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Understanding how adults approach technological challenges: A sequential mixed methods research

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UNDERSTANDING HOW ADULTS APPROACH TECHNOLOGICAL CHALLENGES: A SEQUENTIAL MIXED METHODS RESEARCH

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To my mom who encouraged me, believed in me, and stayed in my heart

as I got my Ph.D.

To my daughter who taught me the importance of structure and balance.

Being her mom has made me a better person.

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GLOSSARY

Active Interaction: This type of interaction between a person and a technological product or process refers to one's adapting and creating technology. It is mainly a design process.

Categorized Theme: The compilation of themes and dimensions: five categorized themes emerged for the ways in which adults approach technological challenges.

Dimension: Three main topics emerged from interviews regarding how participants approach technology. Three dimensions are: Attitudes, Behaviors, and Conceptions.

Experience: Each participant was interviewed twice. Within each interview at least two experiences were described. Experienced from the past were denoted by P, recent experiences during interview 1 were denoted by R1 and during interview 2 by R2, the task presented in interview 2 was denoted by T, and the brainstorming by B. For instance, a citation from participant 2, during the brainstorming should be coded as P2B, while a citation from participant 11, during the recent experience described in interview 1 as P11R1.

Groups: Four sub-samples categorized by lifelong learning and STEM background. Engineers with high lifelong learning skills (HLE), engineers with low lifelong learning skills (LLE), non-engineers with high lifelong learning skills (HLnE), or non-engineers with low lifelong learning skills (LLnE).

Non-STEM-trained individual: A person who has not received any formal education in any STEM field. Background may be understood as a continuum between STEM and non-STEM training, where informal courses or technical degrees may be located within that line. For the purposes of this study I will use STEM background as a dichotomous variable where participants with well-defined background will be selected.

Participant: Depending on the strand, refers to 118-participants initial sample for quantitative strand, or the group of 12 outliers for the qualitative strand.

Passive Interaction: An interaction between a person and a technological product or process featuring the usage and evaluation of technology. Does not involve a design process as the main attribute of the interaction.

Outlier: A participant from the quantitative strand who was selected by cluster analysis to be participant of the qualitative strand.

STEM: An acronym for Science, Technology, Engineering, and Mathematics. Refers to the subjects as integrated fields of study where each offers unique characteristics for approaching innovation challenges while informing and interacting with each other.

STEM-trained individual: A person with a formal background in STEM education. The training may be a career in any engineering field such as electrical engineering, technology such as information technology, science such as physics, or mathematics such as statistics. A STEM-trained individual may also have a non-STEM undergraduate degree, but STEM graduate studies.

Technological habits of mind: A way of thinking that incorporates engineering thinking (systemic thinking, trade offs, constraints, acceptance of failure, iterative thinking, continuous improvement, abstraction to models, etc.), technological self-efficacy (confidence when interacting with new technology, brainstorming technological solutions or self-monitoring learning new technology, etc.), and technological information literacy (asks pertinent questions about technology, seeks pertinent information using efficient tools such as the Internet, books, databases etc., critically evaluates technological information, makes critical decisions about technology, etc.).

Technological Literacy: A level of understanding technology in which knowledge, capabilities, and ways of thinking and acting (Committee on Assessing Technological Literacy, et al., 2006; National Academy of Engineering, et al., 2002) allow citizens to use, evaluate, adapt, and create new technology in critical and responsible ways.

Technology: "Technology is the process by which humans modify nature to meet their needs and wants" (National Academy of Engineering, et al., 2002, p. 2). Technology includes products and processes used to create those products; it is the system in its entirety.

Theme: Part of the classifications of each dimension, which emerged from the interview coding. Three themes emerged within Attitudes, five with Behaviors, and six within Conceptions.

ABSTRACT

Tafur Arciniegas, Mariana. Ph.D., Purdue University, May 20015. Understanding How Adults Approach Technological Challenges: A Sequential Mixed Methods Research. Major Professors: Şenay Purzer and Johannes Strobel.

People from all backgrounds engage with technology in their everyday lives. There is, however, a gap in the public's understanding of technology and limited research on how engineers and non-engineers approach technological challenges. Prior studies have focused on the public's understanding of technology but limited research has been conducted on how people deal with technological challenges as part of their everyday lives. Studying how individuals with non-STEM backgrounds engage with technology will contribute a more comprehensive understanding of strategies for closing the technological literacy gap. Taking into account that technology developments rapidly occur, lifelong learning skills are another critical dimension of technological competency.

The purpose of this study is to identify how adults with STEM (specifically engineering) and non-STEM backgrounds with varying levels of lifelong learning approach technological challenges in their everyday lives.

A sequential mixed methods design using nested, purposeful sampling was performed. The quantitative strand included cluster analysis for outlier identification. The qualitative strand included thematic analysis. Four groups of participants were formed: Engineers with lower (LLE) and higher (HLE) levels of lifelong learning and non-STEM participants with lower (LLnE) and higher (HLnE) levels of lifelong learning. Twelve outliers —three in each group— were selected for the qualitative strand. Two semi-structured interviews were conducted on participants' past and recent experiences with technology and challenges they faced during such interactions.

Three dimensions of approaching technology (attitudes, behaviors, and conceptions) emerged from the analysis. Those with broader conceptions of technology were more active users of technology and were emotionally neutral towards the challenge. Conversely, those who had narrower conceptions of technology were passive users of technology and had strong positive and negative emotions towards the challenge. The analyses resulted in five different approaches to technological challenges: disengagement, scaffolding, transitioning, emotional engagement, and ownership. In particular, background shaped conceptions about technology, engagement, and attitudes towards the challenge. This inclusive understanding informs future research and practice about new strategies for improving technology education for all citizens, aligned with the 21st century skills framework.

CHAPTER 1. INTRODUCTION

Challenging interactions with technology have become a part of daily life. People of diverse backgrounds and varying levels of engagement in learning activities regularly face situations involving technology. From commonly used artifacts such as cellular phones to complex processes such as minimizing the time for delivering a package abroad, people are continuously facing challenges in an increasingly technological world (National Academy of Engineering & National Research Council, 2006; National Research Council, 2002). Previous research has investigated how STEM professionals interact with technology through its design (T. Brown, 2008; Dym, Agogino, Eris, Frey, & Leifer, 2005; Nussbaum, 2004) and its usage (e.g., Hogarty, Lang, & Kromrey, 2003; Hohlfeld, Ritzhaupt, & Ann, 2010; Kotrlik & Redmann, 2009; Teo, 2010); however little research has focused on how non-STEM adults approach technology and engage with it (e.g., Anderson, Nicometo, Courter, Mcglamery, & Nathans-Kelly, 2010; Blackwell, Eckert, Bucciarelli, & Earl, 2009; Krupczak, Simpson, Bertsch, Disney, & Garmire, 2009). For instance, Krupczak and colleagues (2012) recognize the importance of technological understanding among all professions and the utility of developing training opportunities for non-engineers. The analysis shows how potential employers appreciate the importance of technology education as a skill set for non-engineers who will eventually work in STEM industries, interact with STEM-trained adults, and utilize technological products and processes.

These technological challenges are constantly evolving due to the rapid and continuous changes in such products and processes (Marra, Camplese, & Litzinger, 1999). People must be able to keep abreast of new technologies in order to critically evaluate and incorporate technology into their everyday lives; they should be lifelong learners, as suggested by numerous sources (e.g ABET Board of Directors, 2012a, 2012e; Laal & Salamati, 2012). Maintaining current technological knowledge is important for non-STEM trained adults in order to be active citizens in a technological society (Krupczak et al., 2009; National Academy of Engineering, Committee on Technological Literacy, & National Research Council). For instance, taking into account the pervasiveness of technology today, some research shows how understanding technology may provide benefits in deciding one's approach (e.g., Anderson et al.; Levy & Murnane, 2013; Mehra, Black, Singh, & Nolt, 2011; Usluel, 2007). In particular, Anderson (2010) studied whether or not trained engineers consider themselves engineers based on their job characteristics or management positions. When researchers asked those participants who identified themselves as engineers about engineering elements needed in their non-engineering positions, participants identified problem solving, technical knowledge or skills, engineering thinking, and communicating technical information as the main elements required. In contrast, participants who considered themselves as non-engineers valued their engineering career skills mainly in problem solving, technical coordination (e.g., improving organizational systems), applying foundational knowledge, design, usage of specific technical knowledge, and applying mathematics. This study shows how adults no longer working in engineering-related jobs use and perceive the utility of core engineering habits of thinking in their everyday lives, even outside the workplace.

Adults outside engineering fields consider skills such as problem solving, design, technical knowledge, and engineering thinking as important in improving everyday processes; also, employers may see these skills and knowledge as useful for non-engineers working in industry (Krupczak et al., 2012). As mentioned before, Krupczak conducted a study where prospective employers were asked about important topics of technological literacy for non-engineers working in the technology industry. Among the 21 topics evaluated, topics related to engineering thinking (e.g., knowledge about constraints, trade-offs, systems, problem solving, troubleshooting) were ranked in the top 6 positions. Likewise, topics related to information literacy, understood as part of technological literacy (e.g., critical thinking, question formulation, information retrieval) were ranked in the top 11 positions. The list included other topics related to technological literacy; however, those featured knowledge and skills rather than habits of mind (e.g., "articulate the pervasiveness of technology in every day life" or "identify the effects of technology in the environment" (Krupczak et al., 2012, p. 8).

Beyond the importance of technology education in becoming an adept employee and modern citizen, diverse shareholders agree that addressing technology education supports competitiveness and innovation of the nation (e.g., Academic Competitiveness Council, 2007; National Science Board, 2012; President's Council of Advisors on Science and Technology, 2012). Technology is commonly linked to development, innovation and competition (e.g., U.S. Congress, 2010; U.S. Department of Education, 1983, 2008; U.S. Government Accountability Office, 2012). Technology drives socio-economic advancements for all citizens. Research shows how active integration of technology leads to critical changes in how communities of the world operate and interact (Baillie; Cain, Giraud, Stedman, & Adams, 2012; Jonassen, Strobel, & Lee, 2006; Law, 2008; Tan & Morris, 2005).

Although some studies analyze strategies for closing the technology gap and providing engineering skills for non-engineers (e.g., Pope, Hare, & Howard; Zoli, Bhatia, Davidson, & Rusch, 2008), the rapid change in technology development is leaving some citizens –those no longer enrolled in formal education— behind (e.g., Boshier & Huang, 2010; Chapman, McGilp, Cartwright, De Souza, & Toomey, 2006; Guglielmino & Guglielmino, 1994; Ha, 2008; Kirk, 2012; Merriam, 2001; Skilbeck, 2006). According to ABET (ABET Board of Directors, 2012a, 2012e), engaging in lifelong learning and self-directed learning activities are key to meet standards required by technology and engineering education; more broadly speaking, most of the frameworks analyzed by

Vgoot and Pareja Roblin (2010) include both technological literacy and lifelong learning as necessary 21st century skill sets.

The research suggests that closing the technology gap should involve lifelong learning (Hager, Holland, & Beckett, 2002; Laal & Salamati, 2012; Quinney, Smith, & Galbraith, 2013; Tan & Morris, 2005). Some studies reflect how lifelong learning is linked to technology use and serves as a tool for developing technological literacy (e.g., Quinney et al., 2013). Also, a commitment to using technology engages its users within particular learning environments (e.g., Tan & Morris, 2006). In their study, Tan and Morris (2006) conducted two surveys of 148 students in the School of Business and Economics at a land grant university. The first survey measured laptop usage categorized as formal (i.e., coursework or collaborative teamwork), non-formal (i.e., professional or individual development), and informal (i.e., convenience or entertainment). The second survey measured lifelong learning outcomes pertaining to professional, personal, and social development. The authors found that formal laptop use (e.g., taking class notes, communicating with a professor via email, or using of web-based tools for teamwork) was significantly correlated with the majority of lifelong learning outcomes (except for team-based work and personal development); non-formal use of laptops for professional means (e.g., researching company web sites for job postings) was correlated to lifelong learning dimensions. Individual use (e.g., reading current events on a laptop) was correlated only with personal development as a lifelong learning outcome. Finally, informal use of laptops (e.g., managing personal finances or using the computer for music, games or other entertainment) was correlated with lifelong learning in the social development dimension and partially correlated to employment as a lifelong learning dimension (and revealed a significant correlation to convenience).

Similarly, some studies (e.g., Hong, Purzer, & Cardella, 2011; Mumm & Mutlu, 2011; Sins, Van Joolingen, Savelsbergh, & Van Hout-Wolters, 2008; Tang, Shetty, & Chen, 2010) analyze how positive values and beliefs towards technology are linked to higher levels of engagement or achievement in technological tasks. In particular, Purzer's study (2011) shows how academic performance in the design of engineering projects correlates to increased self-efficacy. In her study, the author developed a self-efficacy instrument related to engineering design that assesses participants' confidence levels using products and processes for engineering design, computer applications, mathematical models, physic laws, and social interactions. This list reflects a broad conception of technology that is aligned with National Research Council's definition (2002). Tan and Morris (2006) and Purzer (2011) demonstrate how technological literacy (computer use and design) are associated with lifelong learning outcomes such as professional development and self-efficacy, while Quinney (2013) shows how lifelong learning helps to keep participants current in technological knowledge.

However, professional development and self-efficacy are not the only constructs that comprise lifelong learning. Candy (1991) suggests that a self-directed person should be able to monitor, plan, and manage his or her own learning processes. On the other hand, Roth (2010) defines lifelong learning as a process that occurs over the course of an entire lifespan. Though these differences exist, commonly used scales for measuring self-directed and lifelong learning assess the following attributes: openness to learning, self-confidence and self-management when learning, learning skills, future orientation, and family background (Guglielmino, 1977; Livneh, 1986; Lorys Fuge Oddi, 1984). For instance, Livneh (1986) developed an instrument for measuring characteristics of lifelong learners in the human services professions, for which seven factors were identified as dimensions of lifelong learning. The factor identified for self-motivated achievement can be linked to the self-efficacy level measured by Purzer (2011), while the factor identified as future orientation can be linked with career-related professional development outcomes of Tan and Morris' (2006) lifelong learning indicators. Other factors identified in Livneh's instrument (1986) were professional growth through learning, educability, readiness for change, causation for learning participation, and familial educational background.

Conversely, negative lifelong learning outcomes such as low self-efficacy and lack of perceived benefits (or openness to learn) are reflected in some studies (e.g., Al-Senaidi, Lin, & Poirot, 2009; Celik & Yesilyurt, 2013; Ceyhan, 2006). For instance, using the Computer Anxiety Scale, Ceyhan (2006) examined how anxiety towards computers was related to irrational beliefs, positive or negative thinking, and self-disclosure regarding computers. The author suggests that irrational beliefs about computers may affect an individual's actions requiring higher cognition. Likewise, negative thinking (assessed as the frequency with which participants perceived events in a negative way) was related to higher levels of computer anxiety, as compared to positive thinking. In addition, presence of self-disclosure (assessed as the frequency with which participants disclosed their feelings, thoughts, and needs) was also related to levels of computer anxiety.

These studies show how one's beliefs and values regarding technology influence daily use. Everyday decisions related to technology become part of a continuum between engagement and disengagement in technological lifelong learning. Over time, these habits affect one's ability to maintain technological literacy, especially in the case of citizens who are not involved in continuous formal education.

Although it is important to understand how lifelong learning plays a role in approaching technological challenges, it is equally important to improve our understanding of how non-engineers approach technological challenges in order to build effective programs in technology education (e.g., Daly, Adams, & Bodner, 2012; King, Brown, Lindsay, & Vanhecke, 2007). To this end, Daly and colleagues (2012) conducted a study of how engineers and non-engineers experienced design. The authors state that understanding different perspectives may play an important role in preparing for continuous global change (Daly et al., 2012, p. 189). After seeking out diverse design professionals, the authors interviewed twenty participants based on the diversity of products of the design process of their professions. This group included eight engineers, four scientists, two from consumer and family sciences, two from sciences and education, two from liberal arts, one professional from architecture, and one from education. After coding the interviews, the authors found six different ways in which the group experienced design, from evidence-based decision-making (i.e., logical reasoning is used in designing) to freedom (i.e., tolerance to ambiguity and freedom to redefine the problem). This last category emerged from data collected exclusively from non-engineers, which complements engineering design. Similarly, studying non-engineers' experience of technology may advance actual technological understanding.

These approaches to technology may be grouped into two categories: passive and active interactions. Similar to language literacy, being a technologically literate person should require being able to use or evaluate (passive) and adapt or create (active) processes and products. For instance, using a GPS or retrieving an article from an online-information service can be analogous to reading a book or hearing a lecturer. Creating a music database or designing an efficient way to spend limited money on a vacation can be analogous to writing a letter or making a speech. Active interactions with technology are commonly linked to STEM professionals (e.g., Atman et al., 2007; Dym et al., 2005), while passive uses of technology are often linked to general populations (e.g., Celik & Yesilyurt, 2013; Tan & Morris, 2006). Nevertheless, each must decide how to respond to technological challenges (National Academy of Engineering et al., 2002). Understanding how adults with diverse backgrounds approach those challenges may provide tools for closing the technology gap.

1.1 Purpose of the Study

The purpose of this study is to identify how adults with STEM (specifically engineering) and non-STEM backgrounds with varying levels of lifelong learning approach technological challenges in their everyday lives. Studying these experiences will provide insights into the public understanding of technology and engagement. These insights might suggest strategies for closing the technological understanding gap.

The following questions led to this purpose: Q1. Do outliers represent critical cases of groups based on levels of lifelong learning and career background? Q2. How does the selected purposeful sample experience technological challenges in past and recent situations? Q3. How does a STEM background and lifelong learning shape such experiences?

This analysis will provide an explanation of how the technological literacy gap is created or perpetuated based on habits of mind (National Academy of Engineering et al., 2002) related to technology.

1.2 Overview of Dissertation Document

This chapter overview summarizes the documentation of my dissertation research from the revision of supporting literature, through the description of methods for data collection and analysis, results, discussion, and conclusions. In addition, the present chapter shows my motivations and the importance of the research problem, a summary of the most relevant literature, and the research questions.

The second chapter presents the literature review regarding technology and a definition of technological literacy. The chapter also addresses the importance of including diverse backgrounds in technology education due to its importance in everyday interactions. Finally, the second chapter includes a review of literature related to lifelong learning and technological decision-making, both of which are connected to the learning process that ensures sustained technological literacy. The literature presents lifelong learning as a continuous process necessary for keeping up with the rapid pace of technological changes and defines decision-making as the cause of individual behavior when responding to technological challenges.

Chapter three describes the methodology, which includes research design, participants, instruments and procedures used during data collection and analysis, the role of the researcher, and the delimitations and limitations of the study. This chapter is divided into two strands, the first being the quantitative phase in which outliers were identified using two approaches of cluster analysis. The second phase, the qualitative strand, features a thematic analysis performed to analyze second-order perspectives about how adults approach technological challenges.

Chapter four includes the results of the study. For the quantitative strand, this chapter shows how 118 participants from academia and industry scored in lifelong learning, career, and professional background. 21 outliers, at least three per group, were detected and statistically represented each group. For the qualitative strand, 12 were selected for repeated interviews. Results show how three dimensions (attitudes, behaviors, and conceptions) emerged from data characterizing five different approaches (engagement, scaffolding, transitioning, emotional engagement, and ownership) when faced with technological challenges.

Chapter five presents the discussions of both quantitative and qualitative strands, including the codes and themes that emerged, and the categorized experiences. This chapter also includes implications for theory, practice, limitations, and future work. Finally, chapter six summarizes the conclusions of the study.

CHAPTER 2. LITERATURE REVIEW

This chapter synthetizes four core concepts necessary for addressing the research questions. The chapter includes the description of how technology and a technological challenge are defined for the purpose of this document and research. It also offers a description of technological literacy commensurate with the framework used by the International Technology and Engineering Educators Association (ITEEA), relevant nationally and internationally for standard definitions of technological performance. Third, the chapter includes how STEM and non-STEM trained participants will be defined for the purpose of the study and highlights some advantages of including non-STEM trained people into STEM conversations. The literature review also presents a description of lifelong learning, acknowledging it as appropriate terminology for everyday adult interactions with technology. This will lead to the exploration of generic skills and decision-making. The literature review of lifelong learning identifies a proper instrument for differentiating high and low lifelong learners within both the STEM and non-STEM groups of adults.

2.1 What is Technology?

Several STEM stakeholders have identified technology development as a priority for sustaining a competitive market on a national scale. As the National Research Council suggests (2009), “technology and innovation are synergistic” (p. 19); technology provides tools for scientific research and, at the same time, technological advancements are shaped by science and engineering. The National Academy of Science describes technology as a modification of the natural world by humans in order to meet their needs (Committee on Assessing Technological Literacy, National Academy of Engineering, & National Research Council, 2006; National Academy of Engineering et al., 2002). As the authors of Technically Speaking (2002) describe, technology is more than products developed by people; it is also the entire system that creates those products. Technology should be understood as tangible artifacts and intangible processes manipulated by humans; that is, the complete system of transforming the natural world to meet our societal needs. All members of society are surrounded by technology and interact with it constantly. Accordingly, technological literacy is necessary for members of a modern society.

This conception of technology includes a complete range within Bloom’s taxonomy (Athanassiou, McNett, & Harvey, 2003; Cannon & Feinstein, 2005; Fuller et al., 2007), including the creation of products and processes. Similarly, the definition of technology offered in the report highlights the importance of taking both into account –processes and products— as parts of technology (National Research Council, 2002); however, several studies focus on products in particular (e.g., Judson, 2010; Lee, 2011). This is the case for studies in which authors analyze technological literacy by computer use or knowledge (e.g., Hogarty et al., 2003; Hohlfeld et al., 2010; Kotrlik & Redmann, 2009; Teo, 2010). Although some authors conceive of technological literacy in broader terms, such that products and processes are involved in usage and design, the information gathered shows a narrow view in participants' understanding of technology (e.g., Brown, 2009; Rose & Dugger Jr, 2002). In contrast, the scope of some research is limited to technological literacy as established in the journal of technology education (NAE, TIEEA in e.g., Todd Kelley & Kellam, 2009; M. A. Rose, 2010; Warner, 2009). For instance, some research focuses on information literacy (e.g., Dangani & Mohammed, 2009; Kurbanoglu, Akkoyunlu, & Umay, 2006; Mehra et al., 2011; Pinto, Cordon, & Diaz, 2010), digital literacy (e.g., Chang & Chien, 2008; Marty et al., 2013; O'Neill & Hagen, 2009), or design (e.g., Adams, Turns, & Atman, 2003; T. Brown, 2008; Daly et al., 2012; Dym et al., 2005). The intent of this research study is to place technology within a National Academy of Engineering framework, thereby presenting a broader conception of technology that allows for new ways of experiencing technology interactions.

2.1.1 Technological Literacy

Technological literacy is the ability to interact effectively with technological systems. To be consistent with the National Academy of Science's framework (2002), technological literacy may be defined as the composition of three dimensions: technological knowledge, capabilities, and ways of thinking and acting. These

dimensions align well with Technology and Engineering Literacy (WestEd, 2014).
The complexity of the knowledge, the variety of skills, and the level of critical thinking and decision making about technology vary by a person's age and development. At the same time, this literacy is constantly updated due to the brisk pace of technological change.

A first dimension of technological literacy is *knowledge* (National Academy of Engineering et al., 2002). Three principal types of knowledge emerge: one related to understanding that technology is everywhere and plays an important role in our society, another related to its synergy or integration with other STEM disciplines, and a third related to Mathematics, Engineering, and Science concepts necessary for application. In order to understand the role of technology in our society, one must acknowledge that this field is not limited to computers, the Internet, or other artifacts. Technology consists of an entire system: the products, the processes, the know-how, and the cognitive interactions between people and technology. People, too, are included in the technology-system as part of a two-way interaction described by Bucciarelli (2009). A second dimension of technological literacy is *capabilities*. Skills under this dimension allow individuals to use and engage with technological products and processes. This dimension takes into account human actions while interacting with technology. Technically Speaking (National Academy of Engineering et al., 2002) names the third and last dimension, *ways of thinking and acting*, while Tech Tally (Committee on Assessing Technological Literacy et al., 2006) calls it *critical thinking and decision making*. This final dimension is highly related to the interaction between technology and society; according to these reports, when people think critically in their approach to technological challenges they discover effective guidelines and policies for technological advancements. Particularly, this third dimension measures the ways in which people approach issues related to technology.

However, under the 21st century framework, the third dimension is categorized outside technological skills and grouped with skills related to learning. Critical thinking and decision-making have been defined as life skills or generic skills by numerous groups of researchers (e.g., George, 2011; Murray, Clermont, & Binkley, 2005; Rychen & Salganik, 2005). Generic skills are defined as those abilities and attitudes required to thrive in the 21st Century. Besides critical thinking and decision-making, there are other skills categorized as generic such as communication or teamwork (e.g., Dede, 2010; Murray et al., 2005; Rychen & Salganik, 2005). Some frameworks include critical thinking and decision making as part of technological literacy; others are transversal to additional types of literacy, such as language literacy and numeracy (e.g., Dede, 2010; National Academy of Engineering et al., 2002). According to the National Academy of Science (National Academy of Engineering et al., 2002), these two generic skills are crucial for increasing technology engagement. They suggest that critical thinking and decision making are central to asking relevant questions, searching for information to answer and reflect on those questions, and participating in community decisions about technology development.

2.2 Lifelong Learning

Lifelong learners are needed for closing the technological literacy gap between STEM and non-STEM trained individuals. Technological advancements and rapid iteration periods for improvement are the norm (Marra et al., 1999; Voogt & Pareja Roblin, 2010); therefore, technological competency is necessary in order to learn within formal, non-formal, and informal environments (Laal, 2012; Laal & Salamati, 2012). According to Laal and Salamati (2012), lifelong learning is the continuous development of skills and knowledge, and should therefore be present in structured learning environments as well as in activities that are not intended to pursue any learning outcome but allow a valuable, unstructured learning. Lifelong learning is the combination of skills and attitudes that allows people to pursue learning goals via self-direction, -regulation, and –motivation (Banz Jr, 2009; Merriam, 2001; Ryan, 2003). In other words, lifelong learning is self-directed at its core (SDL).

Lifelong learning comprises skills such as communication, teamwork, critical thinking, problem solving, and decision-making (Gordon & Ramdeholl, 2010; Voogt & Pareja Roblin, 2010). According to Voogt and Pareja Roblin (2010), lifelong learning skills needed in the 21st century knowledge society are also part of key skills or generic skills. Different frameworks have defined lifelong learning skills as part of various core skills needed for contributing to advancements in society. The authors made a comparison between six frameworks (P21, En Gauge, ATCS, NETS/ISTE, EU, and OECD) that define learning and knowledge, skills related to technology, and attitudes for the knowledge of society. Similarly to ITEEA's framework for technological literacy (2007), some frameworks analyzed by Voogt and Pareja Roblin (2010) identified critical knowledge and decision making as crucial skills for the 21st century; however, the majority of the frameworks included these skills as part of learning and knowledge. In contrast, skills related to technology were included in interactions with products, bringing varied definitions and assumptions of technology under the same umbrella; information, digital, ICT, and technological literacies were included and sometimes limited the conception of technology, which shifts from one framework to another by its product and process orientation (e.g., OECD and ITEA).

2.3 Building an Inclusive Conversation Towards Technological Literacy

Everyone needs to be able to act critically when shaping or being shaped by a technology-oriented society. Technological literacy is part of the fundamental education for all citizens to function in today's technological society (Committee on Assessing Technological Literacy et al., 2006; International Technology Education Association, 2000, 2007). As National Science Board (2007) suggests, the U.S. is one of the most technologically capable economies in the world; its society is technology-driven. Technological literacy is constituted by several skills mediated by mindsets that allow individuals to act effectively in our society. Some examples include: knowing how to use several devices for simplifying every-day challenges in life, understanding processes and techniques for approaching problems in effective ways, or learning new technological applications. Guaranteeing technological literacy to the general public will allow citizens to live actively within today's technology-based society. This society is clamoring for problem-solvers and critical thinkers who can shape the future of technology. At the same time, technology developments constantly shape society (Committee on Assessing Technological Literacy et al., 2006; National Academy of Engineering et al., 2002). Innovation and growth should be a two-way development where persons communicate their suggestions about new inventions, rather than act as passive users and consumers of one-way technological development.

These 21st century skills (Murray et al., 2005) are essential to all members of society. Engineers, scientists, technicians, and mathematicians (STEM professionals) are required to be technologically literate, but non-STEM individuals who live in this modern society also must interact with evolving technology and therefore require the skills and attitudes for approaching technological challenges. Some research (Academic Competitiveness Council, 2007; President's Council of Advisors on Science and Technology, 2012) has highlighted the importance of developing resources and learning environments for engaging people in STEM education; however, this is hardly sufficient. People need skills to evaluate those materials critically and become self-directed learners who, even outside formal education, are capable of learning how to address the rapid changes and advances around them. About 70% of United States population lives outside formal education settings, leaving an important group of citizens with informal learning as the only source of staying current with technological improvements (National Academy of Engineering et al., 2002).

Resources for—and resulting levels of— technological literacy are unbalanced between STEM and non-STEM professionals. In fact, with the COMPETES act (U.S. Congress, 2010), the U.S. stated the importance of increasing the pipeline of STEM professionals for economic shareholders. The majority of the effort has focused on potential STEM professionals and little intervention has been done with those who have taken a non-STEM professional path. Despite the fact that several studies highlight the importance of the community in engaging people to study careers such as engineering (e.g., Gianakos, 1999; Kuenzi, 2008; National Academy of Engineering, 2008), there has been limited focus on raising technological literacy for all, both STEM and non-STEM individuals (Academic Competitiveness Council, 2007; Committee on Assessing Technological Literacy et al., 2006; National Science Board, 2007).

Given that there are fewer STEM professionals in the education system than are necessary, some policy reports (e.g., International Technology Education Association, 2007; Katehi et al., 2009; Kuenzi, 2008; National Science Board, 2012) suggest that students should begin engineering education at the precollege level, even as early as preschool. Kuenzi (2008) states that quality of STEM education in K-12 must be improved to sustain U.S. leadership in science and technology, and he suggests strategies such as improving teacher's understanding of STEM knowledge or raising STEM degrees granted within the education community. This approach to STEM education may address the necessity of technological literacy for all citizens during their school years; however, the goal of this strategy is not to learn to interact with technology from a non-STEM perspective, but to attract more students to STEM careers.

If the majority of the resources for addressing technological and innovative advancements to sustain the U.S.'s global competitiveness are to bring more people to the STEM pipeline, what is the role of non-STEM professionals in the national technology conversation? Do those citizens who chose non-STEM paths remain outside the national discussion?

2.3.1 Broadening Technology Understanding

Acknowledging differences between community groups is important for creating an inclusive technology education. Including diverse professional backgrounds, STEM and non-STEM career professionals, may help us to understand the broader challenge of how to effectively promote citizens' participation in the technology conversation. In fact, taking into account diverse approaches to a technological problem, contrasting different points of view, and analyzing their levels of feasibility for certain contexts are considered critical thinking skills (Mejia, 2001). Likewise, the analysis of diverse solutions in a critical way provides the basis for sound technology decision-making.

Bringing non-traditional students to STEM fields also enriches the study of these disciplines. For instance, complex and ill-structured problems, which are present in technology, require diverse and participatory approaches for designing effective solutions. Broadening the group of people involved in engineering problems allows for finding better and more complete solutions (Felder, 2006; Hultberg, 1997). As some reports suggest, broader demographics in engineering education is required for problems that most likely are going to have multi-disciplinary dimensions (National Academy of Engineering, 2004). Likewise, having a more expansive framework of what people in engineering and science can achieve is increasing prospective-student populations and increasing retention due to curriculum narrowly focused on mathematics and science that caters to particular learning styles (e.g., Felder & Brent, 2005); in fact, the National Academy of Engineering (2002) highlights that “very few studies have been done to determine whether the views, concerns, and actions of the non-expert public actually influence choices about technology” (p.97).

It is only fair for citizens to receive equal access and opportunities to interact within the modern world. Although it is important for those pursuing STEM careers to be technologically literate, people with non-STEM interests, such as social scientists, artists, or professional athletes also benefit from technologically literacy. As the National Academy of Engineering report illustrates (2002), the general public needs to know, be capable, and think critically about technology’s products or processes in order to make informed and responsible decisions regarding the integration of new technologies into their lives. For instance, a knowledge of seatbelt and airbag engineering allows users to evaluate the risks and trade-offs of these technologies; being able to search for implications of certain GMOs may give consumers the tools for deciding which food products to buy or avoid; participating in the design of a new airbag may prevent risk conditions for women and children (National Academy of Engineering et al., 2002). Being able to actively participate in the creation of society's technological mandates is the right of every citizen regardless of their background in STEM education (National Academy of Engineering, 2005).

Since non-STEM adults decided not to pursue a technology-related career, they can be seen as part of the community who needs to interact with technology but were trained to and work in a different field. If they have studied in regions within the U.S. or other countries where technology education or engineering education are required or at least promoted (e.g., Carr, Bennett, & Strobel, 2012; Colombia. Ministry of National Education, 2006; Institution of Mechanical Engineers, 2010), they probably have a certain level of technological literacy; still, they decided a professional path divergent from STEM fields. Moreover, those students who did not take technology or engineering classes are likely to have lower levels of technological literacy than STEM trained people or workers (Committee on Standards for K-12 Engineering Education & National Research Council, 2010). This group of non-STEM adults needs to interact with technology in their homes, workplaces, and other settings; they must proficient with new technology being created or updated every year (e.g., cellphones, house appliances, or ways of communication); they need to be able to decide which technology is a better solution for addressing their needs. Therefore, non-STEM adults who had fewer opportunities in formal environments for learning technological knowledge and skills are required to have high levels of lifelong learning abilities for self-directing their learning process about these constantly-changing technologies.

Non-STEM adults may approach technological challenges differently than STEM professionals. They may have different but similarly complex levels of technological literacy. These differences may produce a complementary and valid outcome for the design process and therefore increase solutions and alternatives for overcoming the problem. One example of this benefit is shown in the design process itself. Multidisciplinary groups in formal learning environments (e.g., Coyle, Jamieson, & Oakes, 2005) and professional environments (e.g., Thomas Kelley, 2007; Sutton & Hargadon, 1996) produce richer solutions for technological design, which in some cases addresses consumer needs more comprehensively than those solutions from teamwork within a single discipline. Another example of this inter-disciplinarity resides in the field of engineering education. Some studies shows increasing retention and recruitment when more effective pedagogical strategies are used in engineering learning environments (Adams et al., 2011; Felder & Brent, 2005).

Although inclusiveness will bring benefits to understanding technology, it is important to identify which improvements are caused due to diverse backgrounds and which are caused by differences in lifelong learning abilities, regardless of individual background.

2.3.2 Bringing Together the Best of Both Worlds

STEM trained people are expected to have strong math and science backgrounds – logical, systematic, and analytical approaches for problem abstraction. As the new framework for K-12 science education (Achieve Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS, 2013; Committee on Conceptual Framework for the New K-12 Science Education Standards, 2012) and many other entities (e.g., ABET Board of Directors, 2012a; International Technology Education Association, 2007; National Academy of Engineering, 2004, 2005; WestEd) highlight, the activity of engineers and scientists includes inquiry and design; therefore, students should be able to investigate, reason, calculate, or model the problems that challenge them. Synthesis is a common skill that authors include in STEM learning objectives (e.g., Adams et al., 2003; Byhee, 2010); similarly, the ability to model a problem though its abstraction plays an important role in describing STEM-trained people skills (Achieve Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS, 2013; Adams et al., 2003). Likewise, STEM competencies include problem solving in math (Goldin, Epstein, Schorr, & Warner, 2011) and engineering (Diefes-Dux, Moore, Zawojewski, Imbrie, & Follman, 2004; Jonassen et al., 2006). Problem solving includes identifying the problem, which is most likely to be ill structured (Dorst & Royakkers, 2006; Jonassen et al., 2006; National Academy of Engineering, 2004; Strobel & Pan, 2010), seeking feasible solutions, testing and improving them (Diefes-Dux et al., 2004; Savery & Duffy, 2001; Strobel & Pan, 2010). Finally, it is expected within the STEM fields to have strong content knowledge in each of the four subjects of study: science, technology, engineering, and math (International Technology Education Association, 2007; National Academy of Engineering, 2004).

In contrast, non-STEM trained people are often characterized by a less constrained, creative approach (Rayment, 2007) to challenges through trial-error (Jonassen & Hung, 2006). Given this less-structured approach (Rayment, 2007), sometimes a practical strategy is used, and therefore elicits individual intentions or feelings as a valid approach for the problem. For instance, one successful design company has worked with not only engineers, but also linguists and psychologists (Tom Kelley, 2001); this diversity helps designers to think out of the box. In addition, Non-STEM and STEM disciplines have common goals in developing skills such as communication, lifelong learning, or leadership as a core of the learner's formation. This can be seen by comparing how different disciplines approach the same phenomenon such as design (Blackwell et al., 2009) or interact with technology.

In this study, I propose to analyze how non-STEM trained adults may enrich STEM perspectives about technology. More specifically, this is a study of how adults trained in arts, social science or athletic fields bring a different perspective for technological challenges than the more common approaches by STEM trained adults. This inclusive analysis will help me to understand how it is necessary to change technology education in order broaden public understanding of how to approach technological challenges.

Lifelong learning is an acknowledged necessity in diverse fields. For instance, one ABET criteria (2012a) for engineering education is the “recognition of the need and ability to engage in lifelong learning” (p. 3), while a liberal-arts approach to students outcomes states that “inclination to inquire and lifelong learning” (King et al., 2007, p.5) is the desire to grow with an open-mind and knack for out-of-the-box thinking. These two perspectives differ from technology education perspectives, which highlight specifically self-directed learning instead of lifelong learning as a requirement for technologists (ABET Board of Directors, 2012e).

Standards defining engineering and technology professions demand an engagement in lifelong learning as necessary; likewise, standards for the liberal arts demand an inclination towards it. As McCombs (1991) suggests, a lifelong learner should be motivated; in fact, the author identifies seven principles that connect lifelong learning with motivation. McCombs suggests that learning is natural and people are inclined to search for personal growth in an autonomous way when motivated. The process of learning is mediated by social interactions, and each individual has a unique manner of seeing life. Personal affect and cognition reinforce thoughts while insecurity prevents the natural process of learning. Self-efficacy and confidence generate motivation for learning. This self-development and determination guides behavior. Such a relation between lifelong learning and motivation connects a learner’s behavior with his or her unique beliefs and thoughts shaped by social interaction and guided by personal values.

In fact, the continuous growth due to lifelong learning extends beyond professional development; it involves how individuals make decisions and solve everyday challenges (Jonassen et al., 2006; Laal & Salamati, 2012; Voogt & Pareja Roblin, 2010).

2.4 Decision Making

Decision-making can be seen in at least two different ways: a structured process that can be formal and should include different perspectives and steps for approaching a solution, or an understanding of decision-making based on individual values that support small decisions leading to the solution of a problem or the performance of a task, moment-by-moment as Schoenfeld (2013) described it. In this study, the latter definition of decision-making is used for eliciting participants' actions and values related to technology.

Many studies have analyzed how a decision is made during a complex task such as design (T. Brown, 2008; Dym et al., 2005; Nussbaum, 2004), management (Keeney, 1994; Kim & Mauborgne, 2004), or nursing (Coble, 2000; Spence Laschinger & Weston, 1995). For some authors, it involves understanding the problem, identifying alternatives, selecting a solution, and evaluating the chosen solution (Adams et al., 2003; Davis et al., 2009; Dubberly & Evenson, 2008; Nussbaum, 2004); for others it also includes attitudes such as compromise, consistency, and commitment (Mann, Harmoni, & Power, 1989).

This way of seeing decision-making as a process that can be modeled is called a normative approach by Cohen, Freeman, and Thompson (1995).

In contrast, some research has studied decision making as naturalistic and highly limited by time (Cohen et al., 1995). This is the notion of decision-making that will be used for this study: that moment-by-moment decisions lead our actions in every-day life. It is connected to judgments of what each individual considers as better or worse given the available options (Baron, 2000, 2005; Baron & Ritov, 2004).

During moment-by-moment decisions, some of those elements present in critical thinking are expressed more than others. For instance, understanding the many possible viewpoints may be limited by the priority of short-time responses for the interaction with technology. Decision-making and critical thinking are linked because critical thinking produces informed decisions and actions. Taking into account that this study is focused on step-by-step decisions, I will observe the decision-maker's values and beliefs with which they support the step-by-step interaction with technology. This emphasis is coherent to naturalistic decision-making in contrast to a normative approach to it.

According to Baron (2005; 2004), defining an action that is better than another is the judgment of which actions best allows a person to reach his or her goals; in other words, a judgment supported by norms based in his/her own values and understanding of the world. Even more, Keeney (1994) proposes to prioritize those values in relation with finding alternatives. The author calls the process of seeking alternatives before criteria for judging them a reactive one and suggests that a proactive approach first defines the criteria or values under which those alternatives should be assessed. Through the judgment process, people weigh the consequences of a possible action compared to other alternatives (Mann et al., 1989). However, these options may be challenged to mitigate bias due to our prior knowledge and experiences. In addition, making a decision depends on events the decision-maker can control: which are options or alternatives, and which are non-controllable events that Baron (2005) called states. For instance, a person challenged with organizing an annual fundraising event for a non-profit organization may have to decide to design a protocol for not only the current-year's event, but for years to come. This decision is made under some values or desires of long-term versus short-term goals; the person can control whom to contact for help or resources, but she cannot control who is going to help or the extent of the fundraising. During the process, she will need to make moment-by-moment decisions that test her values of each state. Making values explicit is not always a straight process, but it is a complex one. Keeney (1994) proposed value-focused thinking in defining evaluation criteria; he recommends diverse techniques such as using wish lists, considering shortcomings, predicting consequences, and identifying goals. Although these techniques may help in formal decision-making, when decisions are identified as short-time judgments, evaluating consequences or defining goals is an implicit process and more often difficult to elicit. In this matter Baron (2005) goes further; the author adapts Noam Chomksy's theory of moral development for judging for decision-making. The decisions people make are regulated by their intuition, which may involve the evolution of values and beliefs, although it may lead to bias in the decision process. Intuition plays an important role in every-day decision-making, but reaching the desired outcome guides the process; therefore, biased models lead to some decisions that are not supported by one's own values and may be restructured.

In addition, Mann and colleagues (Mann et al., 1989) identify the importance of social and motivational patterns in the judgment process; for instance, a tendency to avoid decision-making by procrastination, conformity, or impulsiveness may bias the outcome and timing for the decision. The way people use and create technology is based on their own values and intuitive sense of fulfilling their life goals. They may value finishing a task quickly, assuring high quality, or avoiding failure. Eliciting people's short-time decisions on how they approach a technological challenge may provide an understanding of how their values about technology are constructed.

Likewise, decision-making means that there are other alternatives that may be good for reaching the criteria, but they are less effective than the alternative chosen. This process of trade-off depends on individual values and desires. Under similar circumstances, different people will evaluate different alternatives as best (Baron, 2005). The possible discrepancies between chosen solutions exist because the nature of complexity and ill structure of a challenge (Jonassen et al., 2006; Strobel & Cardella, 2007). When a task can be performed using a routine, the level of analysis needed to decide is not complex; therefore, the task cannot be identified as a challenge. Likewise, having a well-defined problem to solve does not require complicated levels of decision-making because —as opposed to ill-structured ones— well-structured problems have one solution. In this case, few or a single method to reach that solution exists, and it may present constraints, variables and constants explicitly; accordingly, it is clear how to evaluate the viability of the solution (Jonassen et al., 2006; Strobel & Cardella, 2007). Complex problems that are identified as challenges in this research tend to have multi-disciplinary elements that can be deconstructed and well-structured problems as Jonassen and colleagues explain (2006). The authors also suggest that ill-structured problems have multiple goals that sometimes can lead to divergent solutions. This means that weighing possible alternatives is the foundation on which trade-offs between constraints are made. When approaching a technological challenge, people make moment-by-moment decisions about trade-offs in investment (understood as money, time, research, or any other effort) and goals achieved (e. g. quality, generalizability, transferability, or other goals). Decisions guided by the analysis of trade-offs imply an understanding of the consequences of certain actions and the possible response of processes, artifacts, or other stakeholders in the action. This process of future-stage analysis is called strategic thinking (Koehler & Harvey, 2008; Shavelson, Ruiz-Primo, & Wiley, 2005). Strategic thinking is widely studied in games and military settings (e.g., Cohen et al., 1995; Koehler & Harvey, 2008); however, this type of thinking is also important for facing challenges in other environments, especially those guided by innovation, which is the case of technology. Although McCormick (2004) considers strategic thinking as part of procedural thinking, Shavelson and colleagues (2005) claim the second type of thinking is related to following algorithms instead of creating them.

The decision process may take diverse routes and paths between stages, and yet there may be similarities in the way people with different backgrounds evaluate trade-offs and judge goodness of an action. This study intends to elicit those trade-offs made by the individuals and their own beliefs and actions that lead them to those decisions.

2.5 Measuring Lifelong Learning for Adults

According to the literature, lifelong learning and self-directed learning are highly linked and often understood as equivalent competencies (e.g., Jiusto & DiBiasio, 2006); however, some authors consider self-directedness as one component in lifelong learning (Cadorin, Bortoluzzi, & Palese, 2013; Chiang, Leung, Chui, Leung, & Mak, 2012; Lorys Fuge Oddi, 1984). Due to discrepancies in the delimitation between lifelong learning and self-directed learning, the process of revising instruments that measures levels of lifelong learning included those explicitly measuring lifelong learning as a process of continuous learning during life, through formal, non-formal, and informal settings. This selection included also those instruments that assess self-directed learning. It is acknowledged that while lifelong learning and self-directed learning are not the same construct, some authors use self-directed learning instruments for assessing lifelong learning (Cadorin et al., 2013; Jiusto & DiBiasio, 2006). Likewise, as Jiusto (2006) explains, instruments such as Self-Directed Learning Readiness Scale (SDLRS) are widely used, whereas instruments such as the Continuing Learning Inventory (CLI) is more direct in assessing lifelong learning.

For the purpose of this literature survey for measuring lifelong learning, other instruments related to technological literacy were analyzed, for instance Luckay and Collier-Reed's TPI, (2011); Aikenhead and colleagues' VOSTS, (1992); Yasar and colleagues' DET, (2006); Kurbanoglu and colleagues' ILSES, (2006); Hohlfeld and colleagues' TS^2L, (2010). There exists an overlap in lifelong learning and technological literacy literature, particularly in searching information, critical thinking, and decision-making. However, the central construct in those instruments differs from lifelong learning construct intended for use in this dissertation work. Likewise, other instruments assessing minors were discarded from the analysis because of the differences between adult learning (andragogy) and pedagogy (Bowen, 2011; Merriam, 2001; Selwyn & Gorard, 2005).

2.5.1 Self-Directed Learning Readiness Scale

Guglielmino (1977) developed the Self-Directed Learning Readiness Scale (SDLRS). The author intended to build a consensus for the self-directed learning construct. This instrument intends to assess individuals (from high school to professionals) in formal and non-formal education, for instance within classrooms or workplaces. The SDLRS was the first attempt to measure self-directed learning in a formal way, addressing the growing trends to acknowledge the importance of continuous learning after school years. The scale measures the following eight factors: openness to learning opportunities, self-concept as an effective learner, initiative and independence in learning, informed acceptance of responsibility for one's own learning, love of learning, creativity, positive orientation to the future, and ability to use basic study skills and problem-solving skills. This instrument presented a reliability of .87 and explained 76% variance of effectiveness in self-directed learning. Although negative-response items constituted the first factor, the author decided to maintain the item structure to avoid problems linked with similar answers for the same factor. In addition, all items were tested and adjusted to meet the 80% of difficulty as maximum value. This instrument has been widely used in research connecting self-directed learning and lifelong learning with other topics such as occupational work (e. g. Durr, Guglielmino, & Guglielmino, 1996), human recourses (Guglielmino & Guglielmino, 1994), and nursing (Fisher, King, & Tague, 2001).

2.5.2 Adaptations to the SDLRS Instrument

As stated before and recognized by other authors (Candy, 1991; Fisher et al., 2001; Harvey, Rothman, & Frecker, 2006), the SDLRS is the most widely used instrument in assessing self-directed learning. However, due to validity issues and inability to validate factor structure (Fisher et al., 2001), some revisions and adaptations have been proposed. For instance, Fisher (2001) developed an instrument based on Guglielmino's SDLRS, but intended to measure self-directed learning in nursing education (SDLRSNE). The main goal of this instrument was to revise the items to assure overall clarity. The instrument assessed three factors: self-management, desire for learning, and self-control. The Cronbach's alpha of .924 showed a high internal consistency.

Teo and Colleagues (2010) developed another adaptation to the SDLRS instrument. This self-directed learning instrument intends to address self-directed learning among minors (tested with 10 to 12 years old children) incorporating technology as a new element. Although the SDLRS mentions some technological settings such as libraries, the authors of the Self-Directed Learning with Technology Scale (SDLTS) refer to technology mainly as the usage of computers and the Internet. The development of this instrument was at initial stages when the selection of the instrument was performed.

The last adaptation that I will address in this review is the Self-Rating Scale for Self-Directed Learning (SRSSDL), although there are some other scales developed based on Guglielmino's instrument (e.g., SDLRSNE). The SRSSDL was developed by Williamson (2007) to move from perceptions towards behaviors in self-directed learning. The instrument assesses five areas of self-directed learning: awareness, learning strategies, learning activities, evaluation, and interpersonal skills. The internal consistency for each area was more than .70 (with a minimum of .71 and maximum of .79).

2.5.3 Oddi Continuous Learning Inventory

The Oddi Continuous Learning Inventory (OCLI) was developed in 1984 to assess self-directed learning as a unifying construct that was previously addressed under diverse approaches (Lorys Fuge Oddi, 1984). This instrument included the assessment of personality characteristics, complementing instrumental skills that others measured as a focus on self-directed learning. Likewise, with the development of this instrument, the author seeks to address the problem from the SDLRS when used in adults with minimal schooling and its loose connection between self-directedness and continuous learning. Though one of the main goals for developing this instrument was to clarify self-directed learning itself, the instrument is based on continuous learning and highlights the process of self-directedness as part of lifetime learning. This instrument is intended to evaluate professionals as framed under Houle's continuing learning (1980), whereas this type of education is performed after gaining a professional certification for practice. Oddi's intention when developing this instrument was to identify adults with self-directed continuing learning as indicative of professional growth. The OCLI scale gives great importance to motivation as a decisive factor in self-directness, which the author connects with constant actualization and openness to learn. This permanent actualization brings the OCLI instrument closer to lifelong learning assessment. The instrument identifies three dimensions to the self-directed learning construct: cognitive openness, proactive or reactive drive, and commitment to learning. Similarly, the construct is explained by five factors: self-confidence in one's ability to perform, ability to be self-regulated, learning by reading and discussion, learning through diverse means, and cognitive openness. The instrument showed an internal consistency of .875 when first tested and in later use (e.g., Harvey et al., 2006; Lorys F Oddi, 1987; Six, 1989; Straka, 1996).

2.5.4 Characteristics of Lifelong Learners in the Professions

In 1986 Livneh developed the Characteristics of Lifelong Learners in the Professions (CLLP) scale (Livneh, 1986). This instrument was created in order to address lifelong learning as the main construct, consolidating some ideas about characteristics for lifelong learning apart from self-directed learning, which Oddi (1984) began calling self-directed continuous learning. Likewise, the author brings the human-service professions into the context for the CLLP. Contrary to SDLRS and the developed instruments based on it, the CLLP focus on lifelong learning, making this instrument more suitable for identifying lifelong learners rather than self-directedness. I acknowledge that the differences drawn from authors' research are small and sometimes indistinguishable (Fisher et al., 2001; Guglielmino, 1977; Lorys Fuge Oddi, 1984). Lifelong learning implies a continuous process where personal characteristics should be present in order to engage in learning continuously; on the other hand, self-directed learning implies a focus on the process rather than in the person (Lorys Fuge Oddi, 1984). According to Livneh's research, (Livneh, 1986, 1988; Livneh & Livneh, 1988) CLLP measures the following seven factors of lifelong learning: professional growth through learning, self-motivated achievement, educability, readiness for change, causation for learning participation, familial educational background, and future orientation. A .91 coefficient resulted from testing internal reliability of the instrument with 195 professionals from social work, nursing, and counseling (Livneh, 1986). In addition to the high reliability level and the direct assessment of the lifelong learning construct, this instrument also has been tested as a tool for identifying high and low lifelong learners with a rate of 68.22% for correct classification (Livneh & Livneh, 1988). Although this ratio is not as high as expected, identifying outliers will improve this percentage due to extreme characteristics intrinsically present in the group.

2.5.5 Other Instruments analyzed

During the search for appropriate instruments for selecting participants, other instruments related to generics and technology were identified. Technology-related instruments were taken into account because of the overlap presented by some frameworks (Voogt & Pareja Roblin, 2010, 2012) between technology and lifelong skills. For instance, some frameworks relate critical thinking and decision-making as characteristics of technological literacy due to its information and communication component, while others locate decision-making under lifelong learning traits and limit technology to the use of artifacts. However, those instruments were less aligned to informal decision-making for every-day interactions with technology, which is the connecting element between technological literacy and lifelong learning being studied in this dissertation.

Similarly, other instruments referred to by the authors of the analyzed instruments related to lifelong learning were excluded from the analysis because they are less known, utilized, and the core construct being assessed differs from the one intended for use in this research. One example is the Autonomous Learner Index (ALI), which was developed in 1978 Abu-Moghli and colleagues (Abu-Moghli, Khalaf, Halabi, & Wardam, 2005; Lorys Fuge Oddi, 1984). Its goal is to assess attitudes regarding self-directedness in nursing. Although a follow up was made for this instrument's development, low levels of reliability and lack of theoretical framework was criticized by Oddi (1984). Likewise, the Individual Development and Educational Assessment system (IDEA) present several instruments; however, those cited are school-oriented and the concepts being evaluated differ from lifelong learning.

2.5.6 Selection of an Instrument

Guglielmino (1977), Oddi (1984), Livneh (1986), and Fisher (2001) and their colleagues are the developers of the principal instruments related to self-directed learning and lifelong learning. Several studies have used these instruments for understanding what self-directedness and lifelong learning (e.g., Harvey et al., 2006) or for identifying these abilities in students and professionals (e.g., Durr et al., 1996). In particular, SDLRS and OCLI instruments have been widely used (Jiusto & DiBiasio, 2006). However, these instruments are intended for use with students; therefore, some newer instruments have been developed for professionals, especially in the public-service sector (e.g., CLLP or SDLRSNE). Table 1 shows how the instruments reviewed have similar or discrepancies in their measurement of lifelong learning and self-directed learning.

Analyzing how short-time decisions and lifelong learning attributes are expressed in approaches to technological challenges may provide a connection between lifelong learning theory and technological literacy theory. It also may inform critical skills or attitudes for interacting with technology from different perspectives, which is useful for engineers, but also for people who need to learn about the new technology constantly evolving around them.

2.5.7 The CLLP Instrument

Several instruments were analyzed in order to select an appropriate mechanism to identify high and low technological lifelong learners for assuring maximum variation within participants for this study. Several instruments were included in the analysis to account for, given the purposes of this study, lifelong learning in relation to technological literacy. This requires an instrument focused on technology affinity and attitudes (e.g., Albion, 1999; Ngambeki et al., 2010; Purzer, 2011), technology knowledge and skills (Aikenhead & Ryan, 1992; Luckay & Collier-Reed, 2011; Teo, 2010; Yasar et al., 2006), and generic skills (e.g., Fisher et al., 2001; Guglielmino, 1977; Livneh, 1986; Lorys Fuge Oddi, 1984). After revising instruments constructs and frameworks, I found that CLLP was the best fit for an adult population in informal environments, where lifelong learning focuses on every-day decisions for differentiating high and low lifelong learners (Livneh, 1986; Livneh & Livneh, 1988).

The CLLP instrument was developed in 1986 (Livneh, 1986) to predict time spent in learning activities. Educability and future orientation were identified as predictors for lifelong learning during researchers' initial approach. The instrument consists of a 36-item Likert scale with seven possible levels; from strongly disagree to strongly agree. According to the study, the instrument presented an internal reliability of .91 (Livneh, 1986).

Table 1 Instrument Comparison for Measuring Lifelong Learning

	SDLRS	OCLI	CLLP	SDLRSNE
Psycho-metrics	.87 8 Factors	.875 5 Factors	.91 7 Factors	.92 3 Factors (but structure changed in revision)
Main construct	Self-Directed Learning	Self-Directed Continuous Learning	Lifelong Learning	Self-Directed Learning
Intended User	Student	Student	Human-Service Professional	Nursing Professionals
Openness to Learn	Openness to learning opportunities Love of learning	Cognitive openness	Readiness for change Causation for learning participation	Desire for learning
Self-Confidence on Learning	Self-concept as an effective learner	Self-confidence in ability to perform	Professional growth through learning	Self-control
Self-Management of Learning	Initiative and independence in learning Informed acceptance of responsibility for one's own learning	Ability to be self-regulated	Self-motivated achievement	Self-management
Skills for Learning	Ability to use basic study skills and problem-solving skills	Learning to reading and discussion Learning through diverse means	Educability	
Think out-of-the-box	Creativity			
Future Orientation Family Background	Positive orientation to the future		Future orientation Familial educational background	

CHAPTER 3. METHODS

This research was developed under a pragmatic worldview (Creswell & Plano Clark, 2011; Tashakkori & Teddlie, 2003). Within this paradigm, researchers expect knowledge be gained through practice-based experiences, observable in everyday individual behaviors and interactions with objects. I suggest that eliciting the experiences of participants' everyday lives informs us of societal behaviors towards technology. While subjectivity is present in the phenomenon, it can certainly enrich the understanding of this behavior. Critical incidents are important in understanding the particularities and unique experiences of each participant and his or her context (Arthur, 2001; Gremler, 2004). A pragmatic approach should be naturalistic; therefore, data was collected from real interactions between participants and technological products and processes. The research outcomes were drawn from a skeptical, yet generalizable and context-dependent point of view (Tashakkori & Teddlie, 2003). In addition, these individual experiences reflect the relation between STEM and non-STEM approaches to technological challenges, seeking to move "from individual perspectives to broad patterns and, ultimately, to broad understandings" (Creswell & Plano Clark, 2011, loc.650).

A long-term goal of this study is to identify strategies for increasing technology literacy in an inclusive way, closing the gap between people with and without STEM backgrounds. In conjunction with this pragmatic approach, the study follows a constructivist framework, assuming that learning technology is a process that depends on each learner's context and previous knowledge (Bransford, Brown, & Cocking, 2000). Participants' narratives about their turning points (past experience) regarding to interacting with technology were examined (Atkinson, 1998; Hamilton & Atkinson, 2009); as a result, this procedure contextualizes each participant's experience. This participant context was then linked to their current experiences with technology, which were described in two repeated interviews. Each description consisted of situated interactions that were related to participants' contexts and learning processes. Based on a Constructivism worldview, repeated measurements allowed a better assessment of a continuum in participants' perceptions of how they approach technological challenges, in contrast to a one-time measurement (Blake & Pope, 2008; Vygotsky, 1986). Further, qualitative data collected through interviews of outliers (high and low lifelong learning skills and STEM-related backgrounds) allowed the in-depth study of some critical cases (Grimm & Yarnold, 1995) regarding how participants interact with technology.

3.1 Research Design

A sequential mixed methods design using nested, purposeful sampling was performed (Creswell, 2008; Creswell & Plano Clark, 2011; Tashakkori & Teddlie, 2003).

This type of mixed-methods design has two stages, one for sampling purposes and another for qualitative analysis of selected cases. The first stage was a quantitative approach to identify a purposeful sample via statistical analysis. The outlier identification design used for this selection was presented at the American Society for Engineering Education (Tafur & Purzer, 2015), and adapted for this dissertation. The second stage, a qualitative thematic analysis (Braun & Clarke, 2006) was performed to more closely examine participants' interactions with technology. Qualitative data from semi-structured repeated interviews was used for eliciting individual experiences for how participants approach technology challenges. According to Morse (2003), this research design can be identified as quan->QUAL, due to the minimal quantitative data involved. It may be assumed as a qualitative-dominant design (R. B. Johnson, Onwuegbuzie, & Turner, 2007), which is typical in participant selection or quantitative preliminary research design (Creswell & Plano Clark, 2011).

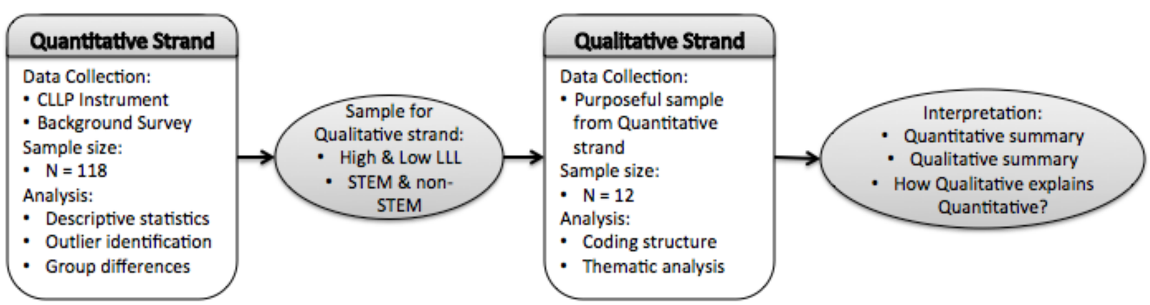

Figure 3.1. Explanatory Sequential Design: Participant-Selection

The qualitative strand of the research focused on the analysis of the open-ended data collection due to the novelty in understanding how adults experience everyday interactions with technology. This qualitative strand provided an in-depth understanding of a participant's engagement with technology using a thematic analysis approach. In this study, thematic analysis was conducted to seek better understanding of people's reflections upon a phenomenon (Braun & Clarke, 2006). Second-order perspectives of individuals' experiences were used; in other words, the researcher describes others' experiences and conceptions related to a phenomenon rather than solely the phenomenon itself (Barnard, McCosker, & Gerber, 1999; Sjostrom & Dahlgren, 2002). A non-dualistic nature of knowledge was assumed, which means that the object of study cannot be separated from how it is perceived by the individual who experienced it (Barnard et al., 1999; Ornek, 2008; Sjostrom & Dahlgren, 2002). In this study, the approach is appropriate because it allows for diverse interaction with technology, thereby broadening the understanding of technology literacy by bringing more people into STEM conversations.

3.2 Sampling Procedure

The selection of participants combined quantitative and qualitative techniques.

3.2.1 Quantitative Strand

The target population for this study was adults with diverse professional backgrounds. Because participants came from a variety of disciplines, two communities were invited to participate, thus narrowing the target population: individuals from either a company or a university, both located in the Midwest, were eligible. Emails were sent to employees in the company using staff list-servs, and flyers were published across the academic campus and through the staff news webpage. The online link for consent to participate in the survey was active for four months. Two groups of people were targeted to narrow the sample: non-STEM majors and engineering professionals. The STEM-trained group was limited to engineers due to its explicit relation with technology, math, and science; the non-STEM group was limited to individuals working outside STEM-focused jobs with majors in the Humanities.

Because three outliers were targeted for each group, twelve outliers was the desired sample for the qualitative strand. The aim was to recruit 10% of the total population; therefore, a sample size of approximately 120 participants was the target population for the quantitative strand. Critical Incidents (Gremler, 2004) were classified using cluster analysis for outlier identification as a nested purposeful sampling.

3.2.2 Qualitative Strand

The second sampling procedure, the selection of critical cases, was a purposeful sample (Coyne, 1997; Sandelowski, 1995) based on outliers identified from the quantitative strand. According to Patton (1990), a purposeful sample is useful in a qualitative study because each case selected is information-rich, which relates to the research objectives and allows an in-depth interaction despite the small sample size.

Using a sampling method that combines qualitative and quantitative techniques led to statistical inferences based on the larger population (quantitative sample). At the same time, a rich, in-depth analysis was performed, as Sandelowski (1995) suggested. Such a combination provided a wide variation of cases for high and low lifelong learning skills interacting with STEM and non-STEM background to a greater degree than a purposeful or random sampling alone, which concurs with combining both research designs according to Creswell and Plano Clark (2011).

3.3 Participants

Quantitative Strand. 180 consented surveys were submitted, but only 146 were complete. Among these completed surveys, only 118 participants included their contact information, necessary to be eligible for the qualitative strand. The majority of participants were White non-Hispanic (73%), 10% were Asian, 7% were White Hispanics, 6% were African American, and 4% omitted ethnicity. The majority of participants were females (66%); 34% were males. The average age was 36 years, with the following distribution: 45% of participants ranged from 21 to 30 years old, 20% ranged from 31 to 40 years old, 16% ranged from 41 to 50 years old, and 18% were 51 years old or older.

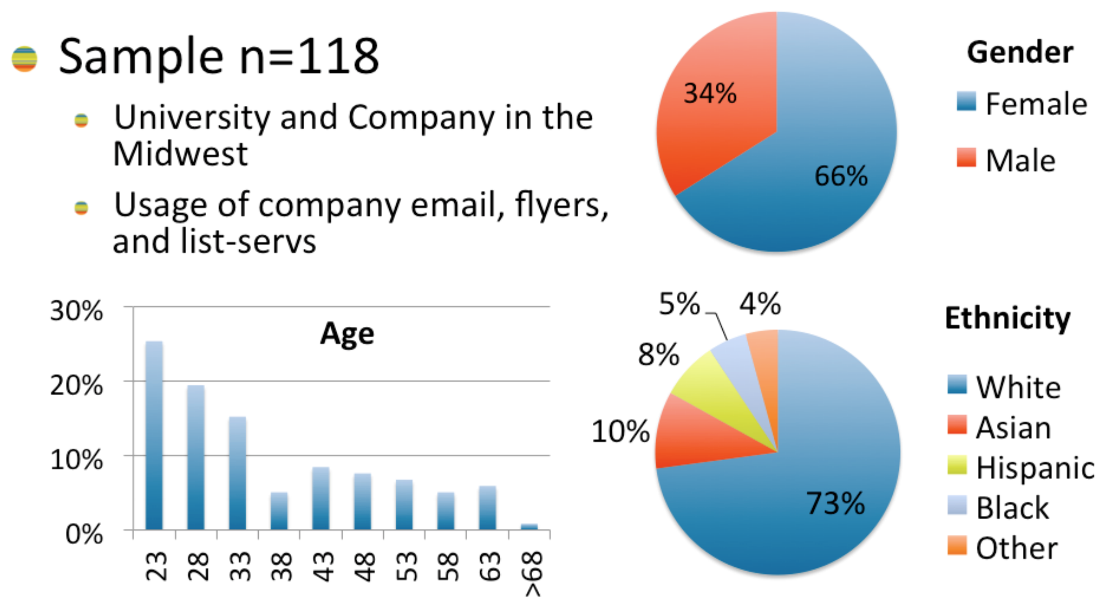

Figure 3.2 Quantitative strand demographics

Qualitative Strand. A purposeful sample (Yin, 2010) of the surveyed group was selected, targeting 10% of the participants selected from the quantitative strand who were outliers according to STEM background (most involvement – less involvement in STEM activities) and lifelong learning (higher – lower CLLP scores). Four groups of critical cases were identified from the interaction between career background and levels of lifelong learning: low lifelong learning and non-STEM background (LLnE), high lifelong learning and non-STEM background (HLnE), low lifelong learning and engineering background (LLE), and high lifelong learning and engineering background (HLE). Within each group three participants were selected among outliers, for a total of 12 participants and 24 interviews, an adequate size for an in-depth qualitative analysis. Although 12 interviewees were targeted, 21 participants were identified as outliers in order to adjust for non-responses due to the high level of dropouts in a repeated-measure design; this also allowed flexibility and ensured richness for saturation and soundness (Guba, 1981).

15 participants were contacted; 12 participants consented to participate. Among this subsample, the majority of participants were White non-Hispanic (10), 1 was Asian, and 1 was White Hispanic. The majority of participants were female (7); 5 were male. The average age was 48 years, with the following distribution: 4 participants ranged from 21 to 30 years old, 1 was between 41 to 50 years old, 3 ranged from 41 to 50 years old, and 4 were 51 years old or older. Gender and ethnicity had similar distribution compared to the population of the quantitative strand, while outliers' ages presented a bimodal distribution compared to a positive-skewed curve for participants' ages in the quantitative strand.

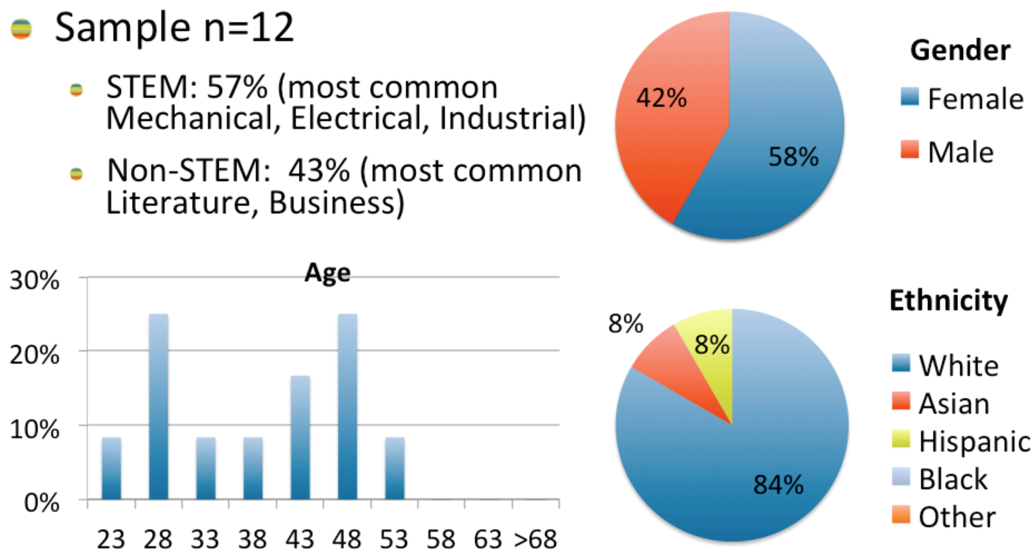

Figure 3.3 Qualitative Strand Demographics

3.4 Data Collection and Instruments

3.4.1 Quantitative instruments

CLLP and Background Survey. This survey was used to select 12 participants from a group of 118 individuals working in academic and non-academic environments, for which background profile and level of lifelong learning were identified. This survey was comprised of three stages of data gathering as explained by Tafur and Purzer (2015). The CLLP instrument consisted in a validated 36-item Likert scale of seven levels (see Section 2.5.4). The background survey was comprised of 27 items related to demographics, academic and professional background, and contact information. Background questions were used to score STEM background, demographics were used to report the sample, and contact information was taken into account for recruitment of the qualitative strand.

18 points were allocated for background score using between -3 to 3 points for each of the following characteristics: undergraduate field, graduate field, professional filed, years of STEM experience (compared to non-STEM experience), technology use and creation, and work-time used for STEM-related work (compared to non-STEM work). 3 points were assigned, for the first three characteristics, to Engineering fields, while -3 points were assigned to Arts and humanities. For STEM experience and work-time, 3 points were assigned to 100% in STEM fields, while -3 point were assigned to 100% in non-STEM fields. Finally, for technology use and creation, 3 points were assigned to process-focus and -3 to product-focus.

3.4.2 Qualitative Instruments

First Interview: Understanding the context. During the initial part of the first interview participants were asked about the context of their interactions with technology, along the lines of a life story (Atkinson, 1998). Individuals' past experiences with technology were elicited to contextualize their relation with technology in recent interactions. Information gathered during the interview consisted of participant's lifelong relation with technology, challenges approached in the past, and familiarity with technology, among others. The main goal for this first interview was to collect data in order to understand different ways in which participants approached technological challenges, contextualized by individuals' past experiences. A second part of the interview led participants through a brainstorming of words (and ideas) when asked to think about technology. The interview was semi-structured, which allowed participants to identify the most relevant challenge and to free-associate their understanding of technology. The interview was performed using a protocol (Appendix D) to guide the questions; each lasted between 35 to 60 minutes.

<u>Second Interview: Follow-up Interactions with Technology</u>. In this interview, participants described a recent challenge similar to that of the first interview. This second interview allowed analysis of the consistency in technology conceptions, and particular actions used to overcome the challenge. In addition, participants were asked to perform a task during the first part of the interview in order to reflect upon their approaches at the interview's end. These reflections helped to contextualize how individuals perceive technology. Similar to the first interview, the second interview also included the brainstorming process. These interviews also ran between 35 and 60 minutes and followed a semi-structured protocol (Appendix E).

Interviews were designed using broad questions aiming to allow ample detail and variety of answers without guiding the participant to certain response. In addition, questions were design so participants were asked to identify the technological challenges in order to study their conceptions of the challenge, and why their selection was a technological challenge. Both protocols have been piloted for eliciting richness and alignment with these design objectives and with the research questions: pilot participants were able to identify technological challenges in past and recent experiences, to explain why it was a technological challenge, and to describe their actions, thoughts, and feelings during the challenge. Interviews were recorded and transcribed, gathering as much detail from participants' experiences as possible. This process facilitated the analysis and distanced the researcher's preconceptions from participants' perceptions (Patton, 1990). The majority of the analysis was based directly on the audio files to ensure the information was accurate.

3.5 Researcher Role

My own background in engineering and education allowed me to study and work within engineering and non-engineering environments. My experiences have instilled in me a motivation to understand how different cultures interact and complement each other. As a researcher, I am open to unexpected, creative, and diverse perspectives in order to better understand people's interactions with technology. I believe that inviting non-STEM individuals into STEM circles brings richness to technology understanding and new information to guide us in closing the technological literacy gap. Additionally, my experience and knowledge of technology allows me to explore participants' experiences and conceptions in depth. Similarly, my experiences with non-technologically literate individuals has increased my awareness that complex, challenging interactions prevail in everyday activities regardless of an individual's background or level of technological knowledge.

3.6 Method of Analysis

Quantitative Strand. The analysis used for this strand was published in the American Society of Engineering Education (Tafur & Purzer, 2015). One cluster was considered for a distance-based analysis of outlier identification (Breunig, Kriegel, Ng, & Sander, 2000). Raw and ranked data was taken into account using an optimized d_{min}, a threshold in which data points with greater distances to the cluster mean were considered outliers. This distance was set in an initial arbitrary value, and adjusted to reach requirements of three outliers per group (see Tafur & Purzer, 2015). The purposeful sample comprised all data points identified as outliers using both strategies: raw data, in which the threshold was an ellipse, and ranked data, in which the threshold was a circle. As a result, profiles for each group of outliers were created. Central tendencies were analyzed to ensure outliers were representative from their group. Common outlier-identification procedures (See Breunig et al., 2000) in conjunction with usage of different identification strategies (i.e., raw and ranked data) and threshold shapes (i.e., circular and elliptical) was used for designing the Tafur Purposeful Sampling technique (TafurPS) developed, for the purpose of this research. Details of the process of analyzing the survey to identify outliers are provided in section **Error! Reference source not found.**.

Qualitative Strand. 12 participants were interviewed on two separate occasions; each represented one of the four groups formed from the interaction between high and low lifelong learning and STEM or non-STEM background (i.e., LLnE, LLE, HLne, and HLE), including three participants in each group.

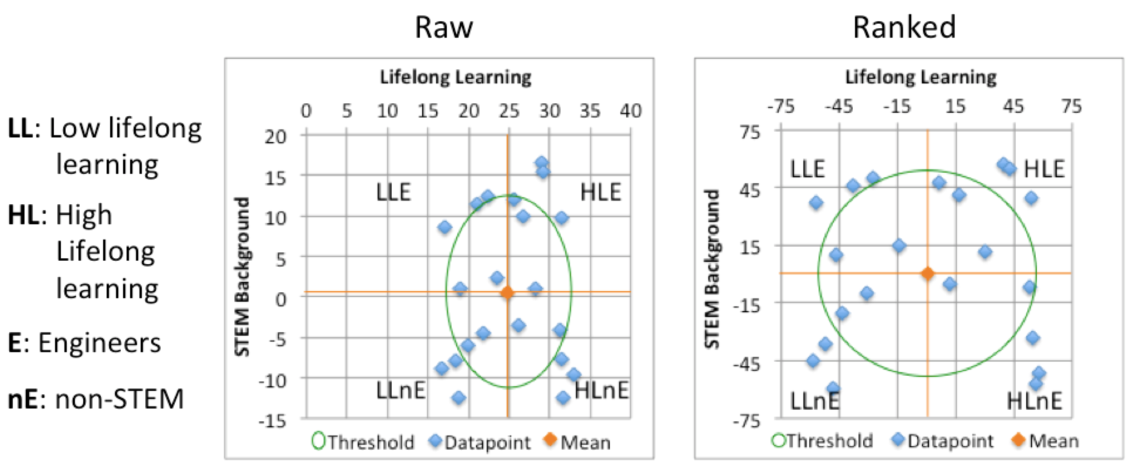

Figure 3.4 Participants' Groups and Strategies for selection

The sample size of n=12 assured variation within and between groups and an analysis of reaching saturation levels (Golafshani, 2003; Guba, 1981; Sandelowski, 1995) was completed. Additionally, performing two different interviews allowed analyzing how approaches to technological challenges changed in time for the same individual. Likewise, having at least four interactions explained by the interviewee (i.e., one past experience, two recent experiences, and one experience about a task activity) provided a source for triangulation within subjects. Further, having three participants per group allowed stability triangulation (for the code schema emerging from the data) within each group, while having four different and extreme groups addressed diversity in background and levels of lifelong learning, assuring a comprehensive analysis. This step-by-step process is explained in section 3.6.1.

Some considerations were taken into account as suggested by researchers (Braun & Clarke, 2006): 1) what counts as theme, 2) how data-set analysis was performed, 3) how the analysis was approached, 4) the theme types being analyzed, and 5) the theoretical framework for the analysis. First, instances relevant to the research questions were identified as possible codes (e.g., benefits, frustration, computers, Google references, or testing devises). Those codes that were widespread within experiences and perceived by multiple individuals were identified as themes. Second, the analysis used each experience as the unit of analysis; each interview had at least two experiences, for a total of at least 48 experiences (some participants described more than one past experience). During the analysis, a focus was set on rich descriptions of the unit of analysis (i.e., the approach of a technological challenge); however, few analyses were performed on particular aspects (e.g., how participants perceived or used Google) to illustrate some of the themes that emerged. Third, the analysis performed in this study was inductive, for which findings were grounded in what strictly emerged from the data; no pre-existing code frame was in use; instead, the code schema was formed after an iterative process of data analysis. Fourth, the analysis was primarily semantic, where themes emerged from what the interviewee explicitly verbalized. However, some underlying ideas about technology were considered in order to verify emerging themes for technological conceptions. Fifth and last, a constructivist framework was used, as explained in the research design (Section 3.1), which acknowledge that interaction with technology is context and content-specific, and experiences guides learning.

3.6.1 Coding and Bracketing Interviews

According to Braun and Clarke (2006) and other researchers (e.g., Richardson, 1999), the process of analyzing interviews should be iterative, themes should emerge from the process of coding, and comparing different interviews helps to find principal themes and sub-themes that cover the space of that dimension. Because the coding schema emerges from the information gathered, initial identification may change during iterative revisions and re-readings of interviews and quotations extracted.

The first step for coding interviews was *familiarization* (Braun & Clarke, 2006; Sjostrom & Dahlgren, 2002). Interviews were performed by one researcher and kept as audio files to ensure accuracy of the proceedings in order to understand holistically the most relevant topics emerging from the first interviews. This step also included transcribing the data (by a second person) and the identification of transcript errors based on the original audio file. The second step performed was an initial *compilation* (Sjostrom & Dahlgren, 2002), or *generation of initial codes* (Braun & Clarke, 2006). During this process, instances relevant to the research questions were identified. From this first iteration, participants' answers were compiled though an iterative process that was performed for relevant instances identification in the third step of the analysis, *searching for themes,* (Braun & Clarke, 2006). As an iterative process, the emerging *themes were revised* (Braun & Clarke, 2006) and grouped until a stable outcome was found. To ensure this, themes that emerged from the first interview (i.e., one past experience and one recent experience) informed the coding schema used for the second interview, while a new iteration for revising themes was performed. This process allowed testing for saturation, and stability was achieved based on lack of changes needed to perform to the coding schema. The fifth step was the *comparison* (Sjostrom & Dahlgren, 2002) of unique features within themes, to find the limits between each theme. The central idea was extracted from quotations supporting each theme. The following step was *naming* (Braun & Clarke, 2006; Sjostrom & Dahlgren, 2002) the sub-themes within primary themes (called dimensions), and categorized themes across dimensions. The last step performed was the *contrastive comparison* (Sjostrom & Dahlgren, 2002), during which themes were compared to find similarities and uniqueness across them.

One of the main elements in this approach to analysis is that coding should be performed to account for participant's perspectives as expressed by the interviewees. Researcher preconceptions and biases should be explicitly separated from the analysis of the phenomenon (Ashworth & Lucas; Richardson, 1999; Watson, 2004). Though it is important to separate interviewer's perceptions from the interviewee's, a researcher's own context and background indeed adds bias on the analysis and is an intrinsic feature of qualitative designs. Bracketing includes research findings and theories, preconceptions and beliefs that may guide interpretation (Ashworth & Lucas, 2000). This bias was taken into account during the first iteration of the analysis, during which a code was created to eliminate those interviewer questions and comments that could bias interviewee answers.

3.7 Data Quality

3.7.1 Threats to validity during Sampling for Critical Cases: Quantitative Strand

As mentioned in CLLP description, the instrument has a high reliability and was tested for identifying high versus low lifelong learning adults. Although the discriminant function analysis used (Livneh & Livneh, 1988) led to only two thirds of correct classification, selecting a quarter of the surveyed participants as critical cases minimizes a possible mis-classification.

3.7.2 Trustworthiness of data collected through interviews: Qualitative Strand

In order to have diverse perspectives of interactions with technology and ensure credibility, the sample was intended to have maximum variation using critical cases. Although gender and age may bring more variation, the main characteristics of analysis for this research study were STEM background and lifelong learning skills; therefore, other demographic characteristics are acknowledged but these two variables guided the selection of participants. Twelve cases were analyzed; however, 25 cases were selected for potential interviews to reach saturation regardless of dropouts and the nature of undefined qualitative sample sizes (Golafshani, 2003; Guba, 1981;

Sandelowski, 1995). Triangulation (Patton, 1990) was taken into account by having participants' repeated measures of interactions with technology (more than 40 different experiences were described by individuals) and information for at least three individuals per group (lifelong learning interacting with STEM background) was included in the thematic analysis. One person conducted all interviews and edited transcriptions to ensure high fidelity of participants' descriptions as suggested by researchers (Graneheim & Lundman, 2004). In addition, two additional researchers revised and gave feedback to themes during analysis of data.

Braun and Clarke (2006) suggested avoiding five elements to assure quality in a thematic analysis: limit the design to collection of data, lacking the analysis; use interview questions as themes; present themes that were unclearly emerging from data; mismatch data and analytic claims, feature findings than cannot be supported by data; and mismatch between research questions and the form of thematic analysis used. These five elements were taken into account.

3.8 Ethical Issues

For this study I invited people within academia and industry for voluntary participation in answering the sampling surveys (Background information and CLLP instrument). Participants were informed about the possibility of being eligible for further interviews to get in-depth information about how they interact with technology

in their everyday lives, and the right to withdraw from the study at any time.
After each interview, participants received compensation of $5.00 for their time.

Due to the nature of this study as a human-subject research, an application for IRB was approved previous to any data collection. This research did not involve more than everyday life risk, and all procedures of data de-identification were strictly followed to honor confidentiality.

CHAPTER 4. QUANTITATIVE RESULTS

In this chapter I summarize the quantitative results of this two-phase study. This strand included a survey of 118 people. Quantitative results informed the selection of participants for the qualitative phase by mapping participants' lifelong learning and STEM backgrounds. A cluster analysis and outlier detection of these two-dimensions informed selection of interview participants to reflect a representative sub-sample. The chapter includes a discussion of how the outlier selection is representative of the purposeful, qualitative sample. Likewise, findings from the sample distribution, based on lifelong learning and career background, are analyzed.

Results of outlier identification were presented at the American Society for Engineering Education (Tafur & Purzer, 2015), and adapted for this dissertation document.

4.1 Setting the Scales

Quantitative scales were consolidated and calibrated for scoring lifelong learning and STEM background.

Lifelong Learning: The total lifelong learning score resulted from the CLLP scores added to education degree level. The range of possible scores was 0 to 39; however, data ranged from 17 to 33, higher than the scale middle point. Technological background: This dimension was scored using four main elements: undergraduate and graduate studies, professional field, STEM experience, and daily time spent on STEM-related activities. The scale was defined, using any engineering field as its maximum score, followed by technology, math and sciences (differentiating STEM background with engineering emphasis); the lowest scores were given to the arts, followed by human sciences (indicating a non-STEM field); finally, middle scores were given to business, economy, and related fields (indicating that the participant was not an outlier). This scale ranged from -18 to 18; however, data ranged from -12 to 16.

4.2 Evaluation of the Normality Assumption

Normality was tested in order to perform further central tendency analyses using ANOVA. Lifelong Learning: Lifelong learning scores met normality Kolmogorov-Smirnov test, Skew=-0.164 (0.223); Kurtosis=-0.811(0.442); D=0.065, $p>0.05$, see Figure 4.1.

Technological background: Although the test of normality indicated a concentration of scores divided into STEM and non-STEM with non-normal distribution –Skew=0.533 (0.223); Kurtosis=-0.882 (0.442)—, this was intended by recruiting procedures. Test of normality was then performed using stratified data, divided into two subgroups with STEM and non-STEM backgrounds. Both groups met normality tests (Kolmogorov-Smirnov for non-STEM, and Shapiro-Wilk for STEM due to the small size of 36) and were approximately normally distributed (Skew=0.368 (0.276); Kurtosis=-0.480 (0.545); D=0.065, $p>0.05$ for non-STEM. Skew=0.083 (0.365); Kurtosis=-1.124 (0.717); W=0.960, $p>0.05$ for STEM; see Figure 4.2 and Figure 4.3).

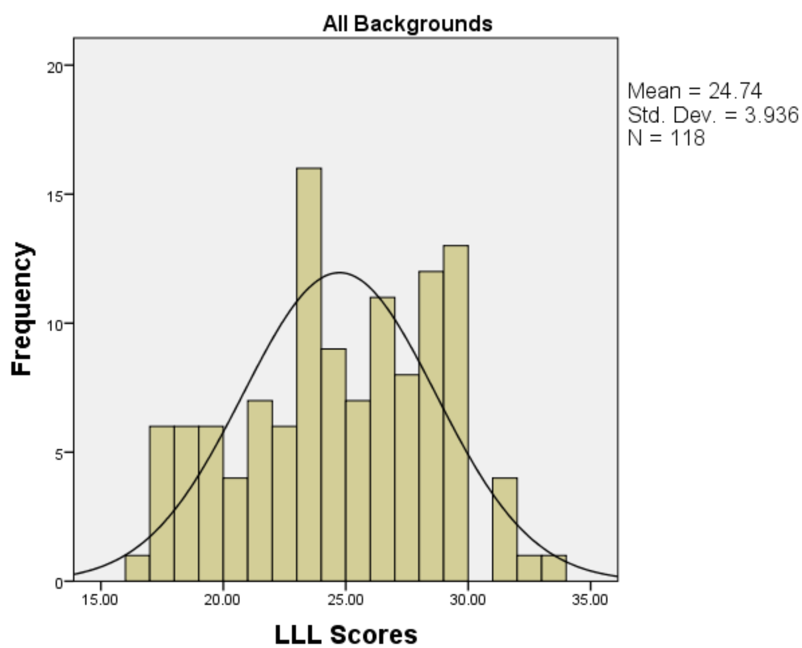

Figure 4.1. Normality Test for Lifelong Learning

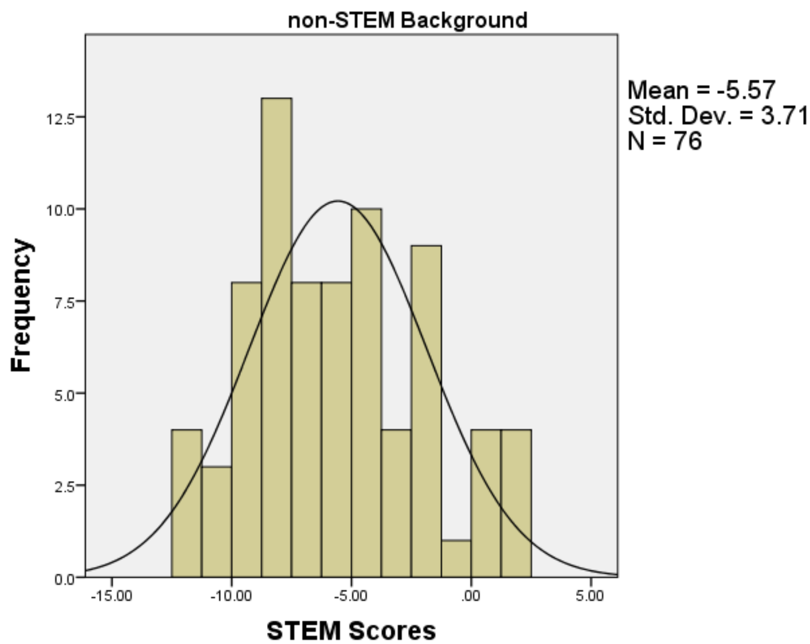

Figure 4.2. Normality Test for non-STEM

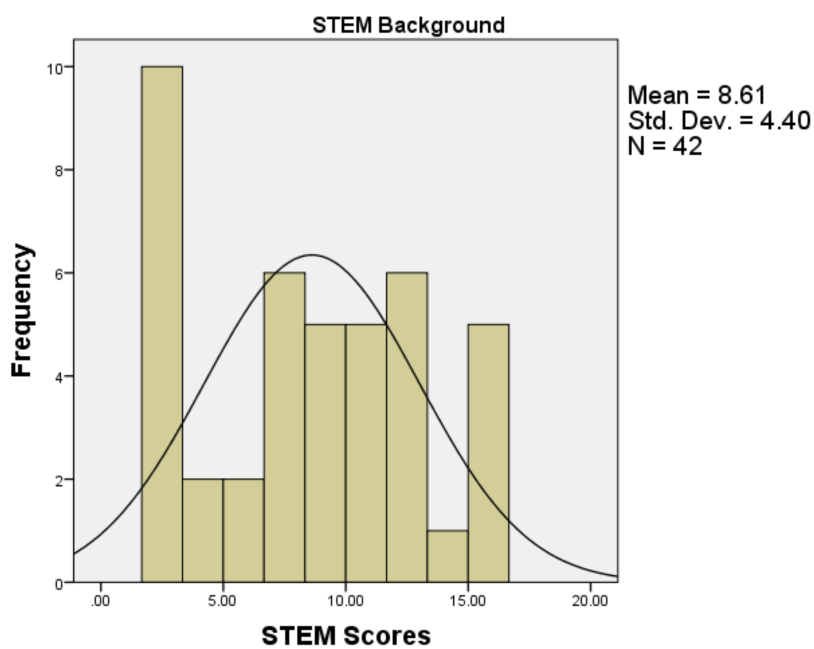

Figure 4.3. Normality Test for STEM

4.3 Cluster Analysis for Outlier Identification

After scoring lifelong learning and STEM background, a scatter plot was created with raw data and with ranked data (see Figure 4.4 left). The raw data presented an elliptical form showing different variation and range between variables; initial vertexes of the outlier-threshold ellipse were v_x=8.14, and v_y=14.50. The first threshold exposed one outlier for LLE, and two outliers for LLnE and HLnE. After adjusting the threshold (v_x=7.60, and v_y=13.54) for identifying a minimum of three outliers per group, a total of 23 outliers were identified (6 for LLnE, 3 for LLE, 3 for HLnE, and 11 for HLE).

For the second method, scores were ranked from lowest (-59) to highest (58) for both variables, resulting in a circular cloud with an initial radius of r=58.5 (see Figure 4.4 right).

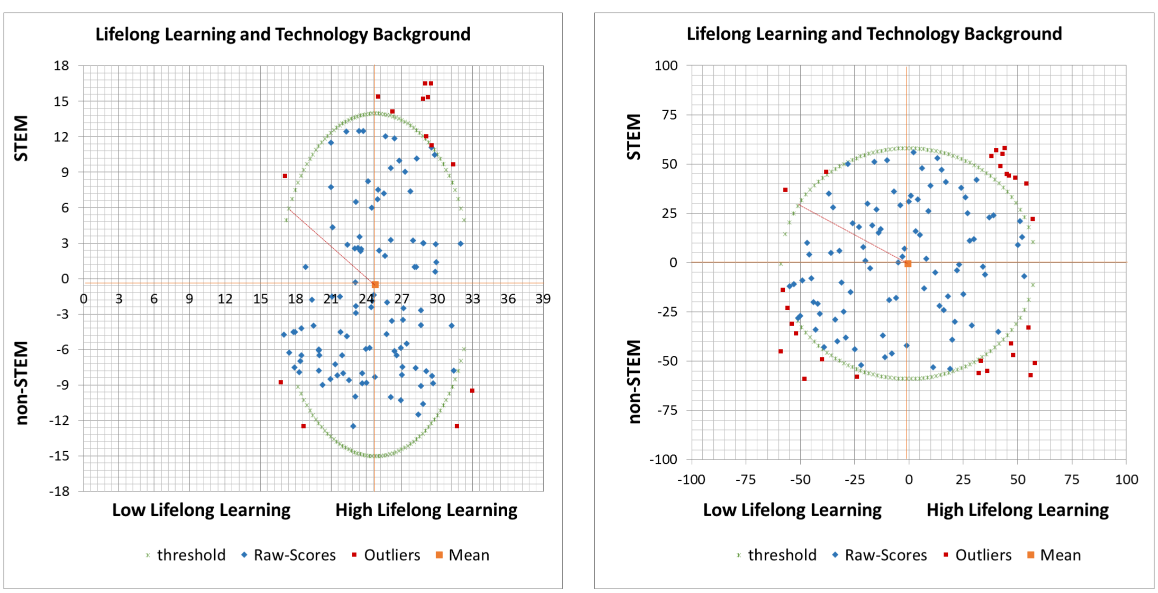

Figure 4.4. Raw Scores with Initial Threshold

The first threshold exposed two outliers for LLE; therefore, it was adjusted (*r*=57.5) in order to include a third outlier for this group. A total of 30 outliers were found using this method (9 for LLnE, 3 for LLE, 8 for HLnE, and 10 for HLE). Finally, 21 outliers were identified when using both methods (6 for LLnE, 3 for LLE, 3 for HLnE, and 9 for HLE). Final results of outlier identification are presented in Figure 4.5 and Figure 4.6.

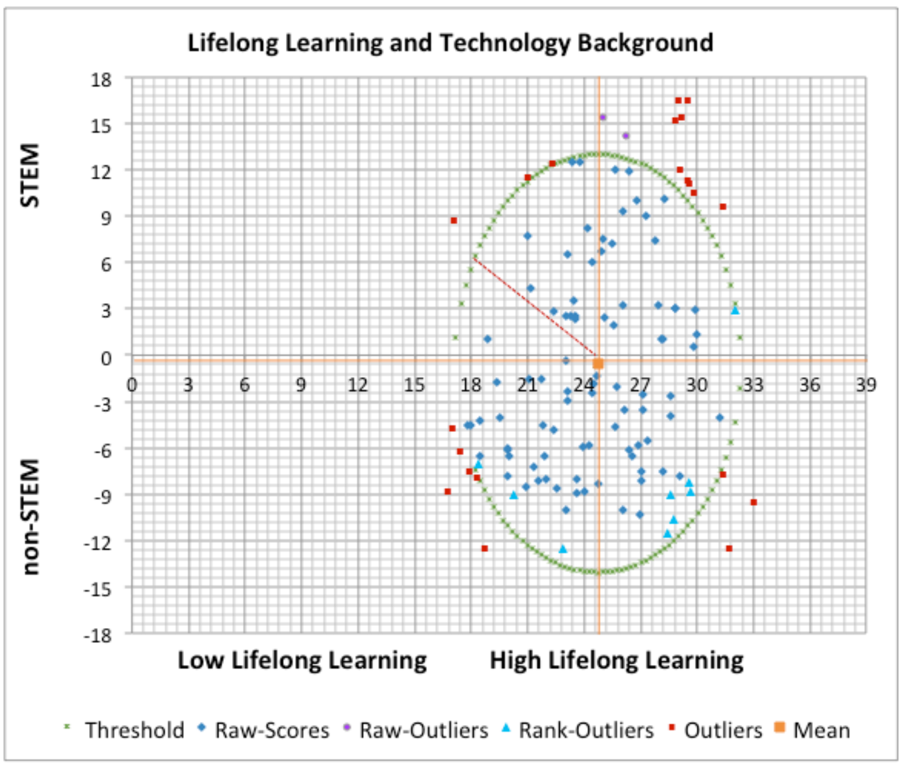

Figure 4.5. Outlier Identification Using Raw Scores

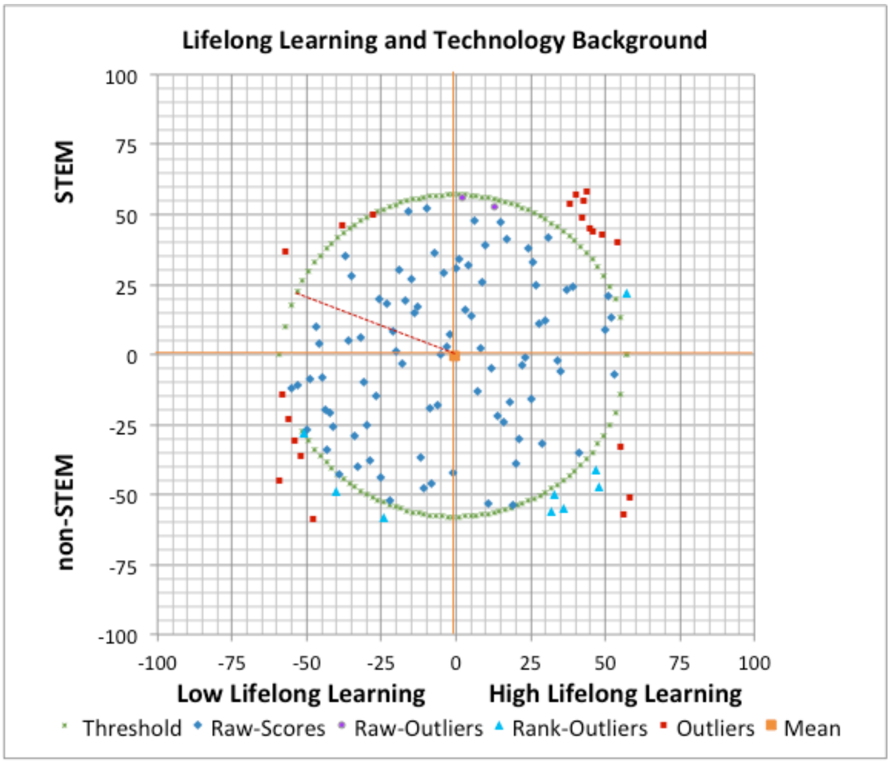

Figure 4.6. Outlier Identification Using Ranked Scores

4.4 <u>Outliers' Profiles</u>

Nine outliers were members of HLE, the group with high lifelong learning and STEM background. Among the seven CLLP factors, this group scored the highest in three. HLE scored above average in all CLLP factors, and the strongest belief was in the importance of keeping updated and competent in their profession.

Three outliers were members of LLE, the group with low lifelong learning and STEM background. This group scored neither highest nor lowest in any of the seven CLLP factors; they scored below average in all factors except for familiar background, and their strongest belief was that keeping updated and competent in their profession is important.

Six outliers were members of LLnE, the group with low lifelong learning and non-STEM background. This group scored the lowest in the seven CLLP factors. LLnE scored below average in all the factors, and they mildly disagreed that their parents participated in learning as compared to other groups. This group of outliers scored more than 1SD lower than the average in three factors.

Finally, three outliers were members of HLnE, the group with high lifelong learning and non-STEM background. Among the seven CLLP factors, HLnE scored the highest in four, and above average in all of the factors.

Table 2 and Table 3 show additional information about outliers. Table 2 presents some demographic information grouped by LLL and STEM categories. Table 3 indicates the mean CLLP profile scores compared to averages and standard deviations from the total population.

The majority of non-STEM outliers were females, while the majority of STEM outliers were males. The average age was similar between groups; however, STEM groups had higher average age compared to non-STEM groups, while low lifelong learners had lower average age compared to high lifelong learners. The highest level of education varied according to lifelong learning; all high lifelong learners had graduate education, while two-thirds of low lifelong learners earned bachelor's degrees. Only high lifelong learners reported parents with graduate studies. In fact, parents of non-STEM high lifelong learners with graduate studies were the majority within their group. As expected, STEM groups reported higher levels of technology usage and development (creating or adapting technology) and of the reported backgrounds in engineering fields, most common were electrical, industrial and mechanical engineering. In contrast, non-STEM outliers reported backgrounds in the arts, literature, and humanities.

Table 2. Background Summary for Outlier Profile

	LLnE	LLE	HLnE	HLE
Ethnicity				
White not Hisp.	100%	67%	33%	56%
White Hispanic	0%	33%	0%	0%
Black not Hisp.	0%	0%	33%	0%
Black Hispanic	0%	0%	0%	0%
American Indian	0%	0%	0%	0%
Asian	0%	0%	33%	33%
Other	0%	0%	0%	11%
Gender				
Female	100%	0%	100%	33%
Male	0%	100%	0%	67%
Age				
Average	37	39	38	42
Degree Level				
None	0%	0%	0%	0%
High School	17%	33%	0%	0%
Some College	17%	0%	0%	0%
Bachelor's Degree	67%	67%	0%	0%
Graduate Level	0%	0%	100%	100%
Certificate (Mean)	0.17	1.33	3.00	2.89
Family Degree				
None	0%	33%	0%	6%
High School	75%	0%	0%	33%
Some College	17%	0%	0%	28%
Bachelor's Degree	8%	67%	50%	17%
Graduate Level	0%	0%	50%	17%
Study Time				
(% of the week)	2%	7%	22%	8%
STEM experience				
(% of total exp.)	2%	77%	15%	96%
Degree Background				
	Business, Economics, Accounting, Criminal Justice, English	Electrical, Industrial, and Mechanical Engineering	Business, Linguistics, Literature, Theology. 1 out of 3 had interdisciplinary degrees	Aeronautical, Electrical, Mechanical, Industrial, Materials and Metallurgical Engineering, and Physics. 3 out of 9 had interdisciplinary degrees
Professional Background				
	Business, Education, Arts, Social Work, Marketing	Electrical, Industrial, and Mechanical Engineering, and Business	Business, Linguistics, Literature, Philosophy	Computer, Electrical, Industrial, Materials, and Mechanical Engineering, Technology, and Business

Table 3 CLLP Factors for Outlier Profile

Characteristic	LLnE (n=6)	LLE (n=3)	HLnE (n=3)	HLE (n=9)
Professional Growth **M= 6.21 SD= 0.59**	5.60 The lowest scored group, more than 1SD below average. Participants agree they believe that keeping updated and competent in their profession is important	5.94 Slightly below average. Participants agree they believe that keeping updated and competent in their profession is important	6.61 Above average. Participants strongly agree they believe that keeping updated and competent in their profession is important	6.72 The highest scored group, above average. Participants strongly agree they believe that keeping updated and competent in their profession is important
Self-motivated **M= 5.83 SD= 0.70**	5.34 The lowest scored group, below average. Participants mildly agree they are motivated and determined to do well	5.40 Below average. Participants mildly agree they are motivated and determined to do well	6.20 The highest scored group, above average. Participants agree they are motivated and determined to do well	6.18 Slightly above average. Participants agree they are motivated and determined to do well
Educability **M= 5.72 SD= 0.87**	4.91 The lowest scored group, below average. Participants mildly agree they have an interest in reading	5.13 Below average. Participants mildly agree they have an interest in reading	6.60 The highest scored group, more than 1SD above average. Participants strongly agree they have an interest in reading	5.93 Slightly above average. Participants agree they have an interest in reading
Readiness to Change **M= 5.91 SD= 0.73**	5.32 The lowest scored group, below average. Participants mildly agree they are able to cope with change	5.75 Slightly below average. Participants agree they are able to cope with change	6.33 Above average. Participants agree they are able to cope with change	6.56 The highest scored group, above average. Participants strongly agree they are able to cope with change

Table 3 (Cont.)

Characteristic	LLnE (n=6)	LLE (n=3)	HLnE (n=3)	HLE (n=9)
Causation for Learning M= 5.53 SD= 0.70	↘ **4.95** The lowest scored group, below average. Participants mildly agree they are involved in learning activities	↘ 5.11 Below average. Participants mildly agree they are involved in learning activities	↑ **6.33** The highest scored group, more than 1SD above average. Participants agree they are involved in learning activities	↗ 6.13 Above average. Participants agree they are involved in learning activities
Familiar Background M= 4.97 SD= 1.67	↓ **3.19** The lowest scored group, more than 1SD below average. Participants mildly disagree their parents participated in learning	→ 5.22 Slightly above average. Participants mildly agree their parents participated in learning	↗ 6.00 Above average. Participants agree their parents participated in learning	↗ **6.07** The highest scored group, above average. Participants agree their parents participated in learning
Future Orientation M= 6.09 SD= 0.69	↓ **4.64** The lowest scored group, more than 1SD below average. Participants mildly agree they have a desire to advance in their jobs	→ 5.92 Slightly below average. Participants agree they have a desire to advance in their jobs	↗ **6.58** The highest scored group, above average. Participants strongly agree they have a desire to advance in their jobs	↗ 6.56 Above average. Participants strongly agree they have a desire to advance in their jobs

Outliers in each group scored...

Green number the highest across groups
Red Number the lowest across groups

↑ More than 1 SD above population mean

↗ Between 0.5 and 1 SD above population mean

→ Less than 0.5 SD from population mean

↘ Between 0.5 and 1 SD below population mean

↓ More than 1 SD below population mean

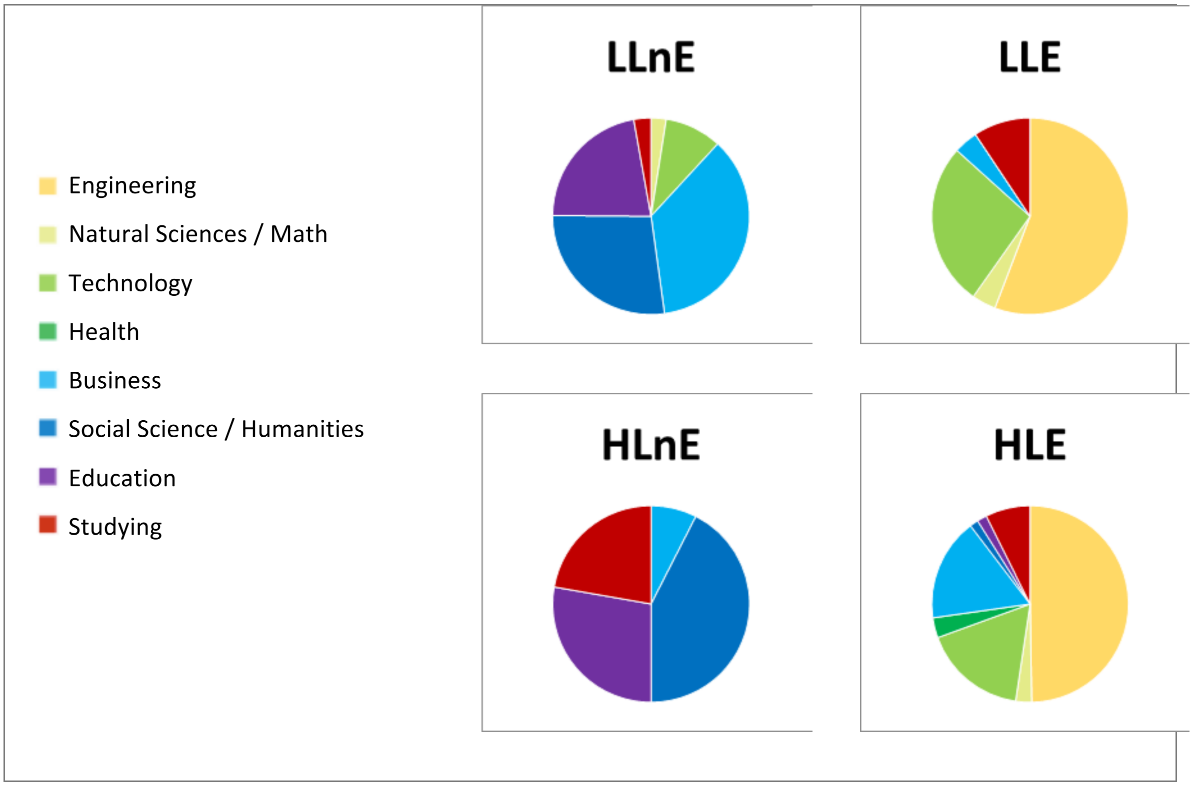

Figure 4.7. Working Time Distribution

Finally, the distribution of outliers' working time is shown in Figure 4.7. Participants were asked to distribute their working time between fields related to engineering, natural sciences or mathematics, technology, health, business, social science and humanities, and education, in addition to time spent studying. All groups spent the majority of their working time in the field of their undergraduate degree and, when applicable, their graduate studies. STEM groups reported the majority of their time in engineering, while non-STEM groups reported the majority of their time in business, social sciences, or humanities, spending an important portion in education.

Furthermore, the two groups with higher lifelong learning skills reported the most and least diversity of fields in their working time: the group with STEM background reported the most diversity, while the group with non-STEM background reported the least diversity of fields, yet the highest portion of time spent studying among all groups. Finally, non-STEM groups had the highest and lowest time allocation for studying.

4.5 Sub-Groups and Outlier Comparative Analysis

A comparison between outliers found and groups from which they were selected (i.e., LLnE, LLE, HLnE, and HLE) was performed to ensure those participants (selected as outliers) were representative extremes from each group. In order to compare outliers' profiles with the group they represented, central tendencies between groups were performed. This allowed identification of the differences between groups and the revision of its consistency with outliers' profiles. An ANOVA analysis was performed to identify those variables for which groups were statistically different; likewise, group means were compared between the total population and outliers.

Levels of lifelong learning were statistically different between groups of low and high lifelong learners $F\ (3,114) = 94.24$, $p < 0.05$. STEM background was also statistically different between groups of non-STEM and STEM participants $F\ (3,114) = 104.81$, $p < 0.05$. In addition, those lifelong learning factors for which outliers scored more than 1SD apart from the mean were consistent with overall group means. Outliers' differences between scores and group means were two and three times larger than scores from all participants in the group. Further, CLLP factors of professional growth, causation for learning, and family background were significantly different: the group with the lowest score for professional growth (LLnE) was significantly different from groups with high lifelong learning skills (HLnE and HLE F (3,114) = 4.22, $p < 0.05$); the group with lowest score for causation for learning (LLnE) was significantly different from the group with the highest score (HLnE F (3,114) = 4.35, $p < 0.05$); finally, the group with lowest score for family background (LLnE) was significantly different from groups with high lifelong learning skills (HLnE and HLE F (3,114) = 6.62, $p < 0.05$). Alignment between the quantitative sample and the qualitative sample are summarized in Table 4.

Table 4. Summary of Quantitative and Qualitative Samples Comparison

	Quantitative Sample	Qualitative Sample
Lifelong Learning	HL=27.92, LL=21.34 F (3,114) = 94.24, $p < 0.05$	HL=30.15, LL=18.49
Career Background	E=7.47, nE=-6.39 F (3,114) = 104.81, $p < 0.05$	E=12.56, nE=-8.61
CLLP Factors	HLnE=6.07, HLE=5.92, LLE=5.68, LLnE=5.55	HLnE=6.38, HLE=6.31, LLE=5.50, LLnE=4.98
Professional Growth	ΔLLnE-HL=0.40 F (3,114) = 4.22, $p < 0.05$	ΔLLnE-HL=1.05
Causation for Learning	ΔLLnE-HLnE=0.47 F (3,114) = 4.35, $p < 0.05$	ΔLLnE-HLnE=1.22
Familial Background	ΔLLnE-HL=1.36 HLE F (3,114) = 6.62, $p < 0.05$	ΔLLnE-HL=2.62

Participants' averages for each group are shown in Figure 4.2. This distribution was, at some level, consistent with the group of outliers; within STEM, the majority had higher levels of lifelong learning. Within non-STEM, the majority had lower levels of lifelong learning. Within lower levels of lifelong learning, the majority had non-STEM background; however, within higher levels of lifelong learning, the majority of participants had non-STEM background, contrary to outlier distribution.

Demographics were consistent between outliers and total population. Higher percentages of White participants were found in low lifelong learning groups, for outliers and total population; higher percentages of women were also consistent between outliers and the total population; HLE was the group with highest average age in both cases (Table 5).

Table 5 Participant Distribution among groups

Group	Size	LLL Score	STEM Score
LLnE	42	21.27 CI [20.59, 21.96]	-5.02 CI [-6.16, -3.87]
HLnE	34	28.28 CI [27.57, 28.99]	-4.88 CI [-6.48, -3.29]
LLE	15	22.67 CI [21.34, 23.99]	8.32 CI [6.46, 10.18]
HLE	27	27.92 CI [27.19, 28.66]	10.31 CI [8.46, 12.17]

Similarly, participant background was also consistent. On average, high lifelong learners had some graduate studies, while low lifelong learners had some level of undergraduate studies, with a significant difference between groups, $F\ (3,114) = 25.66$,

$p < 0.05$). Family degrees awarded was on average higher for outliers that for the total population and was significantly different between the group with lowest score (LLnE) and those groups with high lifelong learning levels (HLnE and HLE, F (3,114) = 7.24, $p <$ 0.05). HLnE study-time allocation doubled, in both cases, the time allocated by other groups. Among all participants, mechanical engineering, literature, education, and business were the most studied fields; mechanical engineering, technology, business, and education were the fields participants reported as their occupation. These differences were significant for the entire group, F (3,114) = 60.83, $p < 0.05$ for undergraduate field, and F (3,114) = 47.47, $p < 0.05$ for professional field.

4.6 Analysis of Results

The discussion of outlier analysis was presented at the American Society for Engineering Education (Tafur & Purzer, 2015), and adapted for this dissertation document.

Identification of outliers was performed using cluster analysis. In this designed technique (TafurPS), the distances for threshold were initially calculated from the maximum values, but later adjusted in order to achieve the criteria set for the research design, as proposed by Breunig and colleagues (2000). In this particular case, one of the parameters set for the purposeful sampling was a minimum of three outliers per group; however, the distance for the threshold may be adjusted for other research designs with more inclusive selections. This flexibility makes for a convenient process to purposefully selected samples that follow two or more criteria; in this example, the variables taken into account were lifelong learning and STEM background. Although the visual representation of an analysis with more than three criteria may be complex, it is possible to perform this process using a higher-dimension cluster in which the threshold depends on the number of variables.

Having two approaches for finding outliers —one using raw data and other using ranked data— allows for a more robust selection of eligible data points. This verification is also possible for other data sets and measured variables due to the nature of the process. Further, the threshold curve may have different shapes depending on researcher criteria, such as avoiding middle scores in one or more variables (e.g., a diamond or rectangle shape).

Regarding the number of data points needed for the analysis, this criteria was also defined by the researcher and depended on the percentage of cases targeted among the total population. In this particular case the percentage was set at 10%, acknowledging that 1 of 10 people participating in the study was considered an eligible subject for qualitative analysis. In general, the approximate number of participants should be $N=(o \times c)/p$, where o is the desired number of outliers, c the expected number of groups, and p the percentage of outliers compared to the total sample size. Two analyses were performed using a larger sample of n=146 (see Tafur & Purzer, 2015) and a subsample of the former with n=118 (see CHAPTER 4) testing stability of the method.

In both cases at least three outliers were found per group, and those outliers were representative of the group they belonged.

For reliability verifications, those data points identified as outliers were further studied by comparing an outlier profile with the group represented. Participants and outliers had similar characteristics, with statistical difference between some of the factors that contributed to lifelong learning and background scores. For most of the elements assessed, highest and lowest scores between groups were consistent among outliers and participants; in fact, in just three cases where scores were switched between groups but no significant differences were found for these instances (LLnE and LLE for self-motivated, HLnE and HLE for readiness for change, and HLnE and HLE for Familial educational background). Similarly, for reliability verification in background score, technology experience and usage was compared and found a similar order for outliers and clusters, although outliers were more extreme. Finally, undergraduate, graduate, and professional fields of study/work were verified for outliers in order to assure that the sub-sample met the criteria of selection.

Consistent to the analysis performed for a larger population, this method of outlier selection presents a statistical strategy for finding representative outliers in a purposeful sample used for qualitative research. This process of identifying rich cases among large populations promotes qualitative research quality as required by researchers (e.g., Suri, 2011), and simultaneously provides a rigorous procedure for purposefully selected samples, allowing for statistical inferences (Sandelowski, 1995).

CHAPTER 5. QUALITATIVE RESULTS

This chapter presents an analysis of qualitative results, the second phase of the study. This strand included interviews with a sub-sample of 12 participants from the initial sample. The qualitative results show how adults interact with technology based on recent and past experiences. The structure and relations within and between dimensions are analyzed to highlight critical differences and uniqueness between instances and themes, which leads to the identification of how adults approach technological challenges or categorized themes. A visualization of the thematic outcome is presented and discussed.

5.1 Theme Identification Process

First Iteration: The first iteration for theme identification was performed using a subgroup of interviews from the first round of data collection. Some common instances emerged from what both pilot participants expressed during interview. The emerging codes and commonalities across interviews led to the creation of three main dimensions, which later helped to identify themes and categorized themes: attitudes towards technology, behaviors facing technology, and definitions used for technology. The initial iteration of the coding schema also included one methodological code used to identify structural parts from the interview to ensure a consistent protocol.

Structural coding comprised opening and closing, participant background, recent experiences, and bracketing of the interviewer.

Second Iteration: This iteration included the process of identifying relevant utterances in response to the research questions. Central here was the revelation of those attitudes, behaviors, and definitions of technology. Behaviors facing technology--one of the three outcome dimensions--included actions performed by the participant when facing a technological challenge. Behaviors included: trial and error, breaking-up complexity, critical thinking, asking for help, quitting, or finding alternatives. A second dimension of the thematic analysis featured diverse attitudes toward technology, including positive features such as: perception of benefits, confidence, and acknowledging a need. This dimension also included negative features such as: anxiety, barriers for achieving the goal, frustration, perception of wasting time, and neutral attitudes in which participants engaged with reflection but explicitly said that they did found those reflections neither positive nor negative in nature.

Finally, a third dimension showed technology conceptions, which emerged when participants described a technological challenge or explained why an experience was classified as technological. Relevant utterances within this instance included: breaking-up complexity, continuous improvement, design process, early prototype, efficiency, flexibility, simplifying tasks, hi-fidelity, information technology, problem solving, scaling, technology development, technological environment, technological processes, artifacts, trade-offs, and trial and error.

Third iteration: The third iteration for theme identification included the consolidation of those key features within dimensions, which were found to be part of critical differences between themes. For the definition of technology, critical differences were found in participants' descriptions of technology, and their focus varied from digital artifacts to a broader definition of technological products and processes. Table 6 summarizes critical differences found within themes by dimension, which are detailed in section 5.2.

Fourth Iteration: Critical differences found within themes were analyzed in order to describe the uniqueness of each dimension within emerging themes.

In the case of attitudes, two critical differences were found across participants. They perceived strong feelings and performed a pros and cons analysis for engaging with the technology challenge (emotional approach), or their attitudes were not elicited despite being asked to describe them (neutral approach). Within behaviors, participants explained their role in three different ways: as active agents in overcoming the challenge (creators or adapters), as searchers of a solution given by others (passive users), or as disengaging and quitting the challenge (not involved). Within conceptions, two critical differences were found: participants described technology as products with a focus on computers, cellphones and tables (technology as digital artifacts) or as processes used to create or adapt products (technology as a process). The analysis for this iteration is discussed in sections 5.5.1 and 5.5.2.

Table 6. Themes for Dimensions of Interaction with Technology

Dimensions of Interaction with Technology		
Attitudes	Behaviors	Conceptions
	Quitting	*Common electrical artifacts*
Positive	- Changing tasks	- Computers
- Perceived Benefits	- Changing products	- Cellphones
- Acknowledged Needs	- Deciding not to use technology	- Tablets
- Confident	*Passive search for Answers*	*Any electrical stuff*
- Other positive feelings	- Step-by-step procedures	- Domestic Appliances
	- Trial-&-error	- Things containing a chip
	- Shortcuts	
Neutral	*Active search for Answers*	*Any new Product*
- Indifferent	- Testing models	- Latest pen
- Disinterested	- Researching	- Transition glasses
- Mix of subtle Positive and Negative Feelings	- Identifying Problems	*Non-Natural Things*
	Interacting with others	- Bikes
	- Asking an expert or mentor	- Glasses
	- Asking a friend or peer	*Combination of fields*
Negative	- Exchanging with colleagues	- Math
- Perceived Barriers	*Formal Decision-Making*	- Science
- Waist of Time	- Critically thinking	- Engineering
- Anxiety	- Analyzing alternatives	*Process*
- Frustration	*Modeling*	- Problem solving
- Other negative feelings	- Controlling Variables	- Improvement
	- Quantifying Variables	- Trade-off analysis
	- Creating Solutions	- Simplifying situations

Fifth Iteration: The last iteration was performed to consolidate the three dimensions analyzed in previous iterations. Five final categorized themes were used to examine how participants approach technological challenges. 1. Disengagement: participants in this categorized theme perceived their experience as very emotional, they referenced strong positive and negative feelings, which related to the level of success with the challenge. Their role may have started as users, but they decided to quit the challenge. This group defined technology as a digital artifact, most commonly as a computer or its internal software. 2. Scaffolding: participants in this categorized theme perceived their experience as very emotional, similar to the previous categorized theme. However, their role in the challenge was mainly that of a user. Though they may have found a technological challenge very frustrating, they did not quit the challenge and instead searched for expert help. This group defined technology as digital artifacts. 3. Transitioning: participants had changing attitudes, behaviors, and conceptions regarding technology. They may have acknowledged their anxiety, but their descriptions did not have strong identifications with the challenge. Their role was sometimes active, sometimes passive towards technology; they perceived themselves as technology experts in some situations, but as a novice or outdated in other situations. Their conceptions also presented a dualism between digital artifacts and processes; they explained how technology *should* be described instead of how technology *is* described. 4. Emotional engagement: participants in this categorized theme also had changing conceptions, but are emotional and active creators and adapters of the technology involved in the challenge. They had strong feelings about technology, which are more inclined to be positive. The role of this group towards the challenge was active, featuring an agency in finding a solution and overcoming the challenge itself. Their conceptions about technology varied from a product focus to a process focus. 5. Ownership: participants in this categorized theme were neutral towards the challenge, their role was active in that they constructed solutions or claimed to be expert when overcoming the challenge. Their conception about technology was broad and includes products and processes; however, their explanations focused on the process. The outcome space and discussion of this final iteration are presented in chapter 5.

5.2 Themes Identified

5.2.1 Attitudes

Within this instance, interviewees' references to positive, neutral, and negative attitudes were coded. During the interview, participants were asked to describe what they were feeling during a past or recent interaction with technology; also, interviewees often referenced their attitudes spontaneously when describing technological challenges they experienced.

Positive Attitudes towards Technology. Positive feelings and reflections towards technology were grouped under this theme. The more common utterances found across experiences and participants were the perception of benefits, acknowledgement of technological needs, and positive feelings such as confidence (when trying to achieve a goal) or interest (when learning new technologies).

Particularly, the perception of benefits was connected to flexibility of communication, efficiency, and efficient way of living. For instance, one participant reflected “*I really appreciate the opportunity to correct drafts without using whiteout, all of those sorts of things. The big thing is I have doctoral students who are in other parts of the world, or other parts of the United States, and they can email me a chapter of their dissertation*” (P7P). She also explained that “*getting information is very… would be very helpful. And when one of those huge storms came through. I was actually able to see, okay the worst is past. I can see where this storm was*” (P7R1). Likewise, another participant cited the benefit of technology to be its innovative nature: “*to be honest, when I am just giving the lecture some of them will do their homework, they just stare at… maybe their iPhone or other stuff like that. But when I show the videos they actually would pay attention to that. Another thing is like if I want them to like use the technology to write their essay or to do their research… as I said it is a new experience for them, and they have to do it at first; but when they have to do it, and then they just figure out how this things are happening, then so it’s kind of fun for them… rather than just repeating doing the same thing all the time*” (P2R1).

Besides the benefits perceived by the participants, some individuals referenced getting involved with technology because of a need. For instance, an instructor got involved with an educational application due to her students' request. She stated, "*students frequently say «well, we want that blackboard information.» And that's the reason I did it. I thought, if this is helpful to the students, and if it cuts down on work for me… I mean even if it takes, you know, even if I'm challenged to do that… I mean I believe in learning new things. So I was willing to do that to help the students*"(P4P). Similarly, another participant highlighted the importance of fulfilling stakeholders' needs when describing a design process as part of a technological challenge. He said, "*I have to be able to say relate processing parameters and the effect of those processing parameters on result properties microstructure and be able to show that I can … control those in such a way that I can modify properties to the point that they fulfill our needs*" (P8R1).

Finally, positive attitudes were also coded when participants expressed positive feelings about their interaction with technology. The most common feeling was that of confidence when trying to achieve a technology-related task. In fact, five out of twelve participants acknowledged they felt sure of themselves. For example, when explaining a technological challenge, a participant said, "*I've developed and understanding of the mechanisms by which wear occurs and have been able to kind of envision how that interaction happens at a, essentially a microscopic scale, in such a way I can apply that technology to improve product and processes for a lot of different applications… one of my kind of unique abilities allows me to understand it pretty well*" (P8P).

Neutral Attitudes towards Technology. Neutral attitudes towards technology were also relayed during interviews. Some individuals explained their challenges as ways to cope with technology or with requirements of their field. For instance, one participant explained, "*I accept that it's part of my life and I cannot do without it, but I am not like super super fan of new technology stuff. But I just know that I'm into like… I don't want to get outdated so I know what people are using, and I kind of know something about this, but I'm not like that exposed to the technology*" (P2P). Other participants also communicated mixed feelings when reflecting on their experiences. When explaining the benefits of technology, Participant 4 said, "*I really appreciate the opportunity to correct drafts without using whiteout… but sometimes they send me things that… I can just use that, but their copy is, I can't edit it. But, how to change that... So that's sort of negative… It's really helpful to have [a word processor]*" (P4P). However, the majority of experiences within this theme had no emotional approach to the challenge; therefore there were neither positive nor negative quotes and the explanations did not include particular connotations.

Negative Attitudes towards Technology. Under this last theme, negative perceptions (such as technology being a barrier and waste of time), and negative feelings (such as anxiety and frustrations) were grouped. Participants found barriers such as gaps between user requirements and their own knowledge, or limited resources. For example, one individual expressed, "*students complained they couldn't get access to the information… still that's sort of the combination between my* *incompetence and the students not being able to get access… and, I mean, the IT people said «there shouldn't be any problem, this is set up appropriately» you know… so, I just quit using it*"(P4P); Another reported, "*the PCs may very well be full of keyboard shortcuts and I just don't know them, because… there's no easy way for the PC to be like «hey here's a shortcut!»*" (P5P).

Besides barriers, the perception of wasting time was also a common negative attitude when interacting with technology. In fact, six out of twelve participants expressed discomfort when using technology because it took more time than expected or they felt it was a waste of time. One participant expressed her frustration when she couldn't navigate the equipment for an online meeting, despite having set the same configuration successfully in the past. She said, "*It felt like I had totally wasted everybody's time when I couldn't get the thing to work out right. And I was frustrated because… the interruption of the fire drill, and not being able to resume where we left off*" (P9R1). Similarly, another participant was frustrated by interacting with automatized answering machines instead of conversing with a person over the phone. She explained, "*it's just so frustrating when it comes to customer services that are technology, like they're not real people sometimes… It's time consumption. I feel like I'm losing too much time sitting on the phone and pressing 1, 2. Press 1 if you do this… Press 2 if you do this… I just feel like I just spent 5 minutes giving my information while I'd really like to call, and someone picks up and says, «hello, do you have a question?»*" (P1R1). A commonality across many negative experiences was the relation between technology and the time it requires. Some participants expressed their frustration when trying to find a solution or learn a new technology, because that time was perceived as wasted (e.g., P9R1, P4P, P1R1), or barred them from a new product or process (e.g., P5P, P7R1); however, other participants perceived the time required to be a positive aspect of a technological challenge of optimization (P10R1).

Finally, negative feelings were also coded as part of this theme. Feelings of incompetence, anxiety, and frustration were most commonly expressed during the interviews. For instance, a participant shared that, when adapting datasets in excel, she feels able to perform the task, but "*…not real in depth. I don't feel like I'm very good at making the data do things like some within our office can*" (P7P).

5.2.2 Behaviors

Utterances coded within this instance include interviewees' references to their actions when interacting with technology. During the interview, participants were asked to explain in detail how they approached a technological challenge once it was identified. Their behaviors included actions of disengaging from the task, looking for answers informally and via research, interacting with peers, interacting with experts, or being the experts themselves –making decisions and modeling the systems.

Quitting or Disengaging from Technology Interaction. Under this theme, actions described by participants featured a disengaging from or quitting a technological interaction. Some of the individuals linked this action with feelings of frustration, others as the result of a trade-off analysis of a technological challenge. For the latter group of participants, quitting was not the result of a negative experience but instead a practical decision. The act of quitting was identified in descriptions such as "*I did not try [to fix a device problem] because I don't want to waste my time in the class like figuring out a problem with technology, so I just move on and said «okay I'm going to show it for another day»*" (P2R1), and "*I click on the local news, nothing happened. I click on the weather and it says it's currently 71 degrees, but I can't access the forecast. I can't access the radar. I can't access, you know, lots of things… I turn it off*"(P4R1).

Passive Search for Answers. In this theme, participants were engaged in the technological challenge by searching for answers on the Internet, looking for step-by-step answers, trying different solutions in a trial-and-error process, or using some alternative shortcut. For instance, a participant acknowledged that she sometimes uses Google to find answers to a problem. She said, "*I worked in a business technology lab, and so I got to do a lot of behind-the-scenes stuff with [windows]… but not like learning it; I was more of a «here it's giving me this error… I'm going to Google the error and see what Google has to say about how to fix it»… I was that kind of person*" (P5P). In fact, seven out of twelve participants referenced Google during interviews; some participants used the site to find step-by-step solutions to fix a problem, and others used it as a colloquial verb for an Internet search. One participant made explicit the need for step-by-step procedures: "*I'm not exposed to that as much… so that's the* *reason that… if I am given instructions about how to do stuff, I can do it just like one, two, three, one… following the steps, but not like… I am already very familiar with that kind of stuff*" (P2P). Another individual decided to try using trial and error to finish a task: "*I was redesigning a brochure… this is the color the person who designed chose… and printing it, you don't even see [the background]. So I said «OK, what if we change it to a darker color?»… But by the time I went back yesterday to make the rest of it match… [I thought] «Man, how did I do that?» So it probably took me a half hour of trying to figure out, you know, where was that? How do I get exactly the same color?... I can't remember it, and it was so easy… so I probably went through… selecting just the right box, and then getting the color changed… you know, so pull up menu, pull up menu… not that is not it, so pull up menu… a lot of back and forth that way… trial and error*" (P3R1).

Active Search for Answers. In this theme, participants were searching for answers. Contrary to the previous theme, this represents actions connected to creation or adaptation, such as testing models or solutions, conducting research, or problem identification as part of a technological design. For instance, one participant explained the use of test results for a design decision: "*[a colleague] say «we need steel, we use [a material] because it gives us improved toughness». And I say «OK, but the improved toughness –and I provide her data from published metallurgical handbook that shows actual tests… that have been down and shows the effect of [the material] at room temperature– essentially does not provide any benefit in toughness, but at low* *temperatures*" (P8R1). Similarly, another participant reflected on the importance of testing during the design of a technological product. He said, "*[this is] a relay that is already completed... When we were working on it, we found out that it hadn't been tested, this is a relay… and I've heard that it hadn't been tested, so some newer tests have to come along, so… we had to go back and retest them. We tested the new ones, we tested the old ones*" (P10R1).

Another refined way of finding answers to a technological challenge was conducting research. Participants' conceptions of research were broad, from analyzing and contrasting tests with research studies, searching online for information about a problem, and conducting a literature review —all were part of what was identified as research. Some participants included research as a technological task due to the critical nature of decision-making in technology design (e.g., P6P, P9P, P5P). Other individuals considered research as part of technology because they needed technology products to perform the research itself (e.g., P4B, P2R1). In fact, eight out of twelve interviewees referenced research when explaining a technological challenge or describing technology altogether. Problem identification was also part of an active way of searching for answers. For instance, one participant explained, "*… That is how I got hit with technology: Endeavoring to understand approaches to organize stuff in order to solve Engineering problems, you know.*"(P11R1).

Interacting with Others. One common action elicited from the interviews was social connection when interacting with technology. Some participants explained how they looked for peers, friends, family members, or experts when searching for help; others reflected on experiences when they were considered the experts and had to interact with others to make technical decisions or help others with technological challenges. For instance, one individual who asked a colleague for help said, "*I probably will try to spend 15 to 20 minutes trying to figure it out by myself, if she is available I will go across the hall, I will say «OK, who do you do this?»… if she is not, I will Google it or, you know, I will call somebody else in the department who has experience with that*" (P3P). Here she acknowledged her colleagues as experts regarding to the technological challenge. Similarly, a participant expressed how interacting with others was important for a design process. He said, "*He called this morning. I have a letter email him to write back to the people describing the problem of… «Hey, you know, we have the generic label put on the potting»… that's our next challenge. I don't know what I can do just yet, but I'm going to work at it. And then I'm probably going to go and do a little research and talk to someone… believe it or not we have potting experts here, so I'm going to see if they have any other alternatives*." (P10R1). Another participant referred to how others perceive him as an expert in the field: "*I'm asked to do things, like… the day before yesterday, I was at [a meeting] at [the university] and I'm asked to talk about different things, but it seems that point of view is worthy of other people's to listen to… I don't think I know enough and I'm kind of slowly on a quest to, you know, learn more things* *about. And it's all driven to solve problems, and that's the empathy thing… So… to the extent where my closest colleagues support this, and I got the first set of those guys*." (P11R1).

Making Decisions about Technology. Participants described a wide range of decisions they had to make regarding technology. Some individuals reflected on why they should choose one application over another. Others explained how they used technology artifacts in their everyday decision-making, while others described critical thinking in making a design decision. Though participants reported widespread issues such as changing from Windows to Mac or installing Wi-Fi in their home, the decision-making processes were complex. For instance, a participant reflected on differences in her use of a smart phone as compared to her daughter and grandsons. She said, "*they're all more technologically savvy than I am, so you know, they've all had smart phones if that's what you call them. They've all had these phones that have all these apps and, you know, they play… their primary thing is they play games. Well, I'm not interested in the game playing. You know, but getting information would be very helpful. And, when one of those huge storms came through. I was actually able to see, okay the worst is past. I can see where this storm was, it's moved to the east and there's not that big, so I could see all of Illinois on the radar and I could see, you know, I figured… Well Illinois is going to be at least an hour or two away. However fast he storm was coming, but I could see from the radar exactly where the storm was*" (P4R1). Another expressed, "*I know in most cases the computer will pick up errors that I make, and I am a pretty* *good proofreader, and when I do proofread something, I usually find the things that the computer misses*" (P3P). In contrast to these everyday decisions, other participants made decisions for a complex design project. One participant shared, *"… say you have a part that is a type of structure; well the load may be applied on one end and certain areas of the structure are at very high stress, and then they'll be other areas that effectively see no stress at all. And the requirement… you have to be able to design this component based on the stresses needed at the point of contact, the point of highest severity of load and application. So we need to be able to understand that, the differences in local requirements as well, you know, on how that compares to the more global properties and use*" (P8R1).

Modeling Systems. This last actions theme reflects how participants considered engineering tasks as part of technological challenges. In fact, when some participants were asked about their experiences approaching technological challenges, they identified the following as part of their interaction: modeling, the design process, problem solving, and system analysis. In terms of modeling, a participant explained, "*The issue we are having is developing a vibration isolator on an engine, and I am developing the [design part]; and the issue we have is that we don't have real test data to drive the simulation model with this type of a setup. The inputs we have, only two simulations are kind of unknown, and we currently use that to efficiently try to drive a linear model or analysis capabilities with non-linear properties of these vibration damaging components*" (P12R1). Similarly, another participant explained a technological challenge linked to the design process. He said, "*there are other, I guess, technological issues. They're kind of on the technical metallurgy part side of it, but I have to be able to relate processing parameters and the effect of those processing parameters on result properties on microstructure and be able to show that I can control those in such a way that I can modify properties to the point that they fulfill our needs, plus in some cases I have to figure out a way to quantify those changes such that we can put those values within a specification, so that we can have manufacturing people be able make these such that they have these properties that we need every time they make them, and be able to explain in such a way that, say, mechanical engineers can utilize them in their designs and analysis of new components*" (P8R1).

Engineer participants were more likely to analyze a more complex challenge. They usually interacted with people to make decisions about design processes. They performed tests and broke complex problems into pieces by controlling and quantifying variables in order to find solutions.

5.2.3 Conceptions

Within this dimension, interviewees' references to their definitions of technology were coded. During the interview, participants were asked explicitly to list words that came to mind when thinking about technology; they were also asked to describe a technological savvy person and to identify technological challenges in their past and in recent experiences. These descriptions and their underlying assumptions were grouped and coded as principal conceptions about technology. Those principal conceptions led to categorizations of technology as the following: common electric artifacts, electrical stuff, new products, all not-natural things, a combination of math, science, and engineering, or a process to create solutions to meet users' needs.

Common Electrical Artifacts. Some of the participants perceived technology as common electrical artifacts such as computers and cellphones. In fact, eleven out of twelve participants referenced this definition in the course of the interview. Further, some participants included computers as a given in this theme; for instance a participant reflected, "*I think of technology, I obviously think of computers and all electronics first*" (P5B). Another stated, "*this is the default thing: computers*" (P12B). A third participant explained, "*The first word that pops into my mind is computers*" (P6B). When interviewees were asked to share which words came mind when thinking of technology, eight out of twelve included computers and cellphone in their list, and either was the first word stated.

Electrical Stuff. Besides computers and cellphones, some participants included other electrical appliances such as dishwashers or robots. For instance, a participant reflected about the work of engineers using laboratory equipment: "*Maybe it is technology… And then they also have this cleaning machine… to separate stuff… Maybe it's technology, but it is not the same technology that we talk about most of the time* *today like with computer, or with networking, or with Google, or stuff like that… Yes… I think it is technology if I use electricity*" (P2R1).

New Products. During this brainstorming portion of the interview, two participants included words related to new artifacts, and one referenced "*the latest iWatch*"(P2B) while another referred to "*the latest and greatest*"(P10B). Yet another participant reflected about what is and what is not technology. She said, "*… Computer, cell phone, domestic things like… that's technology too. You know like dishwasher, and washer, and dryer, TV, iPod, iPad, all the smart… android or whatever systems that they have. That's what I call technology. Anything that facilitates your… anything that is a tool that facilitates your life. But not just like your pen. A pen is not a technology*"(P1B). However, other participants reflected on how technology is linked to new developments, continuous improvement, and innovative processes. For instance, an individual explained his perception about information technology as a clear link with the future. He said, "*What you think of the future is what you see now as developing, like cell phones, and access to information, and cloud stuff, and all that… the Internet... That's all information, and how you organize it can make you or break you*"(P11P). Another example is the reflection of a participant on a bike as technology. She said, "*It goes back to the definition of technology. I don't know. I just like kind of like… if you asked me if a car was technology, I would say yes… Bike is more like… OK, so if you asked me whether a pen is a technology or like a feather pen is a technology I would say no, it's not because it's [been] there for a long time. Maybe it's not because it's just like very* *old fashioned and it's [been there] forever. But if you asked me [if] this type of pen is technology, it's kind of new and is a latest trend, and it involved intelligent engineering, maybe it is. So I think technology might include the elements of innovation, invention, creativity, stuff like that*" (P2B).

Non-Natural Things. Participants usually used examples related with electrical artifacts; however, some of their reflections referenced other types of products such as bikes, glasses, or detergents. For instance, a participant responded, "*Can I count my glasses as technology?... Well technically I would say yes they are, because I have progressive lenses*" (P5R1). Similarly, another participant commented, "*Stuff. I think of technology, I obviously think of computers and all electronics first. But then on the other hand I also think of things that people make using that kind of stuff. So anything that's not like trees or grass."* (P5B)

Combination of Fields. Some participants included in their definition of technology other fields such as math, engineering, and science, yet most of the participants included at least one of these words in their interviews when describing their experiences with technology. In fact, ten out of twelve referred to engineering, seven to science, and three to math during their interviews. Sometimes the connection was instant but implicit; for example, when asked to say what came to his mind when thinking of technology, a participant said, "*I guess my first love of science was like space travel or whatever, you know. So the ability to travel the different planets and the* *science behind that*"(P10B). Similarly, another participant referenced a pivotal moment regarding to technology. She said, "*I was always interested in that science and how people interact with those things to solve problems. And since I was high achieving in that, I stayed in four years of that, in science in high school. Let's see. When I was beginning high school, my mother went into her Master's degree program in Instructional Technology. And I think that may have had something to do with it also*" (P9P).

Processes and Systems. This last theme takes into account the cognitive process required for problem solving, trade-off analyses, and human-centered design as part of technology. This theme also includes technology as a system that can be broken down into pieces or variables to simplify situations, improve solutions, and ensure continuous improvement. For instance, during the description of some design processes, participants explained how they isolated variables and filtered noise in order to simplify the problem by breaking-down the components of a system to study a specific problem. In this regard, one participant linked the breaking-down process with a technological challenge and explained, "*My manager explained to me that as an engineer, it's like you can develop or invent the greatest things since sliced bread, but if you can't sell it to your managers or to an audience of users slash adopters, what you've done is kind of irrelevant. So in that kind of maybe thinking, it's like okay yeah you have an understanding better than anybody else at every level to be able to explain things to an audience who maybe may not be engineers… and as such, it's like you have to again* *bring it down to a… more simplistic or basic level that can be understood by someone who doesn't have my technical background and experience*"(P8R1). Another explained how he separated and controlled variables to achieve a design task: "*I was using copper for communication and measurements… And I would have to go through some isolation and filtering and all kind of stuff in order to eliminate noise*"(P11P). Likewise, one participant explained a process of continuous improvement as "*Our group is tasked with taking a look at how we can improve the production through test cells. How can we improve quality that kind of stuff, and then also looking at future kind of project down the road, what do we need for more equipment, for more test cells… I've been doing some of that software development"*(P6P). Another shared that "*I was put in charge of a couple of labs where you have to validate all these components up to a point where they can go on machines, because machines you know… it involved electrical tests, it involved environmental tests, it involved EMI testing where they test for electromagnetic influences and things, a vibration tests. Literally my job was to break stuff*"(P10P). A common process identified as technology was communication and information technology; for instance, one participant described that *"… There's a book I need and I can just check it out. But then I can return it through interlibrary loans. So knowing what the library has, what their collections are, if you're looking for something particular, and of course if I just want the book, then interlibrary loan will do that. They will find out where the book is, and it could be sent through interlibrary loans*"(P4R1). Similarly, another common process connected to technology experiences was problem solving. For example, a participant explained how problem solving is affected by individual background. She stated, "*Different people choose different methodologies to solve the problems in their world. So a carpenter might have a different discipline and a different way of thinking about things than a musician might. And I find it true of Engineers. Even among Engineers there are different specialties that seem to have a different lens that they're viewing the world through. So as an Engineer you're trying to a particular framework to analyze your problems*"(P9P). Finally, another common process connected to technology was its trade-off analysis; in this regard, one participant expressed that a technological challenge was to balance the pros and cons of decision-making. He explained, "*How did I approach that challenge?... understanding the specialization of the software basically, the technology… to understand what the strengths and what the weaknesses are… and balancing the strengths of one against the weaknesses of the other, and kind of have an understanding of the interactions… what is supposed to weight to models' results for a finished product*" (P12R1).

5.3 Critical differences

5.3.1 Critical Differences in Attitudes

Two themes —positive and negative attitudes— included feelings linked to the experience as participants explained them. In contrast, neutral participants rarely mentioned a specific feeling regarding to the challenge, even when they were asked how they felt. Not only feelings set the delimitation between these themes; also, the connotation brought to the description of an experience was another critical element in theme definition. For instance, one individual felt incompetent when unable to solve a technological problem, while another participant found the level of difficulty an engaging element of the challenge. Participants who tended to be more emotional when describing the challenge were prone to link positive feelings with success in the challenge and link negative feelings with their perception of being unable to overcome the challenge. Individuals approaching the challenge in a neutral manner had higher levels of self-efficacy with regards to overcoming the challenge.

5.3.2 Critical Differences in Behaviors

Participants used a variety of actions in their approaches; however, they maintained similar levels of engagement (passive versus active) across experiences. Quitting and passive searching for answers were themes in which participants tended to look for third parties for overcoming the challenge. Making decisions and modeling were actions in which the participant felt agency in overcoming the challenge. Active searching for answers was the theme dividing passive and active roles when approaching the challenge; when identifying problems, testing or researching, participants tended to be autonomous in their actions, yet they were looking for answers in order to perform a related action. Some individuals quit after searching for answers in both passive and active ways, but those making decisions or modeling solutions did not quit the challenge.

5.3.3 Critical Differences in Conceptions

This hierarchical dimension shows the first two themes as electrical artifacts. The narrowest perception of technology includes computers, cellphones, and tablets as the definition of the concept, while the second theme also includes other electrical artifacts such as domestic appliances, or even cars because they can be turned on. A critical difference between these two themes and the following two (technology as new products and technology as any artifact) is that participants who defined technology as new products or any non-natural product did not address the conception that technology requires electricity. However, the third emerging theme defined new artifacts as technology and omitted those creations from the past outside the definition. In contrast, the fourth theme presents a broader perception still: everything created by humans is considered technology, not only new products. The first four themes based the technology definition on the concept of a product or created artifact. Conversely, the two last themes present a more abstract conception about technology. The fifth theme includes fields such as math, science, and engineering in this technology definition. Descriptions under this classification acknowledge the process, but focus the definition on the product created using those fields. Finally, the last theme within conceptions presents technology as a process by which products may be created, but the focus remains on the process. This last theme conceives of a broader definition of technology than those included in previous groupings.

5.4 Summary of Themes and Dimensions

Three dimensions were found during the interviews. Within each dimension, utterances were categorized according to emerging commonalities from data. Attitudes were grouped into positive, neutral, and negative themes. These groups included feelings linked to interactions with technology and perceptions about the outcome of the interaction. The most common attitudes were positive attitudes (such as being confident or perceiving benefits of technology usage) and negative attitudes (such as frustration and a perception of waiting time when using technology). Some participants relayed mix attitudes or feelings about overcoming a challenge, while others reported an emotionally neutral approach. This dimension varied with each experience, regardless of the participant, but in relation to the level of success of the technological challenge.

As a second dimension, behaviors toward technology, was coded. This dimension Included quitting, looking for simple or refined answers, interacting with others, making decisions related to technology, and modeling systems for solving design problems. Different to the previous instance, these themes were somehow related to the background of the participant, insofar as active actions more commonly performed by people with a STEM background compared to those with a non-STEM background.

Finally, a third dimension was related to participants' conceptions about technology. This dimension included explanations of technology from simpler to more complex definitions: from computers and phones to technology as systems and processes. Reflections made by participants in this group included explanations about why artifacts such as bikes, pens, computers, or other products are (or are not) technology. Also included were explanations regarding complex design processes that included problem solving, trade-off analyses, simulating systems, finding and calibrating variables, among others.

5.5 Analysis of Results

The qualitative strand was performed to examine how outliers approached technological challenges. The maximum variation was chosen to expose even small differences on each way of approaching the challenge. Participants were situated at the extremes of STEM/non-STEM and high/low lifelong learning continua, and uniqueness of each extreme was the focus of the study, aiming to find core patterns that emerged across categories (Patton, 1990; Sandelowski, 1995; Suri, 2011). Among participants, changes in emotion and passive or active roles were represented across backgrounds and various experiences; however, conceptions were found to be extreme in a similar pattern as was the case for participants with STEM backgrounds.

5.5.1 Relations within Dimensions for Experiencing Technological Challenges

Attitudinal changes were perceived within the same challenge. Actions taken to overcome the challenge also varied within the same challenge, although levels of engagement were consistent across actions within one experience. Conceptions tended to remain consistent from the first to second interview.

5.5.1.1 Attitudes as a Balancing Act

Cross table (Figure 5.1) shows how individuals' descriptions of attitudes were a balancing act. In general, individuals tend to either express strong (positive or negative) feelings about their experiences with technology or approach the technological challenge in a very neutral way.

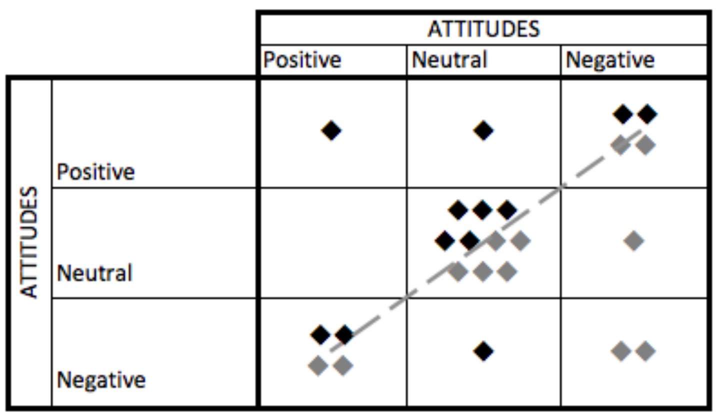

Figure 5.1. Balancing Attitudes

In particular, those who experienced strong mixed feelings performed a trade-off analysis that explained their behaviors when approaching the challenge. They reflected on how the incorporation of technological artifacts (e.g., word processors or the Internet) or processes (e.g., Information search or triangulation of information) led to communication flexibility, product quality, or satisfaction; at the same time, the learning curve or limitations to the technology or the process of understanding led to unnecessary time consumption, frustration, or anxiety. Participants that reported strong feelings were constantly performing a balancing reflection between pros and cons of technology.

In contrast, those who were more likely to describe the challenge in a neutral way did not include strong feelings in their descriptions. In some cases they may have felt frustration due to unexpected outcomes or engagement trying to solve the challenge; yet for both they mention these feelings and attitudes very briefly.

5.5.1.2 Consistent Behaviors between Experiences

Cross table (Figure 5.2) shows how individuals' description of behaviors is consistent between experiences. Interacting with one another was embedded in all other themes but quitting. When participants searched for answers, interactions tended to happen with a more knowledgeable peer or an expert on the subject of the challenge; when participants constructed the solution to overcome the challenge, interactions tended to happen with participants as experts. In general, within the same experience, actions tended to remain either simple or complex in a consistent way. For instance, when a participant approached the challenge looking for solutions using Google, this same participant used similarly passive approaches within the same challenge or to solve other challenges. These actions included: looking for step-by-step solutions in manuals, quitting, or asking for help for solving a simple problem. When participants performed more active actions such as modeling or testing, other actions also performed during the technological challenge were similarly complex such as: making decisions about design or interacting with colleagues to define a complex procedure.

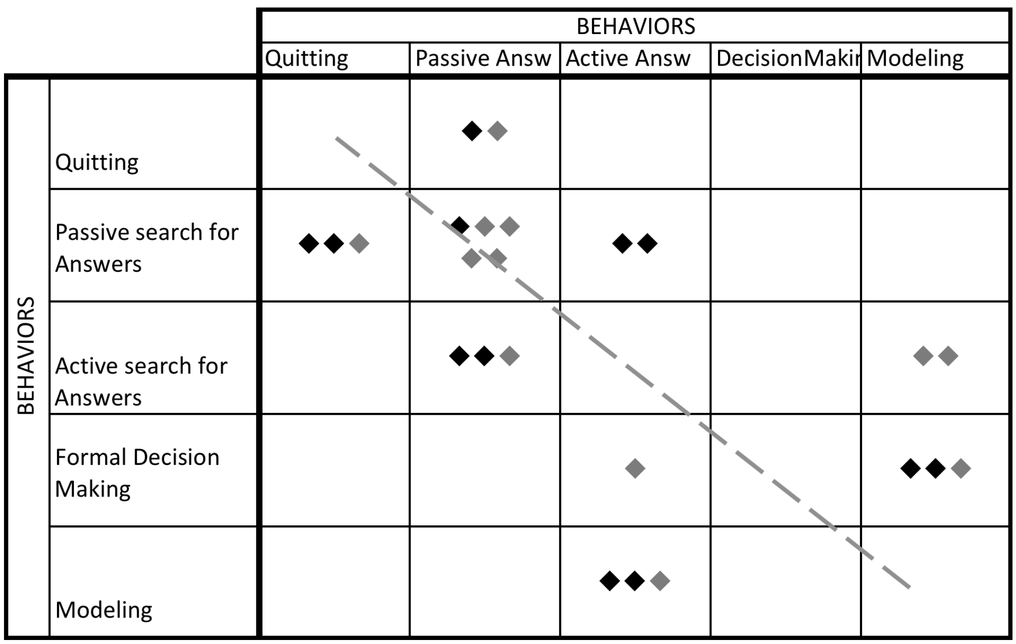

Figure 5.2. Consistent Behaviors

In particular, non-engineers were more prone to search for simpler answers and sometimes quit the challenge. When they interacted with others, the majority of time was spent searching for expert answers. However, one non-engineer explained a task of verifying data received in the cellphone and did perform a more complex analysis in response to the challenge.

5.5.1.3 <u>Extreme Conceptions for Extreme Backgrounds</u>

Cross table (Figure 5.3) shows individuals' conceptions of technology. A hierarchical structure emerged from narrower to broader conceptions about technology. In general, individuals tended to have a bi-modal conception of technology, with either the simplest (computers, cellphones, and tablets) or broadest (technology as a process) conceptions. Although they may include other themes in their explanations, they predominantly frame their technological challenge and technology definition within one of these two extreme themes.

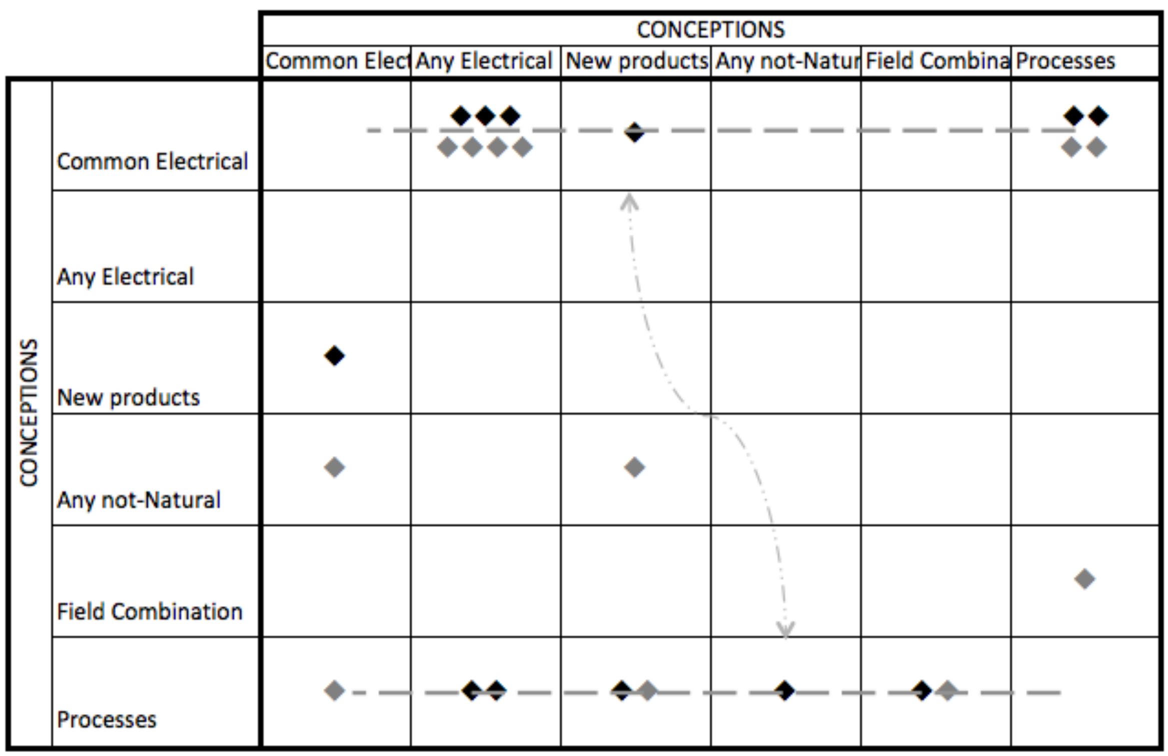

Figure 5.3. Extreme Conceptions

In particular, non-engineers were more prone to identify their challenges as experiences related to a computer or cellphone. In fact, 9 out of 18 experiences were related to computers and software, 4 were about data or digital information management, 2 were related to cellphones, 2 related to other artifacts, and one explained a troubleshooting process.

In contrast, engineers were more likely to identify the technological challenge as part of a process. In fact, 7 out of 18 experiences were related to a design process, 6 about a process of decision making with other colleagues, 3 identified challenges related to computers, one recounted processes related to computers such as adapting and creating programming code, and one explained a troubleshooting process.

5.5.2 Relations between Dimensions for Experiencing Technological Challenges

Additional three cross-tables were created for two-dimension analysis. Connected to the views of the thematic structure, these tables show the interaction between two dimensions, with a more detailed representation of how participants perceived the challenge.

5.5.2.1 Emotional Users versus Neutral Creators

The first two-dimension analysis performed was attitudes interacting with behaviors (Figure 5.4). Participants tended to involve strong feelings and positive and negative connotations in their descriptions when they were in the process of searching for answers. In contrast, participants with neutral attitudes towards technological challenges had a more diverse range of action, from the search of simple answers to modeling problems for a solution.

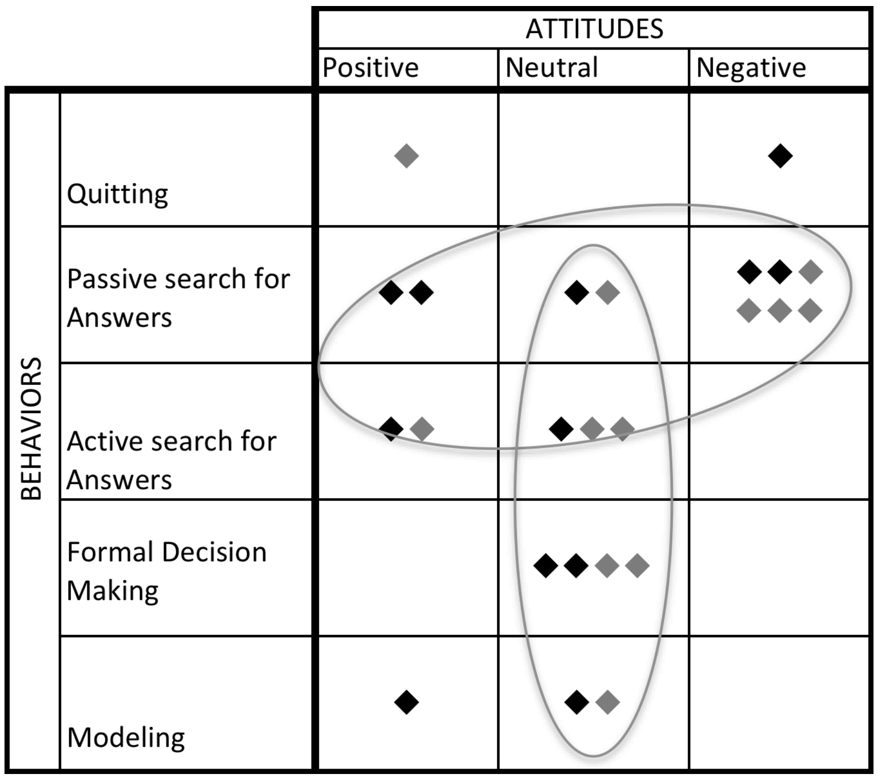

Figure 5.4. Attitudes Interacting with Behaviors

5.5.2.2 <u>Digital Challenges Emotionally Approached versus Challenging Processes Factually Approached</u>

The second two-dimension analysis performed was attitudes interacting with conceptions (Figure 5.5). Those participants defining technology as common electrical artifacts (i.e., computers, cellphones, or tablets) included a variety of attitudes in their descriptions, while those who understood technology as a process tended to present the experience in a neutral way (excluding feelings and positive/negative connotations) and instead used mostly facts in their explanations. This analysis may show a potential path towards complex conceptions of technology where the more positive the attitude, the more complex the conception.

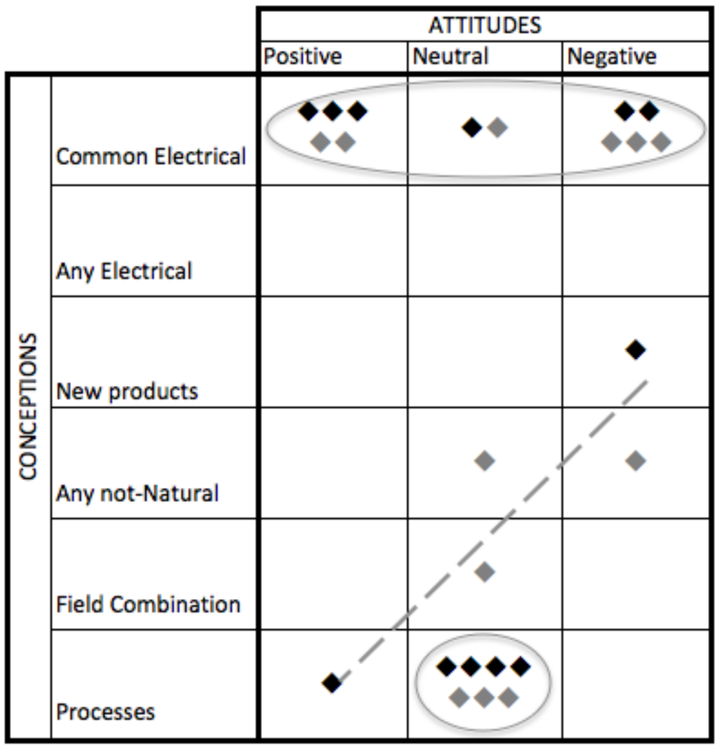

Figure 5.5. Attitudes Interacting with Conceptions

5.5.2.3 Narrow Conceptions and Passive Roles versus Broad Conceptions and Active Roles

The third and final two-dimensional analysis performed was behaviors interacting with conceptions (Figure 5.6). Those participants defining technology as computers, cellphones, or tablets were more likely to perform simpler actions to overcome the technological challenge, while those conceiving technology as a process tended to perform more complex actions such as making decisions or modeling problems to find its solution.

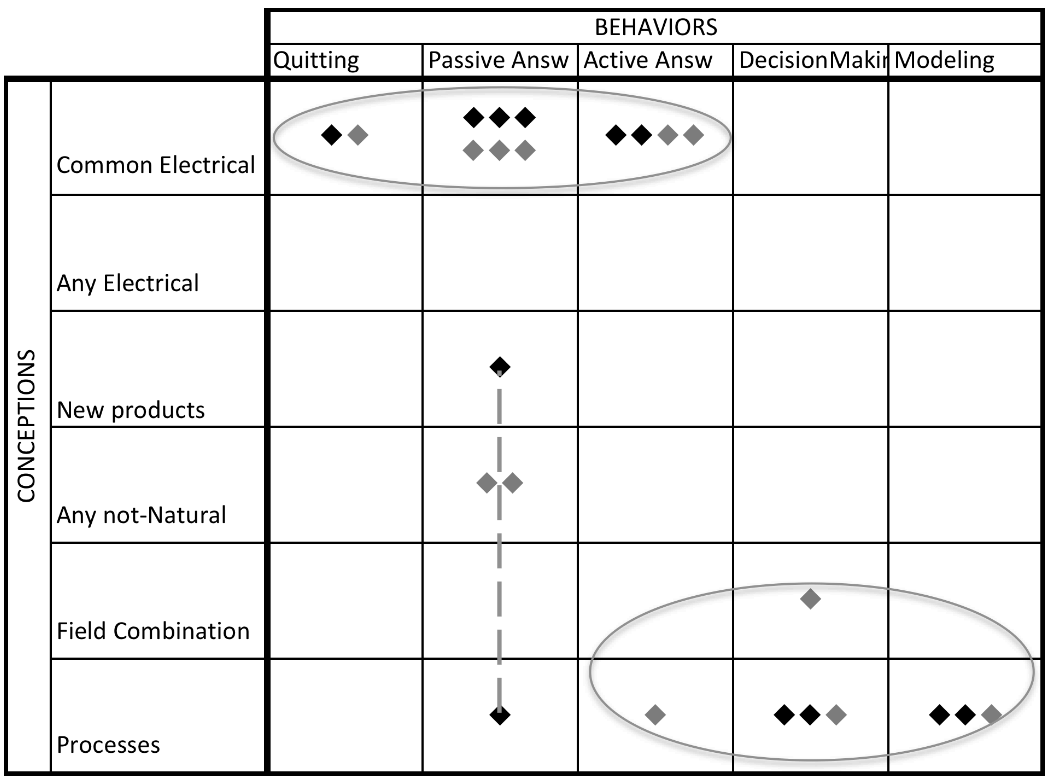

Figure 5.6. Behaviors interacting with Conceptions

5.5.3 Overview of Themes

The creation of five final categorized themes, across the three dimensions, had five iterations in which codes relevant to research questions were selected, analyzed and consolidated into ways of experiencing the challenge according to unique features and critical differences between those themes. Categorized themes emerged from the cross-table analyses, allowing the identification of larger patterns of relationships across dimensions. Because the categorized themes were based on three dimensions that emerged from the data, a resulting tridimensional structure of the categorized themes was derived from the analysis.

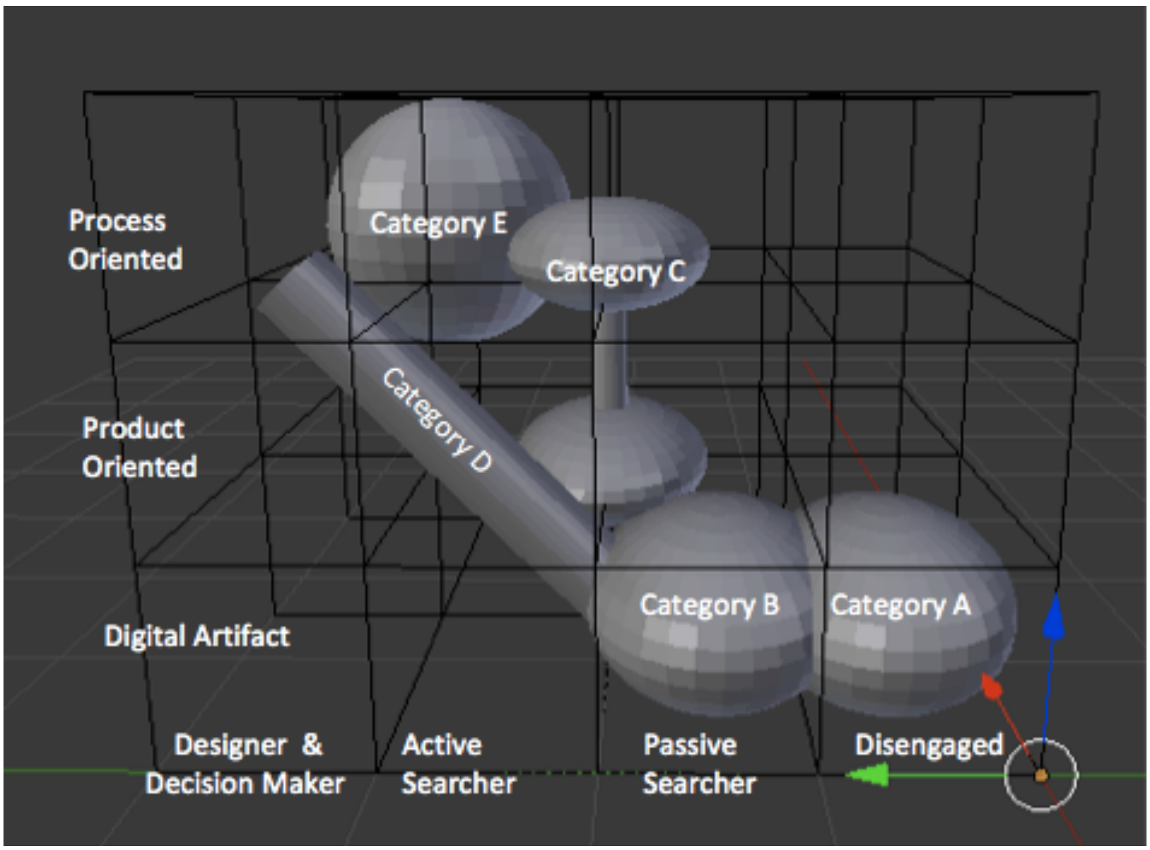

Figure 5.7 Theme structure (Behavior - Conceptions View)

Figure 5.7 to Figure 5.9 show the resulting categorized themes, where the red arrow represents attitudes, the green arrow represents behaviors, and the blue arrow represents conceptions. Although the code schema shows a hierarchical progression among conceptions, the ways in which participants perceived a technological approach was by defining technology either as a digital artifact or as a process. Actions taken by participants were diverse and varied, from disengaging from the challenge to claiming agency to solve the challenge. Those who disengaged from the challenge, after some attempts, ended up quitting. Those participants who engaged in the challenge demonstrated a variety of roles —from passive to active ones— in a continuum for building ownership of the challenge. Within this continuum, changes in attitudes were also observable, from emotional approaches to neutral ones.

Figure 5.7 shows the structure and relation between categorized themes across behaviors (horizontal axis) and conceptions (vertical axis). This shows an expanding awareness of conceptions about technology when participants become more active, building ownership towards the challenge. Categories A (Disengagement) and B (Scaffolding) have similar conceptions about technology, insofar as computers, cellphones and similar digital devices are considered technology. Conversely, category E (Ownership) has the broadest conception of technology, for which a technological challenge was identified primarily as a process to solve a design problem, and participants were considered experts. This group also considered products as part of technology, but their main focus was the process itself. In a path from Scaffolding to Ownership, two categories emerged with two different experienced transitions: category C (Transitioning) presents a more unsteady shift, where conceptions are either narrow (i.e., digital artifacts) or broad (i.e., process), participants’ roles vary between passive and active search for answers, and their attitudes towards the challenge are balanced. In contrast, category D (Emotional ownership) presents a more stable shift, where participants’ conceptions varied from narrower (i.e., digital, electrical, and new artifacts) to broader understandings (i.e., any product, field of knowledge, and processes), but had a consistent emotional approach and an active role towards the technological challenge.

Figure 5.8 shows the structure and relation between categorized themes across attitudes (horizontal axis) and conceptions (vertical axis). This shows an expanding awareness of conceptions about technology when participants are less emotional towards the challenge. Categories A, B and D present an emotional approach to technological challenges; however, category D has changing conceptions about technology, with product as the focus on technology but includes processes in the identification of technological challenges. In contrast, category E, where participants were considered experts in how to face the challenge, a neutral approach was experienced. This may suggest increased comfort when approaching ill-structured problems, managing failure, or approaching a problem as an iterative process where solutions may not come in a linear manner. Category C shows another transition between emotional and neutral approaches towards the challenge.

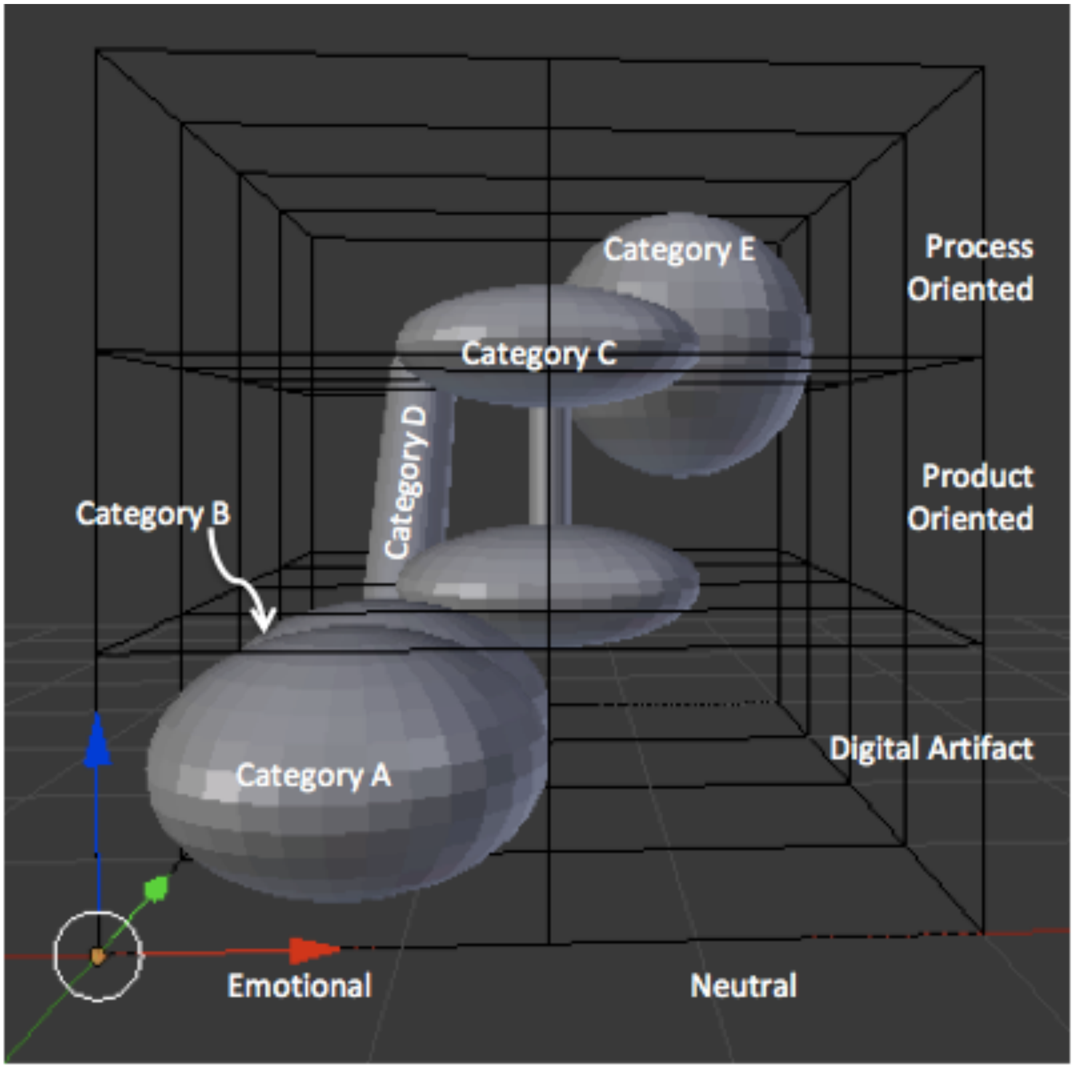

Figure 5.8. Theme Structure (Attitudes - Conceptions View)

Figure 5.9 shows the structure and relation between categorized themes across attitudes (horizontal axis) and behaviors (vertical axis). This shows a progression towards an ownership of the challenge in two different directions: an emotional path and a neutral one. By connecting this variation with the development of conceptions about technology it becomes clear that although the emotional path gains ownership towards the challenge, participants' explicit definitions of technology are primarily focused on products. These participants' conceptions may include a process perspective when identifying the technological challenge, but they had a product approach to technology definition when asked to brainstorm.

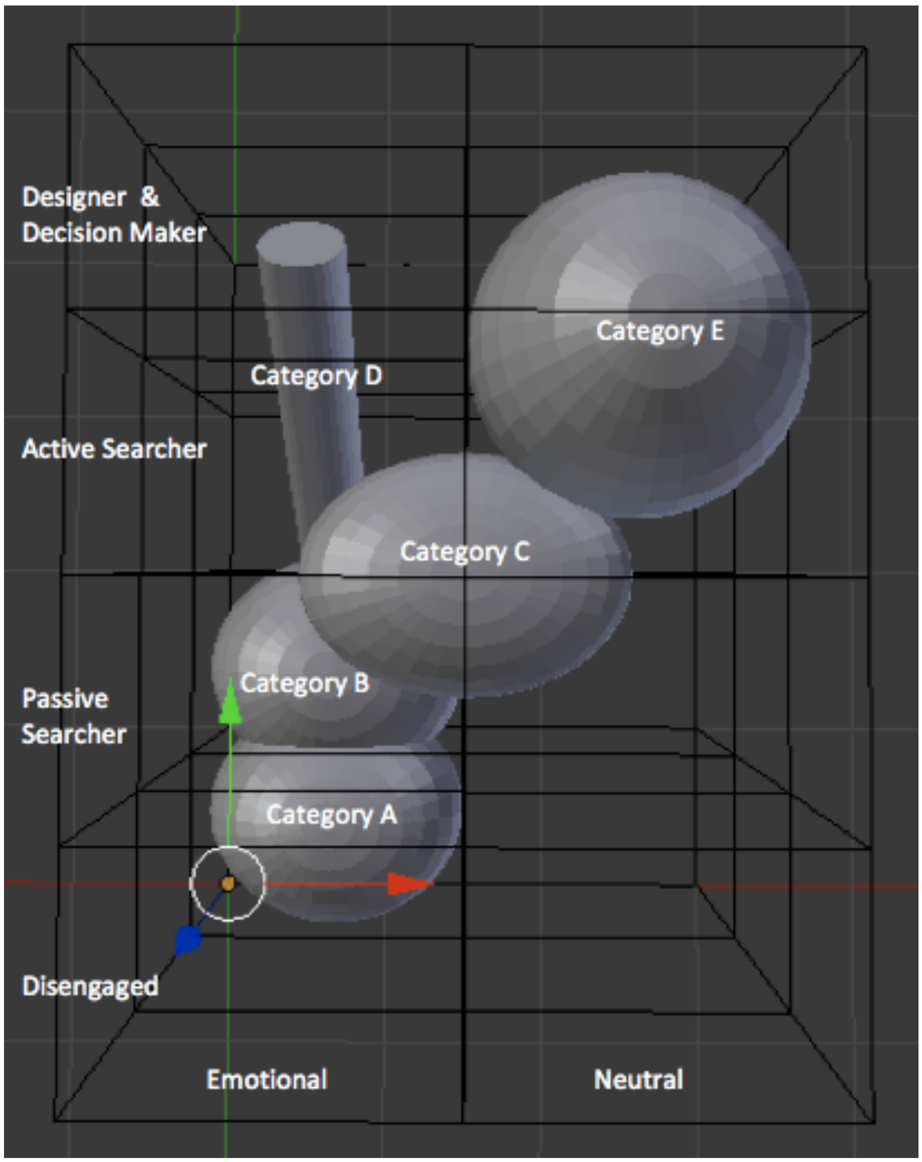

Figure 5.9. Theme structure (Attitudes - Behavior View)

This analysis may show a potential path towards more complex conceptions of technology; this cross table shows a relation between the search for simple answers and a wide range of conceptions. Further analysis should be performed to examine if more complex actions within the same category (i.e., searching for simple answers) are linked with more complex conceptions. Conceptions may evolve when substituting actions from a step-by-step answer given by a third party to trial and error performed by the individual.

CHAPTER 6. DISCUSSION

For both strands, a discussion of transferability is included, the implications for theory and practice, and the limitations of the study. This chapter concludes with future work and a summary of the research discussion.

6.1 Considerations for transferability

Outlier Cluster Analysis for Sampling Selection. The outlier method proposed in this dissertation, also published in the American Society for Engineering Education (Tafur & Purzer, 2015), performs a maximum variability analysis for purposeful sampling with bias reduction due to subjectivity of recruiters. This method can be performed to select any sample for maximum variability (although it excludes middle points) or to select contrasting cases. This process is applicable when two or more variables define the criteria for selection, which for contrasting purposes are the variables used to divide groups. A benefit of the sampling method performed here is that groups can be formed based on continuous variables instead of categorical ones, thereby featuring flexible threshold levels for identifying the purposeful sample.

The way these thresholds are defined also promotes a flexible design of the sample. For instance, in this document *dmin* was defined as a circle for ranked scores, but as an ellipse for raw scores accounting for variability. Other threshold shapes may assure the rejections of middle data points in a desired variable (e.g., rectangular shapes), selection of middle values within two or more groups (e.g., diamond shapes), or selection of outliers within a group (e.g., using more than one cluster). Other criteria may increase this method flexibility: the definition of outlier, for instance. In this research, a cluster analysis based on distance was performed; however, other strategies are commonly used, such as density-based or distribution-based (Cherednichenko, 2005). This flexibility is useful for obtaining a desired, purposeful sampling.

Reducing Bias in Purposeful Sampling. This type of analysis is transferable to any qualitative design that uses the same criteria of selection and maximum variation sampling. Likewise, it is applicable for contrasting cases and is a common strategy to select which communities or groups to research (Hardon, Hodgkin, & Fresle, 2004; Teddlie & Yu, 2007). This mixed approach to research allows a positivist approach to sampling but a naturalistic approach to research, therefore reducing bias in the sample and research findings.

Thematic Analysis. This type of analysis is context specific, which means that the outcome may vary when using other samples or phenomena, such as another other type of challenges or other type of interactions with technology. However, a qualitative approach to STEM problems supplies in-depth indicators of individuals’ perspectives from a predominantly non-positivist approach. One benefit of performing thematic analysis is that it may be used as a foundation of a variety of qualitative methods, including grounded theory and content analysis. For instance, some qualitative researchers suggest an iterative process where interpretation is developed from the relation between the meaning and context and then aligned to an inductive approach (Braun & Clarke, 2006; Patton, 1990). Further, similar steps are suggested for both qualitative designs; starting from familiarization, researchers proceed to extract instances relevant to research questions, which leads to a condensation of themes (for thematic analysis). The process is iterative and concludes with naming the themes found. Compared to other qualitative methods, thematic analysis may seek both, a rich description of data set or one particular aspect of the data (Braun & Clarke, 2006).

6.2 Implications for Theory

The definition of technology has been used in a wide variety of contexts and with diverse meanings. For instance, often this word is limited to digital products such as computers (e.g., Hohlfeld et al., 2010) and information and communication technologies (e.g., Dangani & Mohammed, 2009). However, the National Research Council (National Research Council, 2002) suggests a broader meaning and suggests technology as products and processes used and created by humans. Even though some research includes broader definitions of technology as their theoretical framework, narrower conceptions of technology were implicit in its design where data collections was focused on computer and digital artifacts (L. C. Rose & Dugger Jr, 2002). This study shows different ways adults conceptualize technology, as aligned with this variety of definitions found in previous research. However, data analysis showed that broader conceptions of technology are connected with more active and emotionally neutral approaches to technological challenges.

These discrepancies between technology definitions are also shown within the 21st century skills framework, which includes several perspectives and approaches to technological literacy. According to Voogt and Pareja Roblin (2010), one common focus is referring to technology as digital media and tools (e.g., ISTE and enGauge), as simply tools (e.g., OECD), or as information technologies (e.g., ACTS and P21). These approaches have different levels of conceptions (i.e., narrower or broader), yet the vast majority of technology definitions focus on products. Little acknowledgement has given to technology as a process; however, some characteristics of technology literacy (as defined by NRC) are identified within skills of learning and thinking (Dede, 2010; Voogt & Pareja Roblin, 2010). This research showed that in order to approach technological challenges, more than a tool-focus is needed.

These findings are aligned with the National Research Council framework (2002), in which three aspects comprise technological literacy: knowledge, capabilities, and ways of thinking and acting. This last aspect is directly connected with behaviors (i.e., ways of acting) and attitudes (i.e., ways of thinking), which are two of the three dimensions that constitute the outcome of the research conducted in this study. Although a fellow publication (National Academy of Engineering & National Research Council, 2006) revised this dimension, changing the name from *ways of thinking and acting* to *decision-making and critical thinking*, similarity in the definitions remains. This research shows that ways of thinking are not always focused on critical thinking; it also includes feelings and connotations beyond rational reflections of benefits and pertinent questions. Ways of acting also include researching, identifying the problem, controlling and quantifying variables, and designing solutions. Decision-making emerged from the data as one of the engaging approaches towards technological challenges, when participants performed a formal process of interacting with colleagues and deciding among design alternatives; this theme should not be confused with those informal, short-term decisions that participants made when approaching the challenge aligned with Baron's naturalistic definition of decision-making (Baron & Ritov, 2004).

Not all participants approached the technological challenge using a structured process of decision-making (Cohen et al., 1995), but all participants reflected upon the challenge, explained why they decided to quit, searched for help, or engaged with it, using a naturalistic definition of decision-making (Baron, 2005). For some participants, the challenge differed from the decision itself; rather, the challenge was defined as fixing a problem, designing a device, or optimizing a task. During the interview, all participants' descriptions carried implicit individual values that supported small decisions about which experience to choose as technological challenge, why it was challenging, and why it was technological. Likewise, all participants' referenced moments when intuition and emotion played a role in deciding how to approach the challenge. As Baron (2005) suggested, this naturalistic analysis of trade-offs may lead to evolving values and beliefs about technology itself.

In addition, motivational patterns such as those found in this study (i.e., strong feelings and neutrally emotional approaches) affect the decisions that guide people's actions and biases, as suggested by Mann and colleagues (1989). For instance, the emotional approach and connotation that each individual assumed for the words *technological challenge* led to more positive experiences (e.g., assessing the challenge as an opportunity to learn) or more negative experiences (e.g., defining the challenge as a barrier that needs to be overcome). In fact, attitudes and behaviors played an important role in how people perceive technology. Among participants, the more neutral the approach, the broader the conceptions about technology. This finding is partially aligned with previous findings in literature due to the research approach specifically on emotional users (e.g., Beaudry & Pinsonneault, 2010; Mick & Glen, 1998; Stern & Kipnis, 1993). A gap in the research was found about neutrality in approaching technological challenges. Likewise, the more active the role of the participant, the broader the conception about technology. This may be caused by participants' technological comfort zones. This finding can be supported with literature, since the vast majority of research performed on producers of technology focuses on engineering (e.g., Iorio, Josh, Taylor, & Korpela, 2011), which in this study was found to be demographic of people with broader conceptions.

Those participants who had a less emotional approach tended to be active in the challenge and were open to failure and some were willing to spend more time or attempts to solve the challenge. In general, participants who were more active tended to be more confident about reaching a solution; therefore they had less mood shifts during the challenge. This shows how attitudes and behaviors may be related to broader understandings about technology, therefore to higher levels of technological literacy.

Interestingly, a wider repertoire of actions in those participants with broader conceptions of technology and neutral approaches to the challenge was observed. Within the same challenge, participants were able to adopt diverse roles, from passive to active ones, which suggests critical thinking (Koehler & Harvey, 2008; Shavelson et al., 2005) towards technological challenges.

Although lifelong learning was used as a criterion for participant selection and high importance was given to it in the 21st century framework (Dede, 2010; Voogt & Pareja Roblin, 2010), no apparent differences emerged from data analysis. High and low lifelong learners were encountered cross all themes and categorized themes. One reason for this may be the context in which participants were recruited. A technology-based company and a large public university were used for recruitment. As expected, the academic setting had high levels of lifelong learning among all backgrounds; likewise, the industry presented high levels of lifelong learning. In fact, comparing the means between the sample used by Livneh (1988) and the one used for this study, participants of this study scored 0.15 points higher with similar confidence intervals. This means that those subjects who were selected as low lifelong learners for this study may have scored higher than the average score form Livneh sample, which was comprised by professionals in human service fields (social work, counseling, and education). This may suggest that the sample was, to some extent, homogenous with regards to lifelong learning. Groups of low lifelong learning may still have high scores compared to other populations.

6.3 Implications for Practice

The use of quantitative analysis for purposeful sampling in qualitative designs is a common mixed methods approach (Tashakkori & Teddlie, 2003). Mixed methods are increasingly being used in research because of the benefit of having multiple perspectives (D. Johnson, 2009), triangulation (Morse, 2003), and the opportunity to address multiple challenges in the design, such as having a rich and representative sample (Teddlie & Yu, 2007).

The sampling technique showed in this study and first published by the American Society of Engineering Education (Tafur & Purzer, 2015) presents a design flexible for applying it to other contexts and with other qualitative research questions, aiming to reach levels of representativeness of the results. Likewise, this mixed sampling technique addresses some of the challenges presented for mixed method designs

(Collins, Onwuegbuzie, & Jiao, 2007). First, outlier identification used as purposeful sampling technique takes into account the challenge of representativeness. As Collins states, the small size of samples used in social sciences lead to non-significant results, while non-random sampling prevents for generalizing findings when using purposeful sampling. This research study presented a technique for recruiting from larger populations in the interest of rich cases selected for desired criteria but with a statistical approach. Second, this statistical sampling strategy addresses the validity of results related to measurements. A validated scale was used to score lifelong learning, and observable variables were used to score STEM background. In addition, a validated statistical analysis (i.e., Cluster Analysis) was performed and two analyses were used to triangulate outlier identification.

The third challenge mentioned by Collins (2007) is the integration of quantitative and qualitative strands in mixed approaches. This study addressed the challenge by comparing outliers (i.e., qualitative-strand participants) with the four groups formed using lifelong learning and STEM backgrounds (i.e., quantitative-strand participants) in order to assure representativeness of outliers among their groups.

Statistical analysis for purposeful sampling addresses these challenges, selecting individuals with specific characteristics in a rigorous way. The process can be applied to a variety of fields and types of research questions, and it is especially useful in those fields that are increasingly using qualitative approaches within a context and tradition of qualitative designs, which is the case for Engineering Education. This sampling design may provide greater benefits within those fields where qualitative and quantitative approaches are commonly used and appreciated, due to researchers' familiarity and strengths.

Regarding the experiences of technological challenges, attitudes should be included as part of technological literacy and as part of being confortable within technological environments. Understanding how people perceive technology and their related actions may lead to a better understanding of different levels of technological literacy. A more nuanced representation of how people approach technological challe nges may present a path for increasing technological literacy, thereby promoting better scaffolding for learning technology, based on the following findings.

This study uncovers some potential paths that emerged from the thematic analysis. Regarding behaviors, an initial passive role when searching for answers to a technological challenge may provide a connection for closing the gap between narrower and broader conceptions about technology. This may be explained based on the relation between levels of technical skills and self-efficacy when interacting with technology. In fact in a study about everyday technology (Stern & Kipnis, 1993) author suggests "routinized technologies may elevate inexperienced users' beliefs about their competence" (p.1900), which provide a bridge to being confortable towards future technological challenges.

Likewise, an emotional but positive attitude towards a technological challenge presented a relation with broader conceptions of technology when the focus of those conceptions oscillated between product and process orientation. This suggests that positive attitude towards technology may be related to broader conceptions. These positive attitudes were also linked with levels of success when approaching the challenge, which suggests that setting an appropriate level of difficulty in an educational environment may have an important relation with broader conception of technology. This finding is aligned with research in technology and emotions (e.g.Beaudry & Pinsonneault, 2010; Mick & Glen, 1998).

The characterization of how people experience technological challenges not only benefits educational settings in their promoting technological literacy, it also may provide guidance for approaching users and employees within technology industry settings. This study provides an analysis of how conceptions, behaviors, and attitudes towards technology may impact the experience of adults interacting with technology. Similarly, those potential development paths may inform strategies for closing the gap between new users or employees when interacting with the technology offered by industry. For instance, promoting passive roles as a starting point of interaction may provide positive experiences, boost user confidence, and lead to openness in interacting with and understanding the technology involved in an experience.

6.4 Limitations

Because of the qualitative nature of this study, a small portion of the target population was analyzed. This may lead to a purposeful bias towards the cases studied, for instance towards higher levels of lifelong learning due to the characteristics of the cities and settings where data was gathered. The usage of a statistical analysis for selecting the qualitative-strand sample mitigated this bias.

Another limitation of the study was the nonresponse due to the characteristic of repeated measurements that require high commitment from participants. The sample was oversized in order to mitigate this limitation and optimized distances were taken into account for outlier identification after dropouts. Three outliers dropped out; therefore the sample was less extreme than desired.

The targeted population for STEM background was engineers, while the targeted population for non-STEM background was those from the Humanities. The majority of non-STEM participants were humanists, having less data from artists than desired for a balanced non-STEM sample aligned with the target population.

Although participants in this study were selected from a small region in the Midwestern U.S., the design may be replicated in other contexts to understand unique experiences of people interacting with technology. There was an unbalanced selection between genders; for the quantitative strand, 83% of non-engineers were female but

36% of engineers were female. Similarly, for the qualitative strand, 100% of non-engineers were female and 25% of engineers were female. There was an additional imbalance between communities: for the quantitative strand, 90% of non-engineers were recruited in academia and 59% of engineers were recruited in industry. Along these lines, for the qualitative strand, 100% of non-engineers were recruited in academia and 100% of engineers were recruited in industry. This imbalanced occurred despite targeting engineers and non-engineers in both settings.

6.5 Future Work

With regards to the quantitative strand, this study explored outlier identification for purposeful sampling in a similar way as presented by Tafur and Purzer (2015). For future work, this strategy of sampling can be tested with different samples sizes to confirm its stability and how the number of variables, data points, or clouds affects the outcome. Similarly, diverse methods for testing outlier representativeness (central tendencies of groups compared to outliers' profiles) may show more detail or accuracy in analysis. In addition, this strategy can also be applied to different shapes of thresholds for increasing or decreasing the probability that middle scores are selected and used alongside other techniques (e.g., typical cases, intensity samples, or homogeneous samples) for purposeful sampling (Teddlie & Yu, 2007).

For the qualitative strand, this study performed an analysis of how adults approached technological challenges; however, it is worth studying how their experiences within each categorized theme invite a deeper understanding of the phenomenon. For instance, future work should analyze why some subjects end up quitting while others continue, albeit emotional. A qualitative study about how adults perceive technology when acting passively towards it is an example of some future work to understand the path for becoming technologically literate.

Similarly, it is worth studying how adults experience a more active role when approaching technological challenges; this role was a broad theme that included designers with a systematic approach to technological challenges, thus it is considered part of an engineering skill set.

New hypotheses rose from this study; for instance, it is worth considering if potential paths are present in other settings or other populations. Similarly fruitful might be testing if conceptions about technology are related to levels of STEM background. This study showed how extreme backgrounds led to extreme conceptions; future work may show if intermediate backgrounds (those with some levels of STEM in non-STEM applications, or those within STEM but not in engineering) lead to intermediate conceptions of technology.

Finally, further research should be performed with different communities (i.e., academic institutions, companies, industries, public organizations), in different settings:

with varied geographical locations within and outside the U.S., with gender distribution (i.e., controlling for equal groups), ethnicity and race distributions, and other age ranges.

CHAPTER 7. CONCLUSIONS

A continuum between disengagement and engagement in tech challenges emerged from the data. Levels of engagement were linked to levels of breadth of technological understanding. Participants with broader conceptions of technology were more active users of technology and were emotionally neutral towards the challenge. Conversely, those who had narrower conceptions of technology were passive users of technology and had strong positive and negative emotions towards the challenge.

Five ways of approaching technological challenges were found: *disengagement*, when participants faced a technological challenge and, after some attempts, quit the challenge; *scaffolding*, when individuals asked for help in overcoming the technological challenge; *transitioning*, when participants interchanged between active and passive roles, neutral and emotional approaches, and acknowledged a tension between technology as a digital product or process; *emotional engagement*, when individuals were active and emotional towards the challenge (in this category, diverse understandings of technology were reported); and *ownership*, when participants with broad conceptions of technology had a neutral, active approach towards the challenge.

Within attitudes, a balancing act of emotions occurred. Emotional approaches present strong negative and positive feelings and connotations when individuals faced a technological challenge. Conversely, neutral approaches show very little emotion to the challenge and suggest that individuals are more comfortable with failure, ill-structured problems, and possess a confidence in their capacity to overcome the challenge.

Within behaviors, participants played a consistent role. Some participants experienced disengaging situations, which led to quitting the challenge. For those who did not quit, two approaches were observed: active and passive roles. During the same experiences, a variety of actions were observed such as searching for answers, making formal decisions, or designing a solution. Although the type of actions was not *the same* within the same challenge, they were *similar* for each individual.

Within conceptions, extreme perceptions were found. First, a narrow conception of technology focused on digital product such as computers, cellphones, and applications for those products. Second, a broad conception of technology focused on processes used for optimizing and designing products.

Findings suggest that a broader conception of technology should be promoted. This may be achieved by further studying potential development paths. For instance, a passive search for answers to technological challenges may provide space for broadening technology concepts for those with non-STEM background. Likewise, promoting positive experiences in people with intermediate conceptions of technology may provide an opportunity to broaden their perceptions. In addition, a neutral approach to technological challenge suggests a capacity for strategic thinking when selecting an approach; participants with neutral approaches described a wide variety of actions used to address the same experience.

This study also shows that reducing bias in purposeful sampling can be achieved without sacrificing richness in the selected sample. The use of rigorous statistical approaches for outlier identification allows for selecting critical cases based on quantitative measurements.

The design of a rigorous, yet flexible technique for purposeful selection provides a tool for future qualitative research. The technique used in this research includes adjustable thresholds for reaching sample sizes. Changes in minimum distance of the threshold allows for a more inclusive selection and different shapes of the threshold avoids middle or extreme data points in one or more variables.

The inclusion of diverse career and professional backgrounds resulted in a wide range of perceptions about technology, a more comprehensive outcome of how adults approach technological challenges, and non-STEM perceptions of technology.

This study provides an inclusive understanding for future research and practice of new strategies for improving technology education for all citizens, aligned with a 21st century skills framework.

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APPENDICES

Appendix A. Survey Consent Form

RESEARCH PARTICIPANT CONSENT FORM

Study on Adult Interaction with Technology

Mariana Tafur and Senay Purzer
Purdue University
School of Engineering

Purpose of Research

You are invited to participate in a research study about how adults from diverse backgrounds approach technological challenges in their every-day life.

Specific Procedures to be used

If you participate in this study, you will be asked to answer one survey. After completing the survey you may be asked to participate in up to three interview sessions.

Duration of Participation

The duration of data collection for this study is expected to last approximately 6 months starting on April of 2014. If you agree to participate in the research you will be asked to fill a survey that is expected to take about 20 minutes.

Risks to the Individual

The risks are minimal, no greater than everyday life. There is a potential risk of breach of confidentiality, which will be minimized by erasing your identifiable information (such as name or last name) from the data and handling the information as stated in the Confidentiality section.

Benefits to the Individual or Others

No direct benefits are implied or offered. Researchers may benefit from this study – they may develop an understanding of how STEM and non-STEM trained adults experience interactions with technology challenges. These understandings may ultimately affect the design of courses and professional development for closing the technology literacy gap.

Compensation

After you complete and submit the survey, you will be eligible to participate in a drawing to win one of twenty $10 pre-paid cards. The probability of wining one of those pre-paid cards will be 1:10.

Extra Costs to Participate

In order to participate in this study you will need a computer to fill the survey if geographic location or preferences prevent for filling the survey in person. Researchers will try to set survey appointments near your location if you plan to fill the paper version of the survey.

Confidentiality
Your participation in the survey is confidential and we will take all precautions to maintain your confidentiality. Your name will not be identified in the study; however a code key will be assigned to connect your survey data with interview data if you are eligible and willing to be interviewed. The surveys will be stored in a locked cabinet in the investigators' office and will not be shared with anyone other than the investigators of the study. If the survey is conducted in your work place, your supervisor or director will NOT be present, and they will NOT have access to the information collected. When the study is complete all identifiable information, including the code key will be destroyed completely. The project's research records may be reviewed by departments at Purdue University responsible for regulatory and research oversight.
In order to be able to receive your compensation you may need to provide your name, social security number and address to the business office of Purdue for the sole purpose of payment.

Voluntary Nature of Participation
Your participation in this study is voluntary. You may decline to participate, or if you choose to participate in this study, you are free to withdraw at any time without any penalty and your participation will not have any impact on your job standing if your were recruited through your company.

Contact Information
If you have any questions about this research project, you can contact Professor Senay Purzer at [phone and email] (Principal Investigator) or researcher Mariana Tafur at [phone and email] (first point of contact).

If you have concerns about the treatment we give you, you can contact the Institutional Review Board (IRB) at Purdue University, [address, phone and email].

I HAVE HAD THE OPPORTUNITY TO READ THIS CONSENT FORM, ASK QUESTIONS ABOUT THE RESEARCH PROJECT AND AM PREPARED TO PARTICIPATE IN THIS PROJECT.

Please check the box bellow as your signature
☐ By checking this box I am agreeing to participate in this study.

____
Participant's Name

Appendix B. Interview Consent Form

RESEARCH PARTICIPANT CONSENT FORM
Study on Adult Interaction with Technology
Mariana Tafur and Senay Purzer
Purdue University
School of Engineering

Purpose of Research
You are invited to participate in a research study about how adults from diverse backgrounds approach technological challenges in their every-day life.

Specific Procedures to be used
If you participate in this study, you will be asked to attend a maximum of three interview sessions. The interviews will be audio-recorded.

Duration of Participation
The duration of data collection for this study is expected to last approximately 6 months starting on April of 2014. The first and second interviews are expected to last about one hour each, and if more information is needed to be clarified, we will ask you to attend one shorter third interview just with the purpose of clarifying your previous responses.

Risks to the Individual
The risks are minimal, no greater than everyday life. There is a potential risk of breach of confidentiality, which will be minimized by erasing your identifiable information (such as name or last name) from the data and handling the information as stated in the Confidentiality section.

Benefits to the Individual or Others
If you attend any interview you will be invited to a session for socializing the results and new understanding based on the study, but no other direct benefits are implied or offered. Researchers may benefit from this study – they may develop an understanding of how STEM and non-STEM trained adults experience interactions with technology challenges. These understandings may ultimately affect the design of courses and professional development for closing the technology literacy gap.

Compensation
After completing each interview you will receive $5 and you will be invited to a workshop session were the research results will be socialized.

Extra Costs to Participate

In order to participate in this study you may need a computer to be interviewed in case geographic location or preferences prevent for interviewing in person. Researchers will try to set interviews near your location; however, you may incur in minor transportation costs to attend interviews.

Confidentiality

Your participation in the interviews is confidential and we will take all precautions to maintain your confidentiality. Your name will not be identified in the study; however a code key will be assigned to connect your survey and interview data. The audio recordings from the study will be stored in a locked cabinet in the investigators' office and will not be shared with anyone other than the investigators of the study. If the interviews are conducted in your work place, those will take place in a private room with no one except the interviewer and you; note that your supervisor or director will NOT be present, and they will NOT have access to the information collected. When the study is complete all identifiable information, including the code key and the audio recordings will be destroyed completely. The project's research records may be reviewed by departments at Purdue University responsible for regulatory and research oversight.

In order to be able to receive your compensation you may need to provide your name, social security number and address to the business office of Purdue for the sole purpose of payment.

Voluntary Nature of Participation

Your participation in this study is voluntary. You may decline to participate, or if you choose to participate in this study, you are free to withdraw at any time without any penalty and your participation will not have any impact on your job standing if your were recruited through your company.

Contact Information

If you have any questions about this research project, you can contact Professor Senay Purzer at [phone and email] (Principal Investigator) or researcher Mariana Tafur at [phone and email] (first point of contact).

If you have concerns about the treatment we give you, you can contact the Institutional Review Board (IRB) at Purdue University [address, phone and email].

I HAVE HAD THE OPPORTUNITY TO READ THIS CONSENT FORM, ASK QUESTIONS ABOUT THE RESEARCH PROJECT AND AM PREPARED TO PARTICIPATE IN THIS PROJECT.

________________________________	___________________________
Participant's Signature	Date
________________________________	
Participant's Name	
________________________________	___________________________
Researcher's Signature	Date

Appendix C. Survey

I. Characteristics of Lifelong Learners in The Professions

CLLP instrument Used (Livneh, 1986).

II. Career Background

- What is the highest degree you have obtained?
- How many years have you been in undergraduate college?
- How many years have you been in graduate college?
- Do you have any certificate or have you attended any class besides your formal education?
- How many times did you attend classes and received certificates?
- What is your *Bachelor's Degree* related field?
- What is your *Graduate Degree related* field?
- What is the highest degree your *Mother* has obtained?
- What is the highest degree your *Father* has obtained?
- What is your *Profession* related field?
- Approximately, how many years have you worked in a field related to STEM (Science, Technology, Engineering, Mathematics)?
- Approximately, how many years have you worked in a field unrelated to STEM (Science, Technology, Engineering, Mathematics)?
- What is the highest-level technology (product or process) you have used?
- What is the highest-level technology (product or process) you have created or adapted?
- How many working hours per week do you use for the following activities?
- Engineering Related Job, Natural Science or Mathematics Related Job, Social Science or Humanities Related Job, Technology Related Job, Health Related Job, Business and Management Related Job, Education Related Job, Staying-at-home, Studying

- What is your gender?
- What is your age?

The above information will be confidential. If you want to participate in a follow up interview study please provide the following information.

- Name
- Last Name
- Email address
- Phone number
- Address

Thank you very much for taking the time to assist us in this project.

Appendix D. First Interview

Note: *Comments in italics are meant to guide interviewer and are not supposed to read to de participants*

Introduction[1]

You have been selected to speak with me today because you have been identified as someone who can add diversity in understanding how adults interact with technology regardless of career background. My research project as a whole focuses on understanding how adults with lifelong learning skills and STEM and non-STEM background approach technological challenges, how you use, evaluate, adapt, and create technological products and processes, and whether different perspectives and approaches can make a difference in technology education. This study does not aim to evaluate your technological knowledge and skills. Rather, we are trying to learn more about human-technology interaction, and hopefully understand more perspectives on how to approach technological challenges that help improve technology literacy.

Previous to Interview[1]

In order to assure that I will gather all the relevant information from this interview, I will audiotape our conversation today. For your information, only researchers on the project will be privy to the records, which will be eventually destroyed after they are transcribed. Please sign this form for consent. Essentially, this document states that: (1) all information will be held confidential, (2) your participation is voluntary and you may stop at any time if you feel uncomfortable, and (3) we do not intend to inflict any harm. Thank you for your agreeing to participate.

We will have two interviews in order for me to gather information about your relation with technology in the past and in a couple of times during this research. I have planned each interview to last no longer than one hour. During this time, I have several questions that I would like to cover. If time begins to run short, it may be necessary to interrupt you in order to push ahead and complete this line of questioning.
This interview intends to gather information about some experiences related to technology that you had had during your life and may help to understand your background.

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[1]Adapted from http://www.stanford.edu/group/ncpi/unspecified/student_assess_toolkit/sampleInterviewProtocol.html

Technological Past and Present Interactions

This part of the interview will be guided by the opening questions, and can be complemented using background and lifelong learning questions. These are some of the questions for eliciting past interactions; however this list is not a structured guide for the interview.

Past Experience

1. What is your current job situation?
2. Have you use or create technology in your job? How was it?
3. Do you see yourself as someone that interacts with technology?
4. Can you give me an example? [positive/negative]
5. Have you had any training in technology? How was it?
6. Did you have an event in your life where technology was involved? [positive/negative]
7. Which would you identify as a 'turning-point' event in the way you see technology today? Why?
8. What type of decision(s) you had to make during the experience?

Recent Experiences

1. Did you make any difficult decision with which you had to deal today?
2. Was technology involved?
3. Did you have (today or yesterday) an experience with technology that stuck in your mind?
4. Can you describe the experience?
5. Did you used / evaluated / created technology?
6. What type of decision(s) you had to make during the experience?
7. How did you feel when facing the experience? When [trying to] overcoming the challenge?

Describing the Experience…

1. Life and Career (every-day-life)
2. How is this experience related to your life or work?
3. How often do you experience this type of technological challenge?
4. Lifelong Learning
5. How did your previous experiences helped to resolve this situation?
6. What do you take away from this experience to help you in the future?
7. What stand out from your way of dealing with the challenge?
8. What questions did you ask yourself when dealing with the situation? *Resources/iterations/alternatives/improvement/systems/logic/evidence-based/changing/adaptation*
9. How did the challenge help you to deal with technology in a better way?

10. Did you tried to improve the solution? How many times?
11. Did you have to choose between scenarios or resources to use?
12. Does [*participant's studies*] is helpful for overcoming these challenges?
13. What skills you found useful?

Reflection Questions

According to what we talked today,

1. I want you to brainstorm and tell me the words that come to your mind when I say technology
2. How would you describe a technological savvy person? Are you a technological savvy person?

Closing the Interview

Thank you for participating in this interview. During our next and final meeting, you will be asked to describe, similar to what you did today, two interactions with technology. You should select any interaction you may want to talk about and was experienced a day before the final interview.
We will contact you in order to set an appointment for the second interview.

Appendix E. Second Interview

Note: *Comments in italics are meant to guide interviewer and are not supposed to read to de participants*

Previous to Interview[1]

Thank you again for your agreeing to participate.
I have planned this interview to last no longer than one hour. During this time, I have several questions that I would like to cover. If time begins to run short, it may be necessary to interrupt you in order to push ahead and complete this line of questioning.
Do you have a computer to work with?

A Task to Perform

Do you have a computer besides you? You will perform a short activity. I will give you 25 files zipped in a file. You need to organize them in folders so you can easily find some files later. While doing this task, please say out-loud all that comes to your mind. If you stop talking I will gently ask you to keep saying all that comes to your mind. You have 10 minutes to perform this task…
…*After the 5 minutes…* You have 5 minutes to finish the task
…*After the 8 minutes…* You have 2 minutes to finish the task
…*After the 9 minutes…* You have 1 minute to finish the task
…*After the 10 minutes…* Thank you for doing this task. The time for the task has run out; please send me the folder in a zip file by email.

Identifying Recent Experiences

Introduction

In this second part of the interview I will gather information about at least one interaction you had with technology in the past 24 hours, similarly as we did last interview. The shorter the time since your experiences, the more you will remember about this interaction.

1. Did you make any difficult decision with which you had to deal today?
   Was technology involved?
2. Did you have (today or yesterday) an experience with technology that stuck in your mind?

---

[1]Adapted from
http://www.stanford.edu/group/ncpi/unspecified/student_assess_toolkit/sampleInterviewProtocol.html

<u>Describing the Experience</u>

1. Can you describe the experience?
2. What type of decision(s) you had to make during the experience?
3. How did you feel when facing the experience? When [trying to] overcoming the challenge?

<u>Life and Career (every-day-life)</u>

1. How is this experience related to your life or work?
2. How often do you experience this type of technological challenge?
3. Do you think that a non-engineer/engineer in the team will benefit the project?

<u>Lifelong Learning</u>

1. How did your previous experiences helped to resolve this situation?
2. What do you take away from this experience to help you in the future?
3. What stand out from your way of dealing with the challenge?
4. What questions did you ask yourself when dealing with the situation? *Resources/iterations/alternatives/improvement/systems/logic/evidence-based/changing/adaptation*
5. How did the challenge help you to deal with technology in a better way?

<u>Ways of thinking</u>

1. Did you tried to improve the solution? How many times?
2. Did you have to choose between scenarios or resources to use?

A Task to Perform II

1. While you are saying out-loud all that comes to your mind, please find a file that… *Select the one least like interviewee's categories*
   - 1a. Has a skyline of a city in it
   - 1b. Has the sun in it
   - 1c. Has animals in it
   - 1d. Has mountains in it
   - 1e. Has snow in it
2. If you had to do the task again with similar photos / with much more photos, is there something that you would do different?
3. How did you decide how to organize those files?
4. Is this task a technological challenge? Why?

Reflection Questions

1. want you to brainstorm and tell me all the words that come to your mind when I say: Technology
2. How would you describe a technological savvy person? Are you a technological savvy person?

Closing Interview

Thank you for participating in this interview and research. All information you gave us is valuable for understanding how people approach technological challenges and will help to bring more diversity to technology development.

Any suggestion or comment to this process will be welcome. If you need more information about the research study please contact us and we will address your questions.

Appendix F. Coding Protocol

The final coding schema emerged and stabilized after a couple of iterations in which three dimensions and 14 categories were identified.

Table A- 1

Dimension	Category	Meaning	Example
Attitudes	Positive Attitude	Positive feelings and reflections towards technology were grouped. The more common utterances found across experiences and participants were the perception of benefits, acknowledge of technological needs, and positive feelings such as confidence towards the challenge.	*"I really appreciate the opportunity to correct drafts without using whiteout, all of those sorts of things. The big thing is I have doctoral students who are in other parts of the world, or other parts of the United States, and they can email me a chapter of their dissertation"* (P7P)
Attitudes	Negative Attitude	Negative perceptions such as the existence of barriers and waist of time, and negative feelings such as anxiety and frustrations were grouped. Incompetence, anxiety, and frustration were some of the most common feelings expressed during the interviews.	*"Students complained they couldn't get access to the information… still that's sort of the combination between my incompetence and the students not being able to get access… and, I mean, the IT people said «there shouldn't be any problem, this is set up appropriately» you know… so, I just quit using it"*(P4P)

Dimension	Category	Meaning	Example
Attitudes	Neutral Attitude	Participants' attitudes of coping or dealing with technology, where neither strong-positive nor strong-negative feelings or connotation were elicited.	"*I accept that it's part of my life and I cannot do without it, but I am not like super super fan of new technology stuff. But I just know that I'm into like… I don't want to get outdated so I know what people are using, and I kind of know something about this, but I'm not like that exposed to the technology*" (P2P)
Behaviors	Quitting	Actions described by participants as disengaging or quitting the technological challenge.	"*I did not try [to fix a device problem] because I don't want to waste my time in the class like figuring out a problem with technology, so I just move on and said «okay I'm going to show it for another day»*" (P2R1)
Behaviors	Passive Answers	Actions for searching simple answers may include using the Internet for a simple search, looking for step-by-step answers, trying different solutions in a trial-and-error process, or some alternative shortcut.	"*I worked in a business technology lab, and so I got to do a lot of behind the scenes stuff with [windows]… but not like learning it; I was more of a «here it's giving me this error… I'm going to Google the error and see what Google has to say about how to fix it»… I was that kind of person*" (P5P)

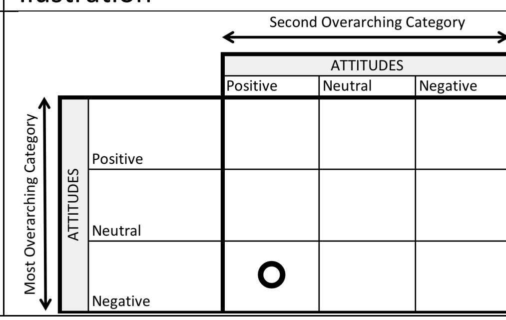
Dimension	Category	Meaning	Example
Behaviors	Active Answers	This category represents more complex behaviors such as testing models or solutions, conducting research, or problem identification as part of a technological design.	*"[a colleague] say «we need steel, we use [a material] because it gives us improved toughness». And I say «OK, but the improved toughness –and I provide her data from published metallurgical handbook that shows actual tests… that have been down and shows the effect of [the material] at room temperature– essentially does not provide any benefit in toughness… it's only at low temperatures*" (P8R1)
Behaviors	Making Decisions	Participants' reflections about why they should chose one application over another, how they used technology artifacts for deciding an everyday action, or how the critically though about a design decision.	*"…I mean «Oh! This is great, this is cool» a lot of this good ideas… but when you actually start trying to make it into a practical, workable device that can be commercially viable… okay, we are being drove by our people to bring in low cost stuff. What can we do for it?"* (P10R2)
Behaviors	Modeling	Participants' reflections related to engineering tasks as part of the technological challenges. Actions such as creating a model of a system, the design process, problem solving, and system analysis were coded within this category.	*"The issue we are having is developing a vibration isolator on an engine, and I am developing the [design part]; and the issue we have is that we don't have real test data to drive the simulation model with this type of a setup. The inputs we have, only two simulations are kind of unknown, and we currently use that to efficiently try to drive a linear model or analysis capabilities with non-linear properties of these vibration damaging components*" (P12R1)

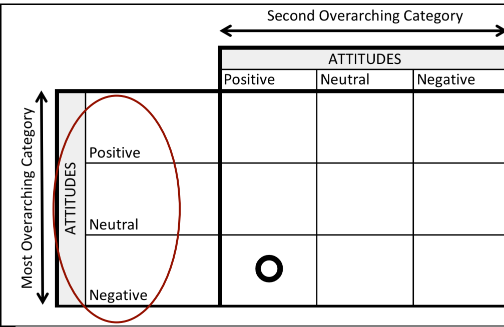
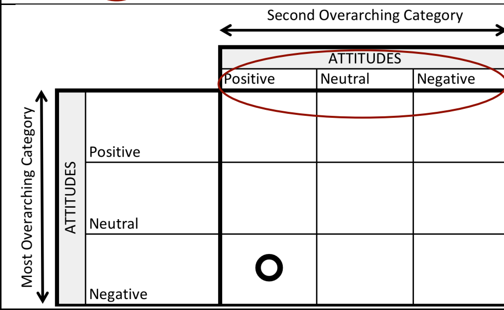
Dimension	Category	Meaning	Example
Conceptions	Common Electrical	Perceptions of technology as common electrical artifacts such as computers, tablets and cellphones.	"*The first word that pops into my mind is computers*" (P6B)
Conceptions	Any Electrical	Besides common artifacts this conception also include other electrical products such as dishwashers or robots.	"*Maybe it is technology… And then they also have this cleaning machine… to separate stuff… Maybe it is technology, but it is not the same technology that we talk about most of the time today like with computer, or with networking, or with Google, or stuff like that… Yes… I think it is technology if I use electricity*" (P2R1).
Conceptions	New Products	Conceptions on how technology is linked to new developments, continuous improvement, and innovative processes	"*…Existing items as books I won't say it is [technology]… well, in the past it may be treated as technology because technology always involve innovation. But books, like back in the XVII century, when the printing or the publication was first invented… it may count as new technology back in that time, but now is just so common*" (P2R2)
Conceptions	Any non-Natural Products	Technology perceived as everything that is made by humans. This perception is product oriented.	"*Stuff. I think of technology, I obviously think of computers and all electronics first. But then on the other hand I also think of things that people make using that kind of stuff. So anything that's not like trees or grass.*" (P5B)
Conceptions	Field Combination	Technology conceived as the product of the union between math, science, or engineering fields.	"*I guess my first love of science was like space travel or whatever, you know. So the ability to travel the different planets and the science behind that*"(P10B).

Dimension	Category	Meaning	Example
Conceptions	Processes	Conceptions that comprise processes such as problem solving, trade-off analyses, and human-centered design. This category also includes technology as a system that can be broke-down into pieces or variables to simplify situations to improve solutions and assure continuous improvement.	*"I was using copper for communication and measurements… And I would have to go through some isolation and filtering and all kind of stuff in order to eliminate noise"*(P11P).

Cross tables were created to analyze the relation between ways of perceiving technological challenges, which was performed after coding two interviews with twelve participants describing more than 40 experiences.

Table A- 2

Term	Meaning	Ilustration
Cross Table	Tool utilized to map individuals' experiences within each dimension and categories for performing one-dimension and two-dimension analyses.	

Vertical Axis: Primary	For one-dimension analysis: Indicates the most prevailing category within each interview. For two-dimension analysis: Indicates one of the dimensions being examined.	
Horizontal Axis: Secondary	For the one-dimension analyses it is used to indicate the second most overarching category within the experience. For the two-dimension analyses it is used to indicate one of the dimensions being examined.	

VITA

VITA

Mariana Tafur Arciniegas
Graduate School, Purdue University

Education:

Purdue University, School of Engineering, West Lafayette, IN Aug 2010 - May 2015
Doctor of Philosophy Candidate in Engineering Education
Research: - Broadening technology literacy understanding
- Technology education for non-engineers adults as lifelong learners
Academic Committee: Dr. Senay Purzer (Chair), Dr. Johannes Strobel (Co-Chair), Dr. Robin Adams, Dr. Morgan Hynes.
Dissertation Title: *Understanding How Adults Approach Technological Challenges: A Sequential Mixed Method Research*

Los Andes University, Colombia Aug 2003 – May 2007
M.S in Education
Research: How motivation affects the development of critical thinking in freshman engineers
Academic Advisor: Dr. Andrés Mejía
Thesis Title: *The influence of motivation in making critical decision*

Los Andes University, Colombia Jan 1996 - Sep 2002
Bachelor of Science in Electronic Engineering
Concentration: Control and Automation
Academic Advisor: Dr. Mauricio Duque
Thesis Title: *Conceptual design for control system learning, applied to interactive tools*

Honors:

Fulbright Fellowship Aug 2010 – May 2013

Research Experience:

Graduate Research Assistant, Purdue University, West Lafayette, IN Aug 2010-2015

Mechanical Engineering
Developed a tool for assessing evolution of learning

Conducted Qualitative and Quantitative research in students' outcomes and learning processes in Dynamics course

INSPIRE – Engineering Education
Developed online-learning modules on engineering design thinking for teachers
Developed a database for a K-12 engineering project in 15 schools with more than 3000 students and more that 160 teachers
Collected data via field interviews with elementary science teachers
Conducted research in STEM K-12 education with emphasis on design fixation, engineering design thinking, and data mining
Conducted research based on qualitative, quantitative, and mixed methods including grounded theory, analysis of variation, and structural equation modeling.

Project Development Researcher, Los Andes University, Colombia Oct 2004-Jun 2010
Developed protocols for training teachers and trainers for Inquiry based learning
Coordinated the development of an online portal for Latin-American K-12 science teachers
Conducted research and designed items for a national project for evaluating science at elementary level
Advised professors in educational design for undergraduate-level courses

Teaching Experience:
Instructor, Purdue University, West Lafayette, IN Jan 2014 – Fall 2014
ENGR132: First Year Engineering – Second semester

Instructor, Los Andes University, Colombia Oct 2004-Jun 2010
Co-Adviser for a M.Ed. thesis: ROBARTE Project: Promoting Research through Robotics and ICT in an Elementary Public School
Committee member for a M.Ed. thesis: A Systems Engineering Capstone Course Design for Authentic Competency Development
Moderation of interactive learning environments, a M.Ed. course
Learning Environments through history, an undergraduate elective course
Education and Science, an undergraduate elective course
Introductory course to General Engineering, a freshmen engineering course
Inquiry-Based Learning Basics and Circuit Applications, a Teacher Professional Development course

Mathematics Teacher, Ideales Gimnasio Santa Ana Foundation, Colombia Dec 2003-Nov 2004
Taught grades seven to ten
Mathematics coordinator

Professional Experience:

External Consultant, Celta Trade Park, Colombia — Aug 2008 – Aug 2010
Designed a proposal for the knowledge management platform
Coordinated the technology education relations with shareholders

Assistant to the Technical Vice Presidency, Odinsa S.A., Colombia — Jul 2003 – Oct 2004
Coordinated risk and knowledge management
Developed a database for project management

Project Assistant, AICO S.A., Colombia — Jan 2001 – Jun 2001
Project documentation

Service Experience:

Paper Reviewer

2015 ASEE Annual Conference proceedings, Seattle, WA.	2015
2015 REES Research in Engineering Education Symposium, Dublin, Ireland.	2015
2015 FIE Frontiers In Education, El Paso, Texas.	2015
2012 ASEE Annual Conference proceedings, San Antonio, Texas.	2012

Community Service

President, Colombian Student Association at Purdue.	2012-2013
Communications Officer, Purdue Fulbright Association	2011-2012
Treasurer, Uniandes Kindergarten Parent Association	1999

University Service

Student Government, Los Andes University - School of Electrical and Electronic Engineering — 2000

Coaching and Tutoring — Jan 1998-Dec 2006
Mathematic, Physics and Programming Tutor
Physics Teaching Professional Development
Math Club for third graders

Affiliations:

American Society for Engineering Education	2011-Present
Golden Key Honor Society	2011-Present
Colombian Student Association at Purdue Board	2012-2013
Purdue Fulbright Association Board	2011-2012
Uniandes Kindergarten Parent Association Board	1999

Funding Awards:

Faculty Development Plan, $44,000
Fulbright Fellowship, 3-year full scholarship — Aug 2010 – May 2013
Global Engineering Program Travel Award, $1,500 — Mar 2013
Purdue Graduate Student Government Travel Award, $1,000 — Mar 2015

Publications:

Refereed Papers Published in Conference Proceedings

Tafur, M. and Purzer, S., (2015) The Role of Outlier Analysis in Reducing Purposeful Sampling Bias: A Sequential Mixed-Method Approach. 2015 ASEE Annual Conference proceedings, Seattle, Washington.

Dingenberg, E., Mendoza-García, J. A., **Tafur, M.**, Fila, N. D., and Hsu, M., (2015) Using Phenomenography: Reflections on Key Considerations for Making Methodological Decisions. 2015 ASEE Annual Conference proceedings, Seattle, Washington.

Douglas, K. A., Yoon, S. Y., **Tafur, M.** and Diefes-Dux, H.A., (2015) Factors Influential to Fourth Graders Engineering Learning and Identity Develop. 2015 ASEE Annual Conference proceedings, Seattle, Washington.

Tafur, M., Douglas, K. A., Diefes-Dux, H.A., (2014) Changes in Elementary Students' Engineering Knowledge Over Two Years of Integrated Science Instruction (Research to Practice). 2014 ASEE Annual Conference proceedings, Indianapolis, Indiana.

Tafur, M., Diefes-Dux, H. (2013) Data Base Development for School-Related Research. 2013 Frontiers in Education Conference, Oklahoma City, Oklahoma.

Kim Boots, N., **Tafur, M.**, Kim, W., Carr, R. L., Luo, Y., Sun, Y., Strobel, J. (2012) Design Fixation and Cooperative Learning Strategies in Elementary Engineering Education. 2012 AERA Annual Meeting Paper, Vancouver, British Columbia, Canada.

Tafur, M., Evangelou, D., and Strobel, J. (2012) Troubleshooting Skills For Non-Engineers In Technological Jobs. 2012 ASEE Annual Conference proceedings, San Antonio, Texas.

Tafur M., Duque M. and Hernandez J. T. (2006) Small Scientific program for pre-college engineering education: A K-6 curriculum for the development of scientific and technological competencies. 9th International Conference on Engineering Education, San Juan, Puerto Rico-Puerto Rico.

Molano A., Carulla C, Duque M. and **M. Tafur** (2006) Assessing and developing socio-emotional and communicative competencies in a pre-college engineering program K-6. 9th International Conference on Engineering Education, San Juan, Puerto Rico-Puerto Rico.

Carulla C, Duque M., Hernandez J. T., Figueroa M. and **M. Tafur** (2006) Participation of civil society as an engine for the Colombian project called Little Scientists. 3rd International Conference Science in Basic Education. 2005, Monterrey, Nuevo Leon, Mexico

Refereed Journal Articles

Carulla C., Hernandez J. T., Figueroa M., Patino M. I. and **M. Tafur** (2004) Little Science, a systemic approach to science learning in school. Social Studies Magazine No.19. Bogota: Faculty of Social Sciences, Uniandes, No. 19 p. 51-56. issn 0123-885X.

Curriculum Design Development

Latin American Portal for Teaching Support on Inquiry-Based Science Education. (Version 2008) www.indagaLA.org

Integrating Engineering into Grades 2-7. Teacher Professional Development. (Version 2013)

Invited Talks and Presentations

Poster presentation. Engineering Habits of Mind for Non-Engineers (Jan 2015) First Latino/a Graduate Student Research Symposium, West Lafayette, Indiana.

Poster presentation. Engineering in Science: Relationship redefined in K-12 US Education (Mar 2013) Second Colloquium for Colombia Purdue Advance Research Institute, Medellin, Colombia.

Poster presentation. Adapting Precollege Engineering Research and Learning at Purdue University for Colombian context (Oct 2011) First Colloquium for Colombia Purdue Advanced Research Institute, West Lafayette, Indiana.

Exhibition of IndagaLA portal and articulation of cooperative work (Nov 2007) National Seminar, Mao a Massa, Recife, Brazil.

Exhibition of IndagaLA portal and linking with other websites as Relpe (Oct 2007) National Meeting of Educational Portals, Bogota, Colombia.

Little Scientists Project Presentation (Jul 2006) International Conference on Engineering Education, San Juan, Puerto Rico.

Workshops

Portal presentation to 10 countries, conducting a workshop for cooperative work (May 2008) IndagaLA Portal Inauguration, Bogota, Colombia.

Workshop. Changing conceptions of the world (May 2006) I National Colloquium on Research and Innovation in Teaching Science, Bogota, Colombia.

Little Scientists workshop on inquiry and physical skills (Mar 2006) Bilingual Schools, Annual Meeting, Bogota, Colombia.

Exhibition of work by Colombian group, and articulation agreements between countries involved (Jul 2005) Inquiry-Based Science Education Projects, Latin American Meeting, Santiago, Chile.

Training for teacher professional development (May 2005) Training Trainers 2005, Bogota, Colombia.

Work in Progress

Tafur, M., Rhoads, J., DeBoer, J., Berger, E., Zissimopoulos, A., Nelson, D. and Krousgrill, C. (Under review) Assessment of the Purdue Mechanics Freeform Classroom: A Revised Framework Capable of Assessing Students' Cognitive Processes. 2015 FIE Frontiers In Education proceedings, El Paso, Texas.

Professional Development Certifications

ISO 9001 certification (2001)
ISO 9001 Internal Auditor (2003)

Technical and Language Skills:

Software

Access	MPlus	Matlab
Excel	HTML	IMovie
Power Point	Arduino	Project
SAS	Vicon	Xmind
SPSS	Visual Basic	Jing

Other Languages

Spanish (Native Language)