, you are on track, you are on track; now, it is here, this is the issue. This is the thing you don't get, but if you don't have some framework to look at it, it is harder to figure out where the issue is, where the misconception was.
Interviewer: Do you think the students fight you more with getting that framework?
Janice: Oh yeah, some of them are compliant and some of them are going to fight to the end. But it is like it used to tell my kids, we can do it the easy way or the hard way, but I win. You know it is, write the units on your answers, write the units on your answers, write the units on your answers, it is like, ha.

This, the second instance, highlights her father's acumen and comfort in the creation and maintenance of physical objects. It also supports the significance she finds in the linearity of, her students, or a gentle attention to exactness, which is something she saw modelled in her father. This moment informed the conscious/preconscious ideals she has upon the cognitive learning happening with her students; furthermore, her idea behind linear thinking, or gentle attention to exactness is a generalization on the current generation, which is really a comparison of two different generations: her father and her students. Janice also broaches a major incentive associated with maker-centered learning, which is iterations. Many supporters of maker-

centered learning extol the importance of iterations and the value of redoing a problem until fixed, but what Janice astutely pointed out is "if you don't have a framework to look at it, it is harder to figure out where the issue", and this is an important detail to recognize in dealing with maker-centered learning and the maker movement from her perspective.

A moment, which almost led me astray during my analysis can also be taken from this section of the interview, as I led, or allowed my preconscious/conscious judgements to guide the conversation. You can see this in the following quote:

> Interviewer: I would agree with that, but I would also say that, there is something about that my dad and my grandfather there were all these procedures, so they had their tools setup because they knew, you know, they knew what steps...

This giving, devised from my own mind, led me to believe Janice had this conception of learning which aligned with my idea associated with procedural learning. I attached meaning, and you can read from the interview itself that I am "guiding" Janice towards my preconscious judgement of what she is intending to communicate. When in fact I do not think procedural, "linear" learning is the proper assumption, and it is a moment where I did a poor job at bracket/bridling. In my analysis, and in rereading it again, I saw and understood that what she was communicating was far more complex than in my intentional reading, and during the response.

In a conversation about the rigid structure most schools operate under with the pressure of standardized testing and feeling the need to show growth over the course of a year, Janice responded in an uncertain way, but also petitioned the powers that be, which she does not know exactly who that is, to give her the answer on best practices to incorporate in her classroom. The following is her response:

> Janice: Um, when you are talking about doing individual research projects and things, there is a feeling that you know, if you wanna go explore this you have to have a certain basis of knowledge and sometimes I feel like, or at least that is the standards, not sure I am saying that right, if we are going to do it we are going to do it right, so it seems like

you have to have a certain level of knowledge in order, if you don't have a certain number of tools in your toolbox, then how can you use your tools to apply it to something, that is where I struggle. I am sure there is probably a different way to teach chemistry, I need somebody at a higher level to tell me what I no longer need to do, if that makes sense. Like I need somebody, and I don't mean just an off handed answer like the professor I asked, the professors I asked when I first went to teach in a college and I said what do you cover and they said everything in the book. That wasn't helpful because there was no way possible to cover everything in the book. But, tell me what a freshman, a sophomore chemistry student needs to know coming in, and if you tell me I can get rid of this, this and this, I am happy, I know I can do that. I don't know what to glean out and no longer do. Because the thing about the maker movement and teaching this way, is it takes a lot longer time to implement.
Interviewer: Yes
Janice: And a good example is our theology teacher has always done something the hands project with seniors, back from when they used to draw their hands to taking photographs of their hands to doing digital design on the computer. They would do their hands and their hands were to represent them, and the way they saw life and where they wanted to do, and so it was what they were holding or what was on their hands or whatever. So, this year Meghan talked them into to um, actually casting their hands, so they took the stuff they made dental molds with, and filled a two liter bottle and they stuck their hands in and they molded their hands and then they filled them with plaster of Paris and so they ended up with these 3D, and it is amazing the detail, I mean every little line in your hand 3D models of their hands, which they then put rings on... they did the same thing, but they did it with this three dimensional thing, and it was really cool; it turned out really well. But it took four times as long to do that, to get all that done, and so you cannot, the issue is, in science you would say you are teaching on inquiry, so instead of my telling you things you are going to go and do these different activities, and you are going to, from what happens and what you observe you are going to generate ideas and come with conclusions and they may be right, and they may be wrong. That is fine and you maybe discuss it and you learn just as much from the fact you were wrong. Kids have to be able to be wrong, we see that as a real issue, but it takes a lot longer to do, so you cannot cover as much material. If you had all the time in the world, making would be a great way to teach anything, but there are all the time constraints and so how do you put that in and what do you leave out, I don't know the answer to that. I need to know what it is they don't need to know.

As Janice begins to unravel to me the intricacies of what is needed for her to do her own job well, there arose an anecdote where I saw the impact and realities of a maker-centered learning project. While the anecdote does not center around her classroom, there is a reflective moment where she states the nature of the project to be time consuming altogether too much for a class to tackle; however, she did recognize the impactfulness of the project. This both

contradicted and supported a previous idea centered around the need for a framework for maker-centered learning. The contradiction Janice presents is a workable framework, “teaching on inquiry”, but derided the time-consuming methods needed for success in this framework. I think Janice sees possibilities for maker-centered learning, but is hampered by the larger controlling factors in the educational sphere which constraints the amount of time allotted to anyone specific area during the course of the year. Time is an important concept to Janice as she feels the need to teach a specific amount of material over the course of a semester, and while she does see value in inquiry from her perspective “it takes a lot longer."

Janice tapped into an important message found throughout the maker movement, which is iteration. The power of students being wrong and having a chance to do it right to learn as they go about the work. The iterative design cycle is a big component found in the creation of maker-centered learning (Clapp et al., 2017). It also is assumed in the maker movement that students would have time to iterate their designs and recreate the object in which they have motivation and passion. In my mind, Janice struggled to understand how to understand and implement an exciting idea, the maker movement, in a practical manner to fit the restraints placed on by her outside forces. They also came into conflict with the gentle exactness which she esteemed. Time in a classroom is clearly defined and restricted, but there isn’t a restrictiveness to “care” and “precision” which she values and which is found in a specific moment associated with her father. These forces seem unknowable to Janice and frustrate her experiences as a teacher who desires the best for her students; yet feels the pressure of time.

Time was present in Janice’s classroom design as she utilized a flipped classroom approach which allowed students to view the lectures at home through an online portal, and then practice the learning in class. She felt a better use of her in class time would be providing space

to answer questions on problems and illustrating the best methods associated with specific example problems. As a former teacher, I had never employed this practice in my class and had only read about the flipped classroom approach before observing Janice's approach. This approach appeared to be aligned with Janice's interpretation of gentle exactness, and the management of time. She felt the need to reiterate a specific type of learning to the students and held them accountable for the work they did at home as they viewed recorded lectures and came to class with the notes. Janice wanted to work through specific problems in order to attune students to specific procedures through repetition. The following captured her feelings about the students' role in taking notes and the responsibilities associated with homework checks:

> Janice: It was like insert, push a button, and it is the same thing they heard on the video and the same thing they wrote down. So the part I am not sure that happens is they dutifully go write everything down, but I am not sure they are really paying attention to what the material and um, you know that is motivation, so I can um. I try not to totally reteach it because then where is the impetus to go do it the first time, you know. That is one of the reasons I went to these homework checks, instead of giving them credit for bringing in their homework, instead it is here is the homework and here is the goal at the end of this you should be able to do x, y, and z. And then I am going to ask you do this x, y, z. When you finish this assignment, can you now do what you were supposed to get out of the assignment and that has helped some. A lot.
> Interviewer: Have you always done the homework checks?
> Janice: No, I started them last year. Because I was just getting junk, getting stuff written down on paper. And so, you could have a hundred homework average and be failing, and it is like obviously you aren't getting anything out of it. So it was a way to try to force you to get something out of it. I mean they are not hard, if you have done what you were supposed to do, you ought to be able to answer the question and on this one, that could have been last class because they watched the video, so they really had. This time I really, I haven't for a while, I gave them credit for coming up with video notes, and one was a present since they watched it in the class before, you know, just to, just to, buy...
> Janice: Ok, so what we will do tomorrow they will come in tomorrow with that filled out and they will have to look for a pattern. The pattern is if you are in the same column, you have the same number of valence electrons, so if you are in a family, families have similar behaviors and the reason they have similar behaviors is they have the same number and type of valence electrons. So we will see if they will come up with that.
> Interviewer: Do you think they will, do you think the class you just had will be able to make that leap, with there.
> Janice: There are some, there are few kids in there that are really bright, but even they didn't do anything this week. And I can tell when they haven't done anything. They

> didn't do anything over the weekend, so you know what am I going to do with that. I am not asking you to go spend the whole weekend, but it is the way it is, you cannot take weekends off.

This excerpt highlights many of Janice's pedagogical preferences, but where we get a glimpse comes when Janice makes the statement, "you cannot take weekends off". This statement alludes to the importance of time while revealing a part of her own being which is enmeshed with the expectation students will utilize their time to the utmost. Her general stance, which is reinforced by the signs in her class (see Appendix F) and found in their binders from the beginning of the year, focuses on effort in chemistry. Both the sign and quote calls the student to embody a 'can do' attitude in and outside of the classroom. There are other signs (see Appendix F and G) which promote similar virtues and mindsets needed to be successful in her classroom and in life. The physical environment and curriculum which Janice has created in her classroom reinforces and reflects a value which hinges on past experiences which have defined an aspect of her being as a teacher and a person who has a deep understanding of chemistry. It created a part to whole moment as Janice seeks to communicate the parts of chemistry, hard work, and success in life into a comprehensive whole. Janice has in mind to teach chemistry, but also understands what it will take to be successful academically and, in their careers, which also aligns with Janice's understanding of gentle exactness.

In trying to attach language created by the maker-centered learning framework, I aligned a question about looking closely to a lab the students had completed during the class to hear Janice's response and interpretation of the maker-centered learning framing. In thinking about the maker-centered framework, I related it to Janice's idea of gentle exactness expressed in and through her father, and my own interpretation which I attributed in the word thoughtfulness. Here is her response:

> Interviewer: Actually, I do have one more question, would you consider what you were doing today, looking closely.
> Janice: Yeah, probably, but it is just learning, to me, that is, this is this deep, this is the pattern get the pattern, and probably the deeper is can you apply that pattern.
> Interviewer: To the actual.
> Janice: Yeah, here is the information we have. So what do we do with it.
> Interviewer: Yeah because it is just one step. One block of steps.
> Janice: So, everything we have done for the last three classes has been to get to this point. But you cannot just start here, but I don't really care, I mean all the stuff leading to that is going to become superfluous as long as you get this piece and you understand where they came from that is what matters, going forward.

Janice does not necessarily see the lab she had performed as looking closely. She emphasized the process and its build up. The power is not necessarily in just looking closely at an object, but it is in the internalization of the process which appears to be of value to Janice. Finally, it is interesting to note that once patterns or steps have been internalized, they become superfluous as long as the students understand the actual process. From my perspective, the earlier steps are assimilated so that it becomes a part of their developed mindset. As the students perform the procedures and steps necessary to learn the concepts found in chemistry, they become a part of their acquired knowledge and then perform the acquired knowledge for their own personal use.

During a part of one of the interviews, Janice was upset about a student's lack of attention to the process, however, it was not the student's dismissal of the entire process which bothered her rather Janice's ire was raised at the lack of commitment to communication of the measurement units associated with the process. Her ire typifies her desire to challenge the students to be meticulous in the presentation of their ideas, which is entwined with the elevation of the procedures. The following response exemplifies these ideas:

> Interviewer: Like they don't want to do the procedural part, or are they more interested in math.
> Janice: They don't want to go through the process.
> Interviewer: They just want to get the answer?
> Janice: Right, they don't get the answer. And the push back is then work the process.
> Interviewer: Yeah.

> Janice: One of the girls in the last class came in this morning, she had gotten the general idea down, but she hadn't written any units down, so it doesn't mean anything. Getting them to understand a number has meaning in science, not just meaning in math, these are measurements not just numbers. They mean something, but you haven't told me what they mean and so the reader has no idea what they mean. And you teach, it isn't that they don't understand chemical principles because we have done all that, but if you are going to apply all that, in some cases you need to quantify it.

The final outcome from Janice's perspective is the lack of measurement unit clarity shows the lack of actual application to what is occurring in the chemical process. Janice tacked from the parts, which is the process and units, to the actual application and the lack of acknowledgement from the student in clearly seeing this aspect is what perturbed to her. Janice had a clear idea of success in chemistry and wanted the students to engage in a similar process. The student cannot identify, nor has the life experience to understand this perspective. Getting the students to understand the numbers are actually measurements and have significant meaning in chemistry is important to the work Janice feels is needed to help the students move towards a deeper understanding to intuit the ideas contained in chemistry.

Because of my own ignorance in understanding the different types of chemistry and in trying to understand her approach to her praxis, I tried to clarify the larger curricular choices she made, which stems from the physics first curriculum started by Lederman (2001). This curriculum argues teaching physics in the ninth grade and chemistry in the tenth, physics builds off a mathematical base which they students should be developing as they engage in learning algebra. Furthermore, following physics with chemistry allows for students to understand the physical forces associated with chemistry through their experience with physics. Both physics and chemistry form a concrete knowledge base as students take biology in 11th grade and have an understanding of the world and its controlling factors to build a scientific base that other

sciences can use to delve deeper in their perspective fields. Janice explained the reasoning and the demands behind such an approach:

> Interviewer: Um, so, what we were doing today, you were very focused with getting them to understand the process, um, why so much focus on the process. I mean you talked about this on the recording, I mean the interview the other day, you want them to understand the process versus the um, algebra or the math associated with it. Why?
> Janice: Well, we spent the first day talking about scientific principles and theory and so, assumingly they got that part and they seemed to be talking the talk correctly, but then how do you apply that to working through a problem, quantifying that. And like I said, when I first came many years ago from a college level, they said they cannot do chemistry because they cannot do math, and it is like that is ridiculous because you don't have to do math. So, it was the weak algebra skills, and so you can do it without algebra you just do it all with ratios and paying attention to units, if you will buy in to working through a problem solving method where you only pay attention to units, you really, you can really do it without understanding any of the theory behind it if you will just work the process and cross out the units, if you don't get the right units there is not way in hell you are going to get the right answer, and so here is how you think through the process, and it gives you a way to say why am I getting the wrong answer, because if they will write all this down it is really easy to say oh, you have that backwards, that is the issue, it keeps them from saying, well I don't understand anything. Well, yeah you do, you did this right, this right and this right. Here is where the issue is, so it allows them, me to dissect what is going on. Where do they go off the reservation and can, then it is easy to get back on, and the challenge is getting them to buy into work, the process, because it requires time and writing.
> Interviewer: How were you taught? When you were going through chemistry?
> Janice: Um, I don't remember it having to be spelled out so much. And I just, I am sure I just picked up a lot of these things along the way from somebody else, but it is pretty necessary, if you want them to do numbers.
> Interviewer: Yeah.
> Janice: It is like I figured out if you will buy into this I know this will work, as someone has said I have figured out how to teach chemistry so they can all get through chemistry, if they buy into the system.

At the end of this conversation Janice extolled the importance of her students buying into the process and system she has created. Furthermore, it is important to remember that she designed the science curriculum which is something I often forgot during the interviewing process. And I think upon reflection I see Janice's concerns are not only for the students learning chemistry, but in the development of the entirety of the students' scientific knowledge in high school. The needed scientific knowledge is intertwined with Janice's idea of gentle exactness which is

defined by Janice's ontological being. The understanding of Janice's being as a teacher is supported by her being as a person in her lifeworld, and while the classroom is only one segment of her lifeworld; it is a large part of her larger lifeworld which extends outside of the classroom. While my research is bounded by Janice's classroom lifeworld, there are places where Janice's classroom lifeworld extends out towards her larger lifeworld. A perfect example of this is Janice's idea of gentle exactness which is an idea developed outside of her classroom, but very much present. The way Janice thinks about teaching is important to understand how a maker-centered framework could be implemented in her classroom and other classrooms which look like hers.

Stepping into Janice's lifeworld came with the realization of bridling my prejudgments and judgements. In order to attune to Janice's epoché, I had to bracket/bridle my own pre-understanding in order to be open to and allow for the Janice's hermeneutic tacking (whole-part-whole) to be at the forefront of this analysis. I feel we do get a sense of Janice's lifeworld being as a chemistry teacher through moments captured such as gentle exactness and the emphasis on hard work. Furthermore, the reduction proper allowed the flashes of Janice's being to come through as anecdotal moments were highlighted which helped me understand Janice's being and experience as teacher confronting maker-centered learning in her chemistry classroom. While this section focused on Janice internal mental being as she dwelled in her lifeworld, the next section attends to Janice's in class physical movements as I saw the manner in which she physically dwelled in the classroom as a contribution to her overall lifeworld being. Both are independent, but also interdependent as humans are not merely physical creatures, but also mental/intellectual creatures who tack back and forth from their mental and physical being.

Janice's Movement

As I began attending Janice's classes and took observational notes, and then looked at the transcripts from the interviews, I started noticing both the space in which the students' learning took place and the way in which Janice moved in the classroom space. Generally speaking, most physical movement occurred during the labs and the least amount of physical movement took place during times when the teacher was at the front of the classroom going over content. Janice was not always fully aware of her movements, but there were distinct times when they seemed useful to her teaching practice, and were natural parts of what was occurring. This all stood out to me as maker-centered learning often aligns with informal learning environments and the importance of allowing students to be at the center of the knowledge creation. A comment made by Janice revealed her state of being in teaching the same subject matter over multiple class periods and even the entirety of her career. While her comments are not directly tied to movement at the beginning, there was a point of departure as an anecdotal moment arose whereby she was struck by a student's interpretation of material she had taught numerous times and had not seen, which she would not have noticed if she had not been walking around her classroom as the students were practicing a chemistry problem, here is the excerpt:

> Interviewer: Is this the third or fourth class you have taught the same. Fourth?
> Janice: Yeah, fourth. Yeah.
> Interviewer: So, by the fourth class how are you thinking or feeling about your subject matter?
> Janice: Well, you know it is the fourth time, times 27, or whatever, I don't really, it doesn't bother me.
> Interviewer: Yeah.
> Janice: There are times when I am not sure what I have said to who, you know, and I usually say if I said this already just nod politely and go on. Interesting today in walking around, you know Friday was fine, I could see what they were doing and I got it. There were some bizarre diagrams, the one kids had made it a pyramid, I mean just totally went off. I said you cannot make it a pyramid, you got to do it this way. There were three of them that were just really, it was like, how could they, I have a hard time when how could you not do that be able to do that.

Janice's astonishment at the students' inability to reproduce the proper way to figure out the different levels of elements losing and gaining electrons was only supported when she walked around the room to observe how the students were practicing what they had learned from the lesson they had observed the night before. This reinforced the pre-established idea in my head that teacher movement during classwork allows for an assessment of student learning, it also typifies the flipped classroom, as the teacher is concerned with checking student progress on classroom problems rather merely assessing them as homework.

One of the more powerful aspects about the teacher's movement in the classroom is her realization of its impact on the students' overall performance in class. My line of questioning comes from trying to understand how Janice gets the student engaged, and whether or not there is an individualistic component to engaging her students:

> Interviewer: Does it go by individual student?
> Janice: Sometimes, depends on the kid. And there are some kids you cannot, you could never draw attention to, so you just have to let it go, or you go over and stand next to them, or you put your hand on their desk or on their paper or you do something else that is not calling them out.

Furthermore, Janice acknowledges her lack of movement when she is engaged in using the document camera in the following exchange:

> Interviewer: Um, and when you are teaching, how do you decide when you move from the side of the document camera to?
> Janice: Oh, when I am not writing or whatever. When I am trying to, I want you to focus here, not up here.
> Interviewer: Right
> Janice: And I stay one in place too much, I played with the screen at one point I had something where you could walk around and you could basically show up writing on that anywhere. I think whatever I had was ok, but it was too small, there are probably better things now that do that.

In juxtaposition to the teacher's movement during the lab, Janice admits her limited movement when she stands next to or behind the document to illustrate the examples which she finds

important for the students to know. This is curious to me as there is a palpable energy shift which I had witnessed when Janice was at the front of the classroom and when she assisted the students with completing her lab assignments. This shift reminded me of the work the maker movement talks a lot about in trying to get students excited about learning as the students were more animated during lab time than when they were following Janice and taking notes on the document camera.

During a lab experiment which required the students to handle different beakers in order to complete the lab, Janice felt compelled to illustrate the proper handling of the Erlenmeyer flask while turning a valve that released another chemical in order to complete the laboratory experiment. She was very concerned about the students' body placement in front of the burette while holding the Erlenmeyer flask and had the students watch her while she performed the task. After showing off the proper procedures she even went so far to walk around the room and attend to the students who were still struggling with the positioning of their bodies, swishing the Erlenmeyer flask, and turning the burette.

> Interviewer: When you are standing over here, and you are describing the way to stand and operate the Erlenmeyer, what were you thinking as you were doing that?
> Janice: Yes, I was thinking about watching some kids yesterday who were standing on one foot and they were leaning like this, and you cannot control two things, you have to have some, to get your fine motor skills you have to be standing steady, and so you cannot swirl a flask and operate a burette if you are not got control of both your hands, and I have watched that happen time and time again. So, the benefit it is, ok I have watched three kids do this, so let me tell you all the things. Like I didn't think to say that the first class, well no wonder they cannot turn it off when they need to turn it off, and they want to sit down all the time, and if you are going to do lab work safely you pretty much stand up. First off if something happens you want to be able to get away and if you are sitting on a stool you can't back up away, to get out of the way of something, so it is just that idea of learning how to physically be when you go do it.
> Interviewer: Yeah I noticed that, um. The physical movements were very important to you to communicate to them today. Because they have never done, or have they?
> Janice: They hadn't done this before, they've done some lab work, so they knew, I've had to remind them sometimes, they knew they had to be standing, but they haven't done anything that required this kind of coordination. You have to remind them you are going

> to do this lab together and you will find that one is holding a test tube and other is pouring acid into it, and it is like. Wait a minute, I would never put myself in the that position, and you don't have any eye hand coordination unless you are doing it, and you see it and you think, wait a minute does this make any sense that means you do one and you do one, but we don't both do it. So, it does take that eye hand coordination.

Janice was concerned for how the students used the laboratory instruments stemmed from a previous class where her observations of the students' movements with the instruments made her reassess how she was teaching. It lays the groundwork that even a teacher who has been teaching for over twenty years needs to teach certain things, and tying into the gentle exactness Janice spoke about previously. However, this idea manifests itself physically in Janice asking the students to attend to their physical movements in a specific manner as they complete a laboratory assignment. Furthermore, the manner in which Janice would like her students to comport their bodies in relation to the laboratory tools is defined by specific steps she would like the students to perform.

The conversations of Janice's movement and my own observations of her classroom movements led to the following conversation of the classroom setup:

> Interviewer: So, the front desk is really to show what you are doing.
> Janice: Yeah, you do demo, I clear that off and setup stuff and do demos, even the room next door which is when we designed this there were four labs and a classroom and the ideas was you could move in and out of that, but even that has a lab demo with water and gas.
> Interviewer: Was this always supposed to be a full-on classroom/lab or was it just supposed.
> Janice: Well, we had it so we could share a classroom, but I mean you can't really separate them, you should be doing something that is lab based all the time. Um, and then we needed the classroom for somebody, so we kind of lost that adaptability.

Again, during the review of the transcription I was reminded that Janice built the science department and had a lot of input into the layout of the actual room where she teaches and the materials needed to be able to teach chemistry. This also led me to ask about the attraction of a makerspace and the importance of a similar space to the maker-centered learning. And she

directed the conversation towards the adaptability of the other rooms and the inability to do so in her classroom, which is illustrated in the following quote:

> Interviewer: Yeah, I was thinking of like you know makerspaces, part of their attraction is there like the multi-use, multipurpose,
> Janice: Well, that room, the other three rooms you can move, the lab tables are on wheels, you can move it and rearrange it or reconfigure it, we started out with computer labs and they all had straight rows, and we got rid of that and now there are tables that can be reconfigured in different ways. Um.
> Interviewer: The space is very interesting and how we use it in classrooms, or don't use it.
> Janice: They are re-configuring their classrooms all the time, we just can't do that.

She followed with further thoughts on the room setup:

> Janice: And that is one of the, I mean these two rooms they are, they are the way they are because they have to be that way, so you can't, you really cannot, there is not, you are tied, you are tethered by cords whereas some of our newer installations of this stuff is um, wireless, so you can really be anywhere in the room. Like, I'd rather be in the back of the room talking and writing.

In the final statements we see that Janice would rather have the ability to move than be tethered to one space, and she points to the fact the rooms are unable to be changed to fit the context of a makerspace. Janice expressed the reality of the situation, which was that the chemistry classroom is the one she currently inhabits, and the chemistry classroom she has to teach within. There are other spaces in the school which are more adaptable, but that is not her space. Part of the tether Janice alludes to is her use of the document camera and its inability to allow her to move around the room.

The reality of Janice's lifeworld is intrinsically tied to her physical movements while in the classroom, and this became apparent in my observations. But only through bridling/bracketing my expectations of what a chemistry teacher should do, and tried to observe what Janice is doing. Janice's movements tacked back and forth from days when she would predominantly stand by the document camera and on the days she would move from table to table to assist in the labs to form a sort of whole class movement which was dependent on the

curriculum for the day. Her use of the document camera in general brought up a question of body/mind separation which embodies the ideals found in Heidegger's phenomenological interpretation, as well as Husserl's oft quoted line, "Things themselves". In many ways the use of the document camera became the teacher's movements in the class, and even more profound was Janice's writing utensil laden hand which showed in the document camera became the knowledge creator.

Disembodied Hand

As Janice utilized the document camera for review and to allow students to create their own notes, she became entangled with the technology. The way in which the document camera was used in the classroom was as a mediator between Janice and the students. Furthermore, the document camera only showed the worksheet/paper she was working on and a hand with a writing utensil. She used the document camera as a literacy aid to assist students in unlocking the complexities of the work. The focus of the students then was on the notes and the hand which were writing the notes for the students, at least from my perspective as an observer. I engaged her in conversation about how she uses underlining to assist students in understanding the material. More often the notes, or problems, were a way to reinforce the learning the students had performed the night before through watching a video on the subject matter. The time in class with the document camera became a time for iteration and utilization of the content, as she asked the student to mechanically copy notes or practice problem solving techniques associated with the chosen content of the day. This stemmed from the teacher's aim to create a flipped classroom, which places new knowledge acquisition in the hands of learners through online lectures. The kind of in class learning is exemplified through the following:

> Interviewer: Um, oh, I noticed when you were working with the document cam, you were underlining certain words, ah how do you decide which words to underline?

Janice: They were all the connection words in that statement, or that relationship, so there is pressure, there is temperature, there is volume. So here are the main keywords that you are looking for, figure out what you have versus what is changing.
Interviewer: To show emphasis to students.
Janice: To get them to look for those same words, so when they look at a problem, they have to identify oh I have a pressure, I have a temperature, or I got two temperatures, what am I going to do with that.

Another exchange presented itself on Janice's use of the document camera as I saw the teacher using squiggly lines to emphasize specific information and asked Janice for clarification about why she did that and its purpose in conveying the importance of the content. The following is how I posited the question and her response:

Interviewer: The squiggly line on the document with the bracket why did you do that?
Janice: Oh, because they have trouble reading a word problem and putting the data that goes together, together. And what I have learned to do is to say what are the words that connect the pieces of information together, of this, and that. They are all connected.
Interviewer: Yeah
Janice: And so you have to get the relationships that go together, together.
Interviewer: So it is like a visual tool.
Janice: Yeah, and just say here is what you look for. You need to do something like that, that connects them. these things go together.
Interviewer: Um, where did you learn that?
Janice: I have no idea. I don't know I just picked it up at some point. I have been doing it a long time. Because kids will say they have trouble working with word problems, so part of the reason they have trouble with those is that they don't identify the clues within the sentence structure that relates things together. I don't know if you remember we did um, polarities and volumes for dilution we did it for acids and bases, and they will forever, they will set the equation up and then they don't put the volume and polarity that go together, together. They get them on opposite sides, so you have to tell them something to look for. I am sure someone pointed that out to me at some point and that is when I started doing it.
Interviewer: That is very interesting, that you did that because you did the underlining two days ago, and I see that students are underlining their words, so it is cool
Janice: Sometimes they need, they need some things to pick out. For instance the homework quiz they took, the last class, the first question was give the symbol for each of these parameters and there were a whole bunch of them who instead of putting P for pressure and V volume wrote down atmospheres and liters, They wrote units down, they didn't get the symbol, so the idea is you didn't read the question you didn't take time to read the question, so underlining or highlighting makes you slow down, so you are answering the question that is asked for, I am sure they knew that, but they didn't answer what was asked for.

Both quotes illustrate how Janice helped her students create meaning from the chemistry content, and again it goes back to the delivery of the information the teacher wants the students to learn. Part of Janice's being is contained within her physical body and physical presence in the classroom, and not that there is a diminishing of the body as an elevation of specific body parts. The hand the students observe becomes a part of the lifeworld reality of the classroom as the lights are dimmed and the document stands at the forefront of the classroom with Janice literally and metaphorically standing behind it.

While my perceptions and observations on Janice's teaching through a disembodied hand and document lean towards the idea of dislocation and even distancing, I do not feel Janice felt this way. She did acknowledge general feelings about her frustrations with knowing what to teach, or even a better way to teach which could result in better outcomes for her students, but there wasn't necessarily doubt that what was she was doing would produce positive results. Furthermore, as a curriculum expert I feel she was creating opportunities for students to engage with the material multiple times in different ways. Utilizing the hermeneutical circle as a lens to critique the way she has set up her curriculum, the disembodied was a part to the whole as she endeavored to reinforce previous learning from the videos they were assigned to watch at home.

What is of interest for this study is the internal conflict which arose from Janice's involvement with maker-centered learning. It isn't necessarily conflict as her lifeworld being was called into question regarding how she had been teaching, her professional development experience, and how she might balance those two experiences in her current lifeworld. Again, Janice's hermeneutical circle is attached to the different temporal experiences. Janice's being is not defined by one experience, but by all of them which coalesced to create one lifeworld experience which is dependent on different experiences that occurred at different times in her

life. The interviews brought forth questions about Janice's praxis and how she goes about educating her students, and it made her question her lifeworld. But at the same time, she had created a system dependent on her being able to have the students focus on her hand with a writing utensil during the class period. The whole-part-whole of Janice's lifeworld was present in the observations and interviews because I saw and heard her unsureness in how she was communicating the whole-part-whole of chemistry to her students. This suggests our being-teachers is key to teaching, our identity matters, who we are is revealed as we communicate in a school setting.

Another part of Janice's being which became prevalent during the use of the document camera is her voice. The physical movements of her hand and the explanation offered via her voice offered different parts of information in order to create a meaningful unit of knowledge. While Janice's hands created meaningful information on the document camera for the students to copy and imitate; her voice explained the reason behind her hand's movements. They became partners in a hermeneutical dance to communicate the information of the day. Moreover, while the hand might be writing a smaller concept or problem down, the voice would be explaining the larger context of the problem. This kind of give and take, or whole-part-whole, teaching took place quite rapidly and moved freely between the voice and the hand, so that if the voice was discussing a particular point the hand might be writing a general definition or idea. Sometimes both the hand and voice were supporting each other to express a point or idea, and this synchronous moment both parts of the body formed a connective whole, even though they were still separate from the entirety of the body. Furthermore, because Janice had created a flipped classroom where students watch videos of the teacher's lectures and then came to class and performed the work while the teacher assists them. The videos assigned placed emphasis on

voice, sometimes Janice and sometimes someone else, as they relayed information. The lifeworld in which Janice created was one where she became a facilitator, which aligned with the maker-centered learning framework. The way in which she chose to become a facilitator was a bit different as she chose to empower her students by disembodying her physical being to allow students to engage in a hermeneutical circle focused on chemistry knowledge. In general, Janice's practices aim to have her fade from a position of power for the sake of the student's knowledge creation.

Retirement

During the course of the study Janice learned at the end of the school year she would not be returning to the school. However, even before she realized it would be her last year teaching chemistry at the school, I caught a reflective moment where she acknowledged the difference in how her father and his generation approached retirement and how her generation does. The following exchange starts with her father and the specificity of his situation:

> Janice: Yeah when we were teenagers. My dad was an electrical engineer, actually he was an agricultural engineer from the University of Georgia, and then he got a job at Westinghouse, um, that is what took him to Baltimore, and he worked in agricultural engineering for the government and then went to Westinghouse and that was his career
> Interviewer: That is cool.
> Janice: Very different than today.
> Interviewer: Yes, Westinghouse is, um.
> Janice: People don't get to do that anymore.
> Interviewer: No, my dad worked for 30 years for the Long Island Railroad and retired.
> Janice: And my father-in-law worked for Reynolds.
> Interviewer: It is just what you did.
> Janice: That is right, and you were well taken care of too.
> Interviewer: Oh yeah, my dad retired when he was 52, full pension.
> Janice: And they embraced that. And I am here thinking what am I going to do. What I find more people now are not done, they don't feel like they are done.

Not only did I have a chance to hear about Janice's father, but I had an opportunity to share about my father who worked at the same corporation and retired after 30 years of service. I think both she and I were in awe of our father's ability to perform such a feat as the current economic climate is different. The most impactful moment comes at the end where Janice is unsure about what to do once retirement comes. She is 67 years old, and knows numerically her time has come to leave the classroom; yet, she does not feel like not working, or doing what one is perceived to do during retirement (i.e., nothing). I think there is also point of departure for Janice as she comes to the realization she looks up to her father for his acceptance of retirement, and furthermore uses the difference between the generations to talk about how her parents' generation and her own are not the same. I think it is an incredibly strong statement when she states, "they don't feel like they are done", and I think she is applying this to herself. She has not asked to retire. She has not asked to develop a lifeworld outside of the school where she has invested so much time and her being into. And I could feel the uncertainty in her language and her body movements when the topic would arise

Janice did not talk about what it would feel like for her to be not employed anymore, but she did mention the school, and expressed curiosity at what the new chemistry teacher might choose to include. There is an interesting moment though when she stated she is stuck, but followed up with saying she could teach in a manner which used the inquiry methodology, here is the following anecdote:

> Janice: Like, I don't know if it is the best way, I am kind of interested to see what happens next year when someone else is doing that has been doing more inquiry based, um, and I can do inquiry, I am really kind of stuck at this point of somebody needs to tell me what they don't need to do anymore, I don't know the answer to that. What don't they need anymore, so what can you leave out that is content? You can do inquiry, inquiry starts with the assumption that you have a group of curious students that want to learn and if you don't have that, it is kind of like labs, where you can be curious and think

about what is going on, or you just do cookbook kind of stuff and get an answer and don't really get anything out of it.

While Janice does not explicitly talk about her coming retirement in concrete terms, but talks about her curiosity to see how the next person operates within the educational system. Janice seemed enmeshed with the school as an institution, which made complete sense since she has been at the school for a considerable time, but does not know how to not be what she has been for a long time, a chemistry student. She cares and thinks deeply about the school and wants it very much to be successful. She also wants to continue working at the school, if in a diminished role as a substitute, which is odd, at least from my perspective. At the time I asked myself why would she come back to a place that asked her to leave? I think the short answer is she cares. Also, by using the hermeneutical circle I see how she is trying to come to some sort of understanding of her being with a substantial part of her whole lifeworld being removed. So that she is moving from her lifeworld presence at the school which will soon be gone, to try to understand what it means to establish a new lifeworld. And in order to do this she is moving between past and present experiences with others and by herself. Finally, the next quote showed the uncertainty Janice has in leaving and in what comes next:

Interviewer: Yeah, yeah. right. It is remarkable. It is a testimony to the care in this place, and that is a lot. That takes a lot. It is what makes a good educator and creates real change. Lasting change.
Janice: And it is hard not being part of what comes next.
Interviewer: Yeah.
Janice: I mean I will be in some way, but on the outside.
Interviewer: When I had to leave it was hard to leave knowing that it was the right time to go, but also knowing that I wouldn't be a part of what is next. I mean, I still show up and you know.
Janice: I will still be around.
Interviewer: I am around and I live in the neighborhood. So that is awesome, I get to hear things.
Janice: And on the other side. I have been doing this too many years, and what I mean by that is; it needs somebody else to take control, and take it in a different direction, or the same direction, or a different way or whatever. That could be good.

> Interviewer: Yeah, I had the same feeling at AJC. Just because I had been a founding teacher and be there and you know, I felt like I used all my tricks, and you get to a point where this is what I got.
> Janice: Well, you know I brought all these people here, and they are damn good. It is time for them to step up and guide. You know kind of things, so I am excited to see what that is, but I have to, now I have to start over. I had talked to Alexandra about doing something next year, but now I have to start over make sure, and I have a good relationship with Sister Alice, but we will see.

This was one of my favorite moments as I had a similar experience and understood her emotional experience at leaving a school which you had invested a lot of time and energy. But a major difference is that with me I got to choose when I left, and I still feel like she wants to do more, and could do more, or something different. The statement she makes about her students need something different, while a graceful thought does not seem genuine to me. I think she may get to this point eventually, or this state of being, but it is going to take a while. It seems as though she is still thinking about how her life will look once she enters retirement, and the school is still a part of that life, albeit a smaller one. Retirement is a difficult time for many people as they have to reorient their lifeworld to encapsulate different moments when for so long the career was a defining feature which created many opportunities for defining one's being and time. Retirement is also a reminder of one's mortality, and I think in Janice's case the reminder of morality brought forth the relationships she has had with the students and the school, and pushed the importance of the maker-centered learning framework to the background.

Conclusion

Janice had a meaningful experience during her time in the maker professional development to the point she felt it was worthwhile enough to help lead a summer makerspace enrichment program for her students. There were moments captured by the interviews which capture maker-centered learning's impact on Janice's praxis and her being. It matters deeply to Janice that she is not moving and engaging the students and there are elements of the maker-

centered framework within her curriculum which showcase Janice's acceptance of a different way to contemplate teaching chemistry. I do not think she knows how to accommodate her current pedagogical leanings towards the maker movement with the gentle exactness she has cultivated over the course of twenty-years, nor does it seem as if she feels validated in these new leanings. There is a tension between the ontological and the epistemological occurring. Her being is intertwined with her lifeworld presence within the classroom and there seems to be a struggle between her being and her lifeworld.

A huge element thrown into Janice's lifeworld was her coming retirement which was revealed to her during the course of my study. This fact in some ways freed Janice from feeling confined, but in other ways it halted possible growth towards trying to deal with the uncomfortable space the maker-centered learning framework occupied as she was free to think about her future outside of the classroom. There was a tangible shift in her being as the year came to an end, and there were several interviews where she appeared visibly uncomfortable with the topic of her coming retirement; it is hard moment in anyone's life and one which creates uncertainty as a very present lifeworld, which has taken years to create, dissolves and forces one to create and figure out a new lifeworld.

Discussion

My findings reveal a teacher deeply embedded in a school as the sole chemistry teacher who will be leaving her role at the conclusion of the school year. Janice had an impactful learning experience in a makerspace through a PD opportunity, and led students in a similar experience; yet, there are complexities which push and pull at her being, and her lifeworld does not necessitate a drastic shift in her pedagogy. Through this single case study, we see moments where she is recognizing maker-centered learning occurring in her classroom, and the

possibilities the maker movement could offer a chemistry classroom. The reflective interviewing and observation reveal Janice constructed her classroom lifeworld around specific values. The whole of Janice's lifeworld is her being-teacher, which is constructed of anecdotal moments and parts of her life both outside and inside the classroom. There is a tacking from whole to parts and back to whole as she deconstructs past anecdotal moments while referencing and sharing current classroom stories and experiences which illustrate her current state of being. In order to capture the hermeneutical circle apparent from the interviews and observations with Janice, I utilized the maker-centered learning framework (see Appendix A) as a way to structure the discussion surrounding the findings. It served as a way to explore the complexities found as I tried to grasp my own tendencies, as well as my thoughts on what I feel will be important contributions to the field of instructional technology.

Lifeworld Experiences

In trying to capture Janice's lived experience in a chemistry classroom utilizing the maker-centered framework, I had an opportunity to look closely at the ways in which Janice created her lifeworld. She allowed me to look closely at her being by allowing me to observe different aspects of her teaching, while also answering questions about her lifeworld. Both the observations and interviews allowed a deep close look at Janice's predisposition as she endeavored to understand and integrate the maker-centered learning framework.

Janice has been teaching at her school and has been involved with the development of the curriculum since its inception. And while she has implemented elements of a flipped classroom environment into her classroom, I would say at first glance her approach to teaching is very teacher-centered. It would seem the makerspace professional development experience did seem to disrupt her perception about how educational environments could be structured. However, in

my observations of her classes I did not notice the applications learned during her maker professional development experience, or the summer enrichment program she helped to lead. If anything, what she learned about making and maker-centered learning helped to confirm her established practices. This is not to say she did not appreciate the ideals associated with the maker movement, but I think there were not opportunities afforded to shift her mindset.

In the instances where the elements of the maker-centered learning framework were spoken about she related it to something she had been doing in class already. The labs especially seemed aligned in her mind with all three elements of the maker-centered learning framework (see Appendix A) and how it interprets the ways students should learn. In the reflective time I spent with her through the interview process, there were definitely moments where you could see her struggle with the expectations of school curriculum combined with the profound experience, she had at the makerspace professional development. She seemed to have moments where she just wanted to be finished with her obligations as a teacher and to continue teaching. The closer I looked at Janice's lifeworld the more complex it became.

Janice had grown accustomed to teaching, in a manner she found easy and which held importance. Her ingrained thoughts about education can be traced to her personal experience as a student and were influenced by her family. Both reveal the need for hard work, iterative thinking, and the ability to not let failure define the learning experience. I think the element of the maker-centered framework which Janice most easily identified was looking closely as it related to what she termed as linear thinking, or gentle exactness, a kind of slow procedural way to approach learning which she found was lacking in this generation of students. Again, tying to the creation of the lifeworld which Janice created by in the classroom; it was derivative of her experiences which were more deeply established from a long time of teaching, rather than a

limited experience with the maker-centered framework which had not been as long or impactful as her other personal learning experiences. There were anecdotal moments where Janice was calling forth recent memories of maker experiences to help identify and understanding present and future integrations of maker-centered learning. But I think without me asking her to recount details of her teaching practices related to maker-centered learning there probably might not have been a deeper reflective experience to challenge past teaching practices.

Janice did acknowledge she may be stuck in routines which may not be the most beneficial to the students' growth, but in the same instance she had volunteered for the maker movement professional development experience and spearheaded the student summer enrichment program. These stood out to me as identifiers of a teacher who wanted to engage students through a willingness to the possibilities of a different approach to teaching. Many teachers, would simply choose to not engage in an activity which would require more work outside of their direct content area, or outside of school time. The fact Janice was willing to try something out of her comfort zone stood out to me, or this at least was my initial thoughts upon meeting Janice; it was only later did I realize that engaging in maker-centered learning was not necessarily far off from her comfort area. However, her willingness led her to look closely at her own lifeworld both past and present in order to assess whether or not there was some other way to teach chemistry, which led her to be open to the possibilities offered by the maker movement.

One of the more powerful aspects of the maker movement is its use of space to provide students with opportunities to create. Janice's use, or lack of use of space, in her classroom stems from her interpretation of what is necessary for the cognitive growth of the students. In Janice's case she had constructed her lifeworld space to reflect an ideology and reality concurrent with the demands of the traditional school. The reality of the situation in the

classroom is that the space is static. The tables are immovable, as they are in most traditional chemistry classrooms, because they each have gas and water lines at each individual table. The layout of the classroom (see Appendix H), even before Janice enters had been dictated by the physical layout, furthermore the front desk is a long desk which encourages presentations of new experiments for labs. Therefore, the way in which Janice teaches is influenced by the layout as she cannot change its existing structure. Heidegger calls this "facticity" (Polt, p. 47), the idea that Janice's environment is constructed in a manner that it becomes a part of her being, she cares for her space and has learned to incorporate it into her lifeworld (Van Manen, 2015). Again, since she developed the chemistry curriculum and had input into the design of the classroom itself, in many ways she chose the kind of environment her lifeworld would develop. However, even though she did help in the decision of the class setup, there must also be the acknowledgement that most high school chemistry classrooms are setup in a similar manner, with tables that are immovable facing the front of the classroom where the teacher can demonstrate labs and then student can perform labs at their desks. This type of room setup has been the prescribed chemistry classroom design since she herself was a chemistry teacher. This of course begs the question: Did she really have a choice? The answer of course is complex as the design of the room fit with conceived ideas about how a chemistry classroom should be setup; it is only in looking at the maker movement ideals that Janice questions the classroom setup, and even I question the classroom. Without an idea questioning the established setup of a chemistry classroom, I wouldn't have thought about its design. Without the ideals communicated by the maker-centered learning framework, or experiencing a makerspace would I have questioned how Janice's space appears. The maker-centered framework assists in creating

a rational way to reveal Janice's lifeworld space, as it is underpinned by the idea of sensitivity to design, which also allows for looking closely at Janice in her being-teacher at the school.

While the environment may not be an ideal environment for maker-centered learning, and Janice, especially after experiencing a makerspace and realizing its effects on her own learning, she still has to dwell within the space as it is immovable. Janice does seem uncomfortable with how the classroom is currently setup, and how she even exists in the world, but doesn't necessarily feel empowered to build or develop a different space to dwell within as there are larger structural and curricular restraints in the classroom environment. The whole maker-centered learning framework has disrupted the manner in which Janice thinks about educating, but the actualization to change the current curricular and physical classroom structure eludes her. This is directly connected to her being, as she both would like to enact maker-centered learning, but also wants to not give up on the ways she has been teaching, which she views as valid and worthwhile. She finds her established mode has offered plenty of opportunities to students in the past for success, but also sees the potential opportunities afforded by the maker-centered learning framework if appropriately integrated into her curriculum. Janice's past experiences are influencing present reality, and her future being is a combination of the two. When I look closely at Janice's lived experience in a chemistry classroom, I am exposed to the many different opportunities to incorporate maker-centered learning, but the reality is the complexities of Janice's developed lifeworld belay the seemingly simplicity of maker-centered learning.

A complex issue which I keep on revisiting is Janice's support for the flipped classroom approach. The idea of the approach is to empower students to own their learning, and then reinforce their knowledge acquisition during classroom time. But it didn't necessarily feel empowering or even real, as the learning was mediated through technology. I do not know how

to express this except during the observations and in looking at how she designed the curriculum resulted in a feeling of dislocation. I use the term dislocation to communicate the feelings perceived as Janice wrote on the document camera and the students copied down the notes. A further dislocation created was established through the use of online videos which communicated the course content. The classes which involved Janice creating notes using the document camera centered around her standing behind the document camera. She spoke while writing with a pen on a prepared worksheet with the information outlined. She gave definitions and work through problems she thought applicable to further the students understanding of the subject matter. The dislocation or disembodied moment arose as Janice wrote and spoke without the presence of her body, or acknowledging the students' bodies. The transference of information becomes less about her physical interaction with the students and more about the consumption of the written words shown on the document camera. While there were moments where Janice came from behind the document camera and broke from the creation of notes as a point of emphasis, the majority of the time was spent with Janice creating content for the students to digest.

The creation of meaning from the hand holding a writing utensil imparts a sensation the hand is disembodied. This kind of estrangement is awkward as the physical body is replaced by the impact of the hand through the dispersion of knowledge. Although, students could still hear Janice's voice and they were physically seated in the class, the primary focus was on Janice's hand writing and then on their own hand writing the notes. The body in a way becomes an afterthought to the hand and the knowledge it is producing is associated with a specific task utilizing the information to meet the desired content outcome. There is also an interesting interplay occurring between technology and Janice as she uses the document camera to

communicate her ideas to the class. The document camera amplifies one appendage from Janice's body while allowing others to slip in the background.

Along with the document camera, a huge disembodied feature that presents itself in the instructional design of the class comes from Janice's use of voice. In the videos, which contain her voice or another person's voice and a visual of the content being taught there is another moment of disassociation with the physical body and placing the content at the forefront of the exchange between the viewer and creator. The importance of the communication of the content fits with Janice's overall philosophy of teaching which aligns with a cognitivist approach, but I think it also serves that before Janice can do any labs with the students they have to have an entry point of knowledge to allow the students to perform and understand the labs.

Phenomenological studies highlight the importance of time in considering one's selfhood. In allowing to watch and choose to re-watch the lecturing aspects of the chemistry class there is an out of time experience which is occurring with the content being presented. While the actual class is based in a defined time period within the school day, the videos live outside the constraints of a school day and allowed students to interact with a lesson in their own time. The online lesson then becomes less of an expression of Janice's physical being, and more of a presentation organized by Janice so the students can grasp the concepts being presented online. I think this is why some of videos offered for viewing were not even created by her, and the ones which were feature the same type of setup with the hand or voice at the forefront of the interaction alongside the content. This allows the students to move between a prior moment with chemistry and a present understanding to be able to comprehend what is needed about the subject matter, and they could do this as many times as possible.

In juxtaposition to many of the pedagogical choices Janice has made is the maker movement. And an enduring part of the maker-movement is it acknowledges the body as a way to build knowledge through the construction of artifacts. The maker-centered framework focuses on the actualization of student interest and utilizes their motivation to drive the learning. The teacher tries to be more of a facilitator as the students looks closely, finds opportunity, and explores complexity. I would argue Janice aims to accomplish each one of these framework pieces, but her interpretation is slightly different. If you were to ask Janice if her curriculum allows students to look at the complexities of chemistry, she would respond yes, and even offer examples. However, the way in which she achieved that goal would look quite differently than in a 'truly' maker centric classroom with strict constructivist and constructionist values being expressed explicitly in the curriculum.

Conclusion

Heidegger's idea of Dasein, the state of being, states one's ontology supersedes their epistemology which is what makes this study important to the field of instructional technology. As the field started from a place of providing and analyzing best practices for the transmission of knowledge in the 20th and 21st centuries; it has as yet to comprehend the complexities of learning with and through technology from the perspective of a human gaining new knowledge for the use of incorporating it into their being and lifeworld.

The life of a teacher is teeming with complexities that are often overlooked and even though I am only really looking at the manner in which Janice, a chemistry teacher, engages with maker-centered learning in her classroom there are numerous personal intricacies which make up her lifeworld experience, her state of being. I would consider Janice an expert in her subject matter and a teacher who has had a deeply moving experience connected with the maker

movement. She has been well informed on the make-centered learning framework and knows the personal and social benefits of creating objects in a commercial makerspace. What is profound from this study is gaining an insight to how Janice is creating meaning with her new knowledge about the maker movement, as well as the personal experience she has gained through being in a makerspace environment for an extended period of time. Janice has had time and space to experience the complexities of the maker movement prior to this study, so she had enough time to subsume the complex ideas associated with the maker-centered learning framework. Through this study you are exposed to how Janice interacts with her present knowledge about the maker-centered learning framework, and how her past experiences affect how she teaches. It is important to remember the things which make up a person's being aren't necessarily tied to the present, but often come from past experiences. Also, as Janice seek to create meaning from her understanding of the maker-centered learning framework I noticed there are paradoxical ways of being as Janice both stated she included maker-centered learning into her class, and struggled to find ways for her students to perform maker activities. I think if anyone at the school were to understand the maker movement deeply and be able to communicate its effects and importance it would be Janice since she has had so much exposure to it. In addition, her values align with the ideas encapsulated by the maker movement.

Having studied the maker movement in general, and conducting a single-case study of a teacher who had engaged with maker-centered learning, I can say the failing of the maker movement lay in its practical application in a modern classroom. I have not seen, nor heard of a maker-centered curriculum which works within the confines of a specific subject, whether it be chemistry or not, for an extended period of time. The conversation surrounding the maker movement is its association with STEM subjects, which I think is valid, but it is intrinsically

difficult for a single teacher to create and execute a maker curriculum. It is challenging because creating a "cookie cutter" curriculum for a teacher flies in the face of what the maker movement symbolizes as it touts constructivist principles and student-centered learning. However, there is a need to model best practices for teachers and schools to integrate this type of learning into educational institutions. The maker-centered learning framework by Clapp et al. (2016) is a great start, but it is only one framework and we have not yet seen wide adoption of it into school environments. In Janice's specific case, if the school shifted the entirety of the curriculum to adapting a maker-centered learning approach in every class, or if she were giving carte blanche to teach using maker principles and not worry about outcomes than there might be substantial change. However, the reality is Janice's lifeworld isn't singularly constructed, as she must consider her administrators, her field of study, and other factors which influence her disposition towards teaching chemistry. Or maybe the possibility of offering a more sustained maker-centered experience to a teacher, instead of just a summer course, would allow for a deeper enactment of maker principles alongside the teacher's praxis.

One of the driving forces behind educational institutions interest in maker-centered learning is its connection to STEM subject matter. It has been seen as a vehicle to shift student interest in the STEM subject matter through its creative engagement of students' abilities to create digital and physical objects. However, before students become adept at navigating makerspaces and the implements which come from tying an educational institution to the maker movement teachers must come to embrace this type of teaching. It is evident through the literature there is little research presenting a teacher's lived experience with the maker movement or maker-centered learning. The aim of this paper was to capture the experience of a chemistry

teacher as she wrestles with maker-centered learning in her classroom through phenomenological methods.

Janice allowed me into her lifeworld to ask questions and observe what it looked like to be a being involved in constructing chemistry knowledge with 10th graders in a private all-girls catholic school. I was allowed to try to understand how this teacher was constructing her life experiences with her makerspace experiences reveals to the educational technology a real-world integration of maker principles in a functioning classroom. A major concern on reflection is how researchers assume teachers do not bring anything to the table when it comes to understanding maker-centered learning. In the case of Janice, I found in many ways her values aligned with the principles associated with the maker movement and maker-centered learning. A problematic concept which arose and continues to arise is the idea that teachers need to transform their mindset to fit the mold of maker-centered learning. This devalues the teacher's lived experience and often places them at odds with whomever may be performing a professional development on the subject. In the instance of Janice, I found a teacher whose values aligned with the maker-centered framework, but who was at odds with its functionality in the classroom. Finding ways to harness teacher knowledge and experience would allow for more teacher buy-in; furthermore, the conversation surrounding mindset, in this case maker mindset needs to shift. The prevailing notion is that teachers do not understand, or have not developed a maker mindset in order to educate students in the maker movement. When in reality, many of the defining features found in the maker-centered learning already exist within Janice's being and personhood. Janice, and many other teachers, need support to find ways to integrate making into the classroom efficiently and seamlessly without detracting from their current curricular expectations.

A practical answer to finding support for Janice, and other teachers, is helping either develop a community of practice at her school with the maker-centered learning framework, or help navigate a larger community of practice to help the integration of the maker community alongside the school. Making can take many forms, and has many iterations within educational institutions, and it takes time and effort to find ways to integrate it into a classroom. Instead of dictating the need and development of a maker mindset researchers could be finding resources and ways to support making in classroom environments which is inclusive of the teacher's own previous teaching experience.

For the field of instructional technology, and the maker movement in education, we should be deeply concerned that a teacher like Janice does not see a clear way to integrate maker-centered learning in her classroom. She is a teacher who has thought deeply about it, and who has had an impactful experience; yet, she has had a difficult time incorporating the maker-centered learning framework into her lifeworld. In order for the maker movement to continue it has to find a way to be relevant in teacher's lives and support their current praxis while introducing new ideas which can add further complexity, opportunity, and depth of learning.

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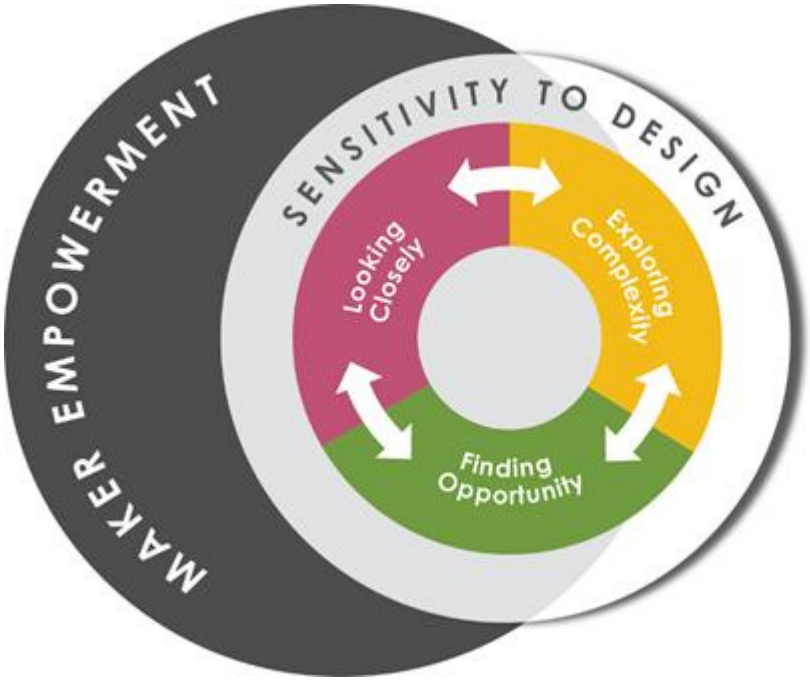
Appendices

Appendix A

Maker Centered-Learning Framework



Appendix B

Agency by Design Framework

Ways for Educators to use the Agency *by* Design Framework for Maker-Centered Learning and The Making Moves

The Agency *by* Design Framework

A key goal of maker-centered learning is to help young people and adults feel empowered to build and shape their worlds. Acquiring this sense of maker empowerment is strongly supported by learning to notice and engage with the designed dimension of one's physical and conceptual environment—in other words, by having a sensitivity to design.

Maker Empowerment:
A sensitivity to the designed dimension of objects and systems, along with the inclination and capacity to shape one's world through building, tinkering, re/designing, or hacking.

Sensitivity to Design:
Learning to notice and engage with one's physical and conceptual environment by looking closely and reflecting on the design of objects and systems, exploring the complexity of design, and finding opportunity to make objects and systems more effective, more efficient, more ethical, or more beautiful.

Sensitivity to design develops when young people and adults have opportunities to: look closely and reflect on the design of objects and systems, explore the complexity of design, and understand themselves as designers of their worlds. Accordingly, the Agency *by* Design framework describes three interrelated capacities that help learners develop a sensitivity to design: Looking Closely, Exploring Complexity, and Finding Opportunity. For each of these capacities, there is a set of observable "moves" — or indicators — that learners and educators can use to help design maker-centered learning experiences, and to support, observe, document, and assess maker-centered learning. They apply to individual as well as collaborative learning.

Appendix C

Contact Summary Form

Table 1. *Contact Summary Form*
Observation Grid for Teacher Learning

Researcher: Date/Time:

Focus Area Being Taught:

RQ1: What is the lived classroom experience of a chemistry teacher with maker movement knowledge?
RQ2: How are the three components (looking closely, exploring complexity, finding opportunity) of maker-centered learning present in the teacher's praxis?

	Research Issues			
Areas of Observation	Looking Closely	Exploring Complexity	Finding Opportunity	Guided Learning or Open Time
Behavior				
Conversation				
Context				
General Mood				

Other Areas				
Reflective Comments				

Appendix D

Preliminary Interview Questions

Preliminary Interview Questions

Biographical Background

	Interview Question	Sub Questions	Research Question Addressed
1	What is your educational background?	• Have long have you been a teacher? • How many other subjects did you teach?	RQ1: What is the lived classroom experience of a chemistry teacher with maker movement knowledge?
2	Have you ever had a job outside of an educational environment?	• What was the moment you decided to leave the former occupation for a career in education?	RQ1: What is the lived classroom experience of a chemistry teacher with maker movement knowledge?

3	Can you describe a moment where you knew you had chosen the right field of work?	• Is there a story which you could share which highlights the confirmation of this decision?	RQ1: What is the lived classroom experience of a chemistry teacher with maker movement knowledge?
4	Have there been any moments of regret during your tenure of teaching?	• Could you name those experiences and describe a specific moment where this occurred?	RQ1: What is the lived classroom experience of a chemistry teacher with maker movement knowledge?
5	Is there a story, or an incident which tells the reason you decided to stick with science both in your education and career?	• Can you describe why science holds so much importance for you?	RQ1: What is the lived classroom experience of a chemistry teacher with maker movement knowledge?

Makerspace Professional Development Experience

	Interview Question	**Sub Questions**	**Research Question Addressed**
1	Can you take me back and walk me through the experience you had in the makerspace during your professional development?	• Was there specific interaction or creation experience which stands out in your memory as significant?	RQ1: What is the lived classroom experience of a chemistry teacher with maker movement knowledge? RQ2: How are the three components (looking closely, exploring complexity, finding opportunity) of maker-centered learning present in the teacher's praxis?

2	Was there a time since your professional development experience where you changed a lesson based off you makerspace experience??	• What was the situation, or content? Can you remember where you thought you could use the knowledge gained from your professional development experience?	RQ2: How are the three components (looking closely, exploring complexity, finding opportunity) of maker-centered learning present in the teacher's praxis?
3	Was there a moment where you realized maker-centered learning components could easily become a part of your current curriculum? Or you realized they already had been, but were identified in a different manner?	• What was this moment? What was the story surrounding this moment?	RQ2: How are the three components (looking closely, exploring complexity, finding opportunity) of maker-centered learning present in the teacher's praxis?
4	What area of chemistry you do think already incorporates maker-centered learning?	• Can you tell me a moment from your professional development where you thought about your current teaching practice and the activities you completed at the makerspace?	RQ3: How are the three components (looking closely, exploring complexity, finding opportunity) of maker-centered learning present in the teacher's praxis?

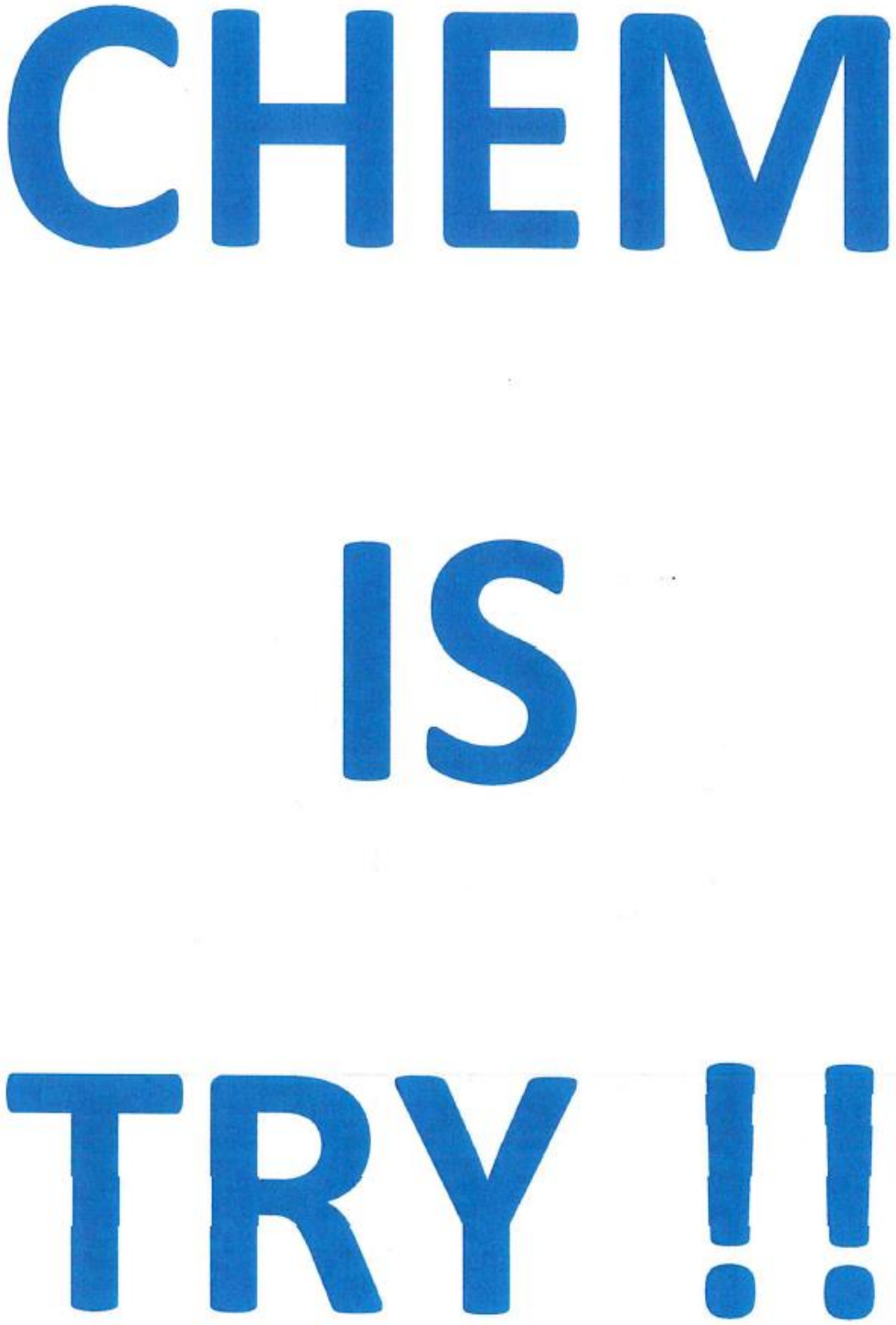
10	What ways can you envision the maker movement changing education?		RQ1: What is the experience of a female chemistry teacher as she engages with a maker-centered learning curriculum?

Appendix E
Reflection Questions

	Reflection Question	Research Question Addressed
1	How much time did you spend planning with the maker-centered learning framework? ● Where did you spend most of your time for the day?	RQ1: What is the experience of a female chemistry teacher as she engages with a maker-centered learning curriculum?
2	Did you try anything new in class today/this week? ● Did anyone assist you in learning something new?	RQ1: What is the experience of a female chemistry teacher as she engages with a maker-centered learning curriculum?
3	Did you find yourself struggling with integrating a maker-centered framework? ● How did you overcome this? ● Did you use any online resources to assist you in your struggle?	RQ1: What is the experience of a female chemistry teacher as she engages with a maker-centered learning curriculum?
4	Is there anything else you would like to share about the maker-centered learning framework?	RQ1: What is the experience of a female chemistry teacher as she engages with a maker-centered learning curriculum?

Appendix F

Signage



Class expectations

WAKE UP

BE THANKFUL

BE APPROACHABLE

COMPLAIN LESS

SMILE, REALLY

START EARLY & GO LONG

GO BEYOND EXPECTATIONS

HAVE A **SENSE OF URGENCY**

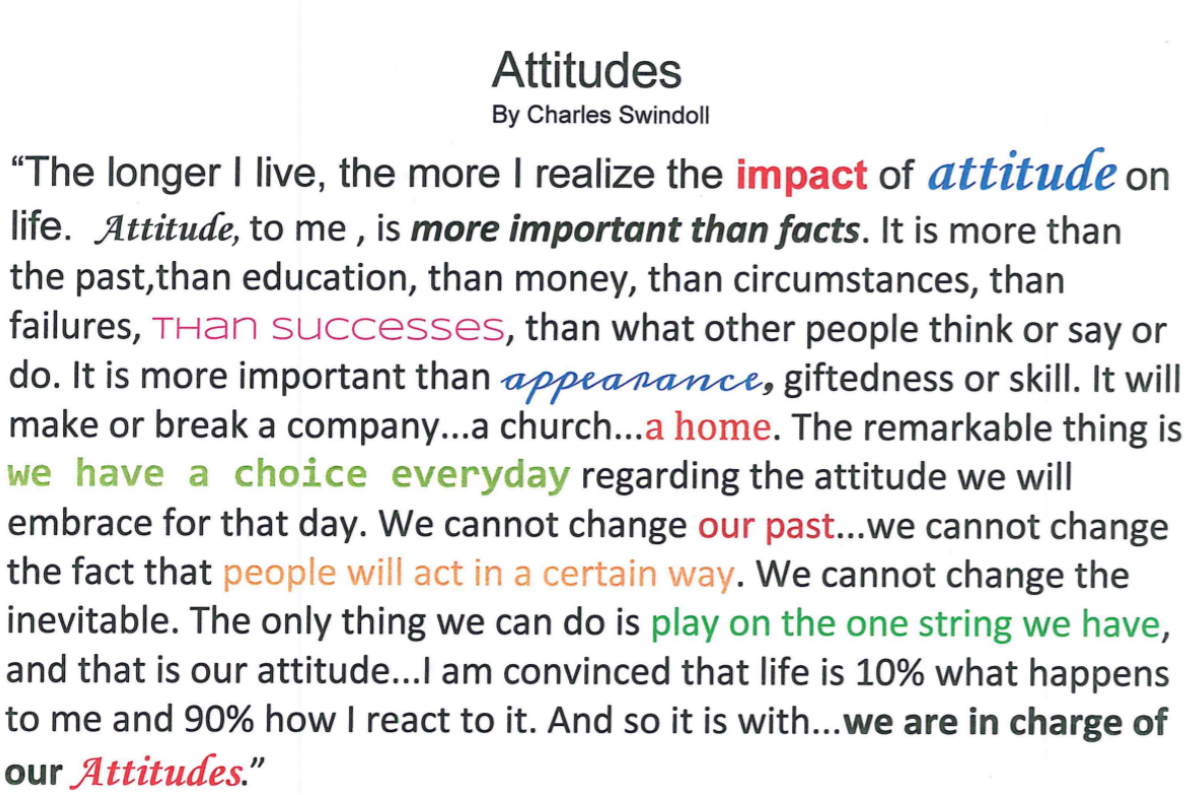
BE RESOURCEFUL & RESILIENT WITH NO EXCUSES

smile & move

Here's to a great year!!

Appendix G

Attitude Signage



Appendix H

Classroom Setup