INDUSTRY-SITUATED STEM LABS: A CASE STUDY OF A NOVEL APPLICATION

by

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Dedication

For my parents.

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ABSTRACT

Click here to enter text.Click here to enter text.Choose an item.Choose an item.Click here to enter text.The purpose of this research was to understand: (1) the influence that an industry-situated STEM lab experience has on students' (ages 10-18) perceptions of careers in manufacturing, and (2) the challenges and opportunities that this space presents. To answer these questions, this study analyzed participant pre- and post-draw a manufacturer tests as well as manufacturing career perception surveys that included Likert-scale items and open response questions. Along with these data sources, five semi-structured interviews were conducted with industry stakeholders in order to understand the conception and operation of the STEM lab, as well identify any challenges or opportunities to improve or replicate success for other industries. From there, the data were analyzed through thematic coding for the drawings, open-response questions, and interviews, and a Mann-Whitney U test was performed on the survey results in order to look for general shifts in responses to specific questions from before to after the STEM lab experience. The results gained from the three different data collection techniques were looked at in aggregate and used to triangulate specific understandings, questions, and recommendations. The results confirmed a lack of students' awareness and understanding of manufacturing, misperceptions surrounding the careers within, and a disconnect between industry needs and educational output. Along with the data, literature on vocational psychology supports the need for students to participate in authentic learning opportunities to build self-efficacy and form more accurate outcome expectations with regards to future career selection. However, the data did reveal that the industry-situated STEM lab experience likely led the participants to an improved understanding of the manufacturing ecosystem and provided an opportunity for local educators to engage with industry. While this research looked at a novel application of a STEM lab and highlighted its influence on students' perceptions of manufacturing careers, there is obviously no "silver bullet" for fixing the talent pipeline for manufacturing and continuous work in this area needs to be done.

INTRODUCTION

CHAPTER 1.

1.1 Context

Since the early part of the 21st century, organizations like Deloitte and the Manufacturing Institute (Deloitte, 2018) have been keeping a watchful eye on the state of the manufacturing industry in the United States and have predicted that, even before the 2020 pandemic, the field may be in trouble. As increasing retirement numbers from the baby-boomer generation looms over the horizon, a lack of interest and awareness for manufacturing careers from the next generation is creating a vacuum of talent for tomorrow's jobs (Deloitte, 2018). Even if the trend of pushing back the retirement age continues, there may still not be enough new employees to replace the projected attrition. This phenomenon is colloquially known as the *Manufacturing Skills Gap* (Deloitte, 2018), and is immensely complex, with near-limitless contributing social and technological factors. In Deloitte's 2018 *Skills Gap in Manufacturing Study*, industry executives list a few potential reasons for the projected shortage of talent (other than increasing retirement numbers); these included: the lack of interest in manufacturing careers due to misperceptions of the industry and a shift in the skills that cutting-edge manufacturing technologies and processes demand. Moreover, some even suggest that a "perceptions gap" related to manufacturing may be the industry's biggest challenge over the skills gap (Lee, 2017). This idea of a "perceptions gap" was supported by a study conducted by Strimel, Krause, Bosman, Serban, & Harrell (2020a) that found children to hold negative perceptions of manufacturing both before and after an industry-led outreach initiative focused on robotics in manufacturing. This can be a concern for the next generation of manufacturing within the United States and may be a limiting factor to future competitiveness of the industry.

Relatedly, the National Science & Technology Council (2018) set forth the goal of attracting and growing tomorrow's manufacturing workforce through manufacturing-focused science, technology, engineering, and mathematics (STEM) education programs and industry-education partnerships. As such, some states, like Indiana and West Virginia are focusing on work-study programs, while other efforts include the expansion of STEM curriculum programs such as *Project Lead the Way*, to help students become aware of, and build skills toward, the future of work in the manufacturing industry. These educational programs are often connected to learning environments that have been created to engage students in making, tinkering, programming, and honing other skills relevant to tomorrow's workforce while exploring related career pathways (Vossoughi & Bevan, 2019). These learning environments are typically referred to as STEM labs (laboratories) and/or makerspaces (Roy & Love, 2017). As a result of the related educational initiatives over the past decade, STEM education and the maker movement is in full swing, with both formal learning entities (schools) and informal learning entities (i.e., libraries, museums, and community centers) investing in the hands-on learning environments deemed necessary to foster the skills for the future workforce. Consequently, there are many STEM initiatives that attempt to address the previously mentioned workforce concerns by establishing interdisciplinary learning environments to generate interest in, and capabilities with, hands-on skills. However, in regard to industry-led outreach and children's career perceptions, specifically in manufacturing, the cart is often put in front of the horse through implementation of programs/initiatives without knowing the influence they may have (Center for Advancement of Informal Science Education [CAISE], 2019). In addition, many of these programs are elective and fail to address misperceptions early in the talent pipeline (CAISE, 2019; Strimel, Grubbs, & Wells, 2016). Therefore, in an effort to investigate a novel application of a STEM lab—with an intentional focus on shaping the manufacturing perceptions gap through an enhanced tour of a manufacturing facility—this research was conducted in partnership with a local outreach effort. Specifically, this effort includes participation in manufacturing-relevant STEM activities (e.g., programming a small robotic arm to stack cubes, computer aided design, and 3D printing).

STEM labs, which are similar to makerspaces, can be defined as physical spaces where students can collaboratively learn integrated skills and content through hands-on experiences (Roy & Love, 2017). The industry-situated STEM lab, that is the focus of this study, is a unique application of such a learning environment in an informal space that is similar to those implemented within a children's museum. However, the aim for this specific space is to offer local students, ages 10-18, an opportunity to see manufacturing, the people that work there, and the skills that might be necessary to pursue a future career in manufacturing. The justification for using age instead of grade-level in this study is a result of the facilities not allowing students under 10 years of age to tour the facility due to safety and liability concerns, as well as the instruments used to gather data. This research will not attempt to justify the STEM lab initiative, but will instead provide a critical view of this informal learning environment with the goal of understanding the influences, if any, that the industry-situated STEM lab experience has on student perceptions of manufacturing careers. This research objective was achieved by talking to key industry stakeholders and analyzing an existing dataset of students' perceptions of manufacturing careers, collected by the manufacturer over the first year of the lab's operation. By triangulating the data gathered from stakeholder interviews and both student surveys and drawing tests, which were collected before and after their experience, this research intends to uncover some of the challenges that similar industry-situated learning environments might have, as well as provide opportunities to improve the experience from both the student and industry perspective.

1.2 The Problem

Industry leaders continually seek ways to involve local schools in processes that will help prepare students for future careers in positions with projected shortages, in order to establish a pipeline of capable, interested employees to fill the jobs that are opening due to factors such as an aging workforce and a lack of interest from potential new employees (Deloitte, 2018). Conversely, education institutions are tasked with preparing students for careers and life beyond schooling. The manufacturing sector can often go underrepresented in education for reasons listed by Deloitte (2018). Another issue might be a lack of direct interaction that students have with manufacturing in an educational context, as well as the nature of the interaction they do have. Oftentimes, students' only interaction with manufacturing is what they learn in their history classes which explores the dark, dirty, dangerous elements of manufacturing during the first and second industrial revolution (Bosman & Strimel, 2018). Therefore, students are in need of an accurate representation of what modern manufacturing is (Deloitte, 2018), and the skills and education they might need in order to pursue one of the many careers in the field. One way for students to interact with manufacturing is through changes in a school's formal curriculum; another is through informal learning experiences such as facility tours and hands-on activities conducted within an industry-situated STEM lab. While an industry-situated STEM lab can serve multiple functions, it may also represent some unique challenges. Once a manufacturer decides that it wants to connect with education, what steps should they take to make sure they are implementing changes in an effective, enduring, and exciting way? Also, how can a company rationalize the resources necessary to do so and provide data to show the influence that such an initiative can have toward talent pipeline development?

As economic demands and technology change, so too do the skills that employers are seeking. The implementation of flexible, informal learning environments—like a STEM Lab within an industry setting—can aim toward addressing some of the concerns with the talent pipeline earlier rather than later, as the research and career education initiatives often focus solely on high school students (CAISE, 2019; Strimel et al, 2020a). Currently, the industry-situated STEM lab examined in this study is used for school tours and local outreach opportunities. That said, there may be more opportunities to use the space for other applications. While this specific manufacturer might be considered innovative for using a STEM lab in this context, it can have the opposite of the intended effect if it is not properly implemented and maintained (Krause & Strimel, 2019). Therefore, the problem addressed by this study relates to the need to understand how an industry-situated STEM lab can influence the career perceptions of students and establish best practices (or at least practices) for the continued development/use of such informal learning environments, which may help to provide a model for other industries that are interested in developing and implementing similar space.

1.3 The Purpose of This Study

The purpose of this research project is to conduct a case study on a novel, industry-situated STEM lab experience in order to determine its influence on student's career perceptions and identify the challenges that might arise with regards to implementation and effectiveness, as well as, opportunities for improvement in both student experiences and data gathering techniques in future implementations in industrial settings. This research centers on one novel implementation of an industry-situated STEM Lab learning environment, its conception, and the effectiveness in accomplishing its intended goals. That said, the experience as a whole, which includes hands-on activities within the STEM Lab and a tour of the manufacturing facilities, may be an influencing factor on student perceptions. This research will also investigate specific influencing factors of the overall experience by triangulating the data collected through interviewing industry representatives with data from student perceptions of careers in manufacturing before and after their experience with a STEM lab enhanced manufacturing tour.

An organization based in the American Midwest has teamed up with local manufacturers to implement industry-situated learning environments as well as similar spaces within local elementary schools. This case study, however, will only focus on the industry-situated learning environment, its implementation, and the influences it has on the career perceptions of its participants. The STEM lab specific to this study is located within a major automotive manufacturing facility in the Midwest. With the goal of introducing the next generation of workers to manufacturing, this industry-situated STEM lab has been operating since August of 2018 and has been collecting surveys and qualitative data on student perceptions since inception. Using the data collected, as well as additional interviews and observations, the research questions detailed in the following section were addressed.

1.4 Research Questions

This research centered on one specific application of an industry-situated learning environment (a STEM Lab) within a manufacturing facility. The research questions that guided this study were:

1. What influence, if any, does an industry-situated learning environment (STEM Lab) have on the perceptions of careers in manufacturing for students?
    1. What influence, if any, does an industry-situated learning environment have on the perceptions of careers in manufacturing for students in grades 5 through 6 (ages 10-12)?
    2. What influence, if any, does an industry-situated learning environment have on the perceptions of careers in manufacturing for students in grades 7 through 12 (ages 12-18)?
2. What are the challenges and opportunities involved with establishing and operating an informal learning environment (STEM Lab) within a manufacturing facility?

First, Research Question 1 is divided into 2 sub-questions. The reason for dividing the question has to do with the sources of data used for each. For Research Question 1 there are two pre-existing datasets from the manufacturer that were requested, received, and analyzed. The dataset for Research Question 1a was a “Draw-a-Manufacturer” test that was administered to the participating students from Grades 5 through 6 (ages 10-12) by the industry associates before and after their experience. This drawing test was based on the "draw a scientist test" (Huber & Burton, 1995; Langin, 2018) and was used by the manufacturer to evaluate the experience based on the age of the participants and their knowledge of the manufacturing industry. The pre-existing dataset for Research Question 1b was a survey focused on examining perceptions related to manufacturing careers, which included both Likert scale items and open-ended response questions, that was administered to students in Grades 7 through 12 (ages 12-18) by the industry associates before and after their experience. The Likert scale items were based on the misperceptions of manufacturing highlighted in Deloitte's Perception of Manufacturing Careers Study (2017). The open-ended response questions, which were only included in the post-survey, were asked to gain a more holistic view of students' perceptions of manufacturing and their experience with the STEM Lab activities. The drawings, Likert scale items, and open-ended responses were collected, examined, and triangulated to determine the influence, if any, that this industry-situated learning environment had on the perceptions of careers in manufacturing for participating students. It is important to note that these data were collected by the manufacturer during its first year of operating the STEM Lab, (between the years 2018 and 2019), and the researcher was not involved with the data collection process. The data were de-identified by the manufacturer and requested following the institutional review board's exemption protocol.

Research Question 2 was investigated by conducting semi-structured interviews with the industry stakeholders responsible for the implementation and operation of the STEM Lab experience. These interviews were transcribed and coded for any emerging themes related to the challenges and opportunities involved with establishing and operating an informal learning environment within a manufacturing facility. In addition, these interview transcripts were analyzed using the data from Research Question 1 as a lens for examination to enhance the trustworthiness of the results. Also, the interviews will be leveraged where possible to support or oppose the findings related to Research Question 1. Lastly, in order to account for bias, the interviews included member checking questions and the interviewer/researcher practiced reflexivity and peer debriefing when analyzing the data. The complete methods for this study are addressed in greater detail in Chapter 3.

1.5 Definitions

- **Manufacturing Facilities:** A building (or campus) that produces a product or sub-assembly at volume (LawInsider, 2020).
- **Manufacturing Skills Gap:** The projected shortage of skilled, interested workers in the manufacturing field (Deloitte, 2018).
- **Manufacturing Perceptions Gap:** The gap between people's perceptions of careers in manufacturing, and the reality of those careers (Strimel et al, 2020a).
- **Industry-led Outreach:** Programs and initiatives put on by local manufacturing industry that aim to improve perceptions and public relations within the community (Strimel et al, 2020b).
- **Talent Pipeline Initiatives:** Programs that aim to build interest early and recruit from a larger potential pool of employees (Ghosh, 2019).
- **Informal Learning Environment:** Contexts in which students are learning outside of a formal school setting (National Science Foundation [NSF], 2020a).
- **Industry-situated Learning Environment:** General term for any informal learning environment found within an industry.
- **Industry-situated STEM Lab:** Specific term for the industry-situated learning environment that is the focus of this research. In this case, the STEM lab is situated within a manufacturing facility and provides a space for students to participate in activities that relate to manufacturing.
- **STEM Activities:** Lessons, activities, and games that relate to concepts from Science, Technology, Engineering, and Math (NSF, 2020b).
- **STEM Lab:** STEM labs, which are similar to makerspaces, can be defined as physical spaces where students can collaboratively learn integrated skills and content through hands-on experiences (Roy & Love, 2017). Activities in these labs can include programming a small robotic arm to stack cubes, computer aided design work, and 3D printing experiences.
- **Social Cognitive Career Theory (SCCT):** A vocational psychology theory in which people choose careers based on internal factors such as agency and ability, as well as external factors that range from parents to culture (IResearchNet, 2016a).

- **Manufacturing Career Perception Survey:** A survey used in this research adapted from previous research that aims to understand students' perceptions of careers in manufacturing (Strimel et al, 2020a).
- **Draw-a-Manufacturer Test:** An instrument used in this research that aims to use students' drawings as a method to understand their perceptions of manufacturing (Strimel et al, 2020a).

1.6 Assumptions

The assumptions of this study were:

- For Research Question 1a, the drawing tests are the participants' personal conception of manufacturing.
- For Research Question 1b, all participants completed the surveys honestly and to the best of their abilities.
- The students had the cognitive capacities to understand and answer the survey questions and complete the drawing tasks (the instruments have been designed to account for the appropriate language for the different age groups.)
- The adults participating in the interviews understood the questions asked and responded honestly.
- The drawing tests were a more age-appropriate data collection method than surveys for the younger (ages 10-12) participants (Strimel et al, 2020a).
- The instruments were accurate measurements of manufacturing career perceptions (Strimel et al, 2020a). (The questions were based on the Deloitte Report and the Draw-a-Scientist test.)
- The results of the Manufacturing Institute and Deloitte (2018) study, that informed this research, were reflective of the state of the manufacturing industry.
- The methods that The Manufacturing Institute and Deloitte (2018) used to gather research and make recommendations is reflective of the current state of the industry.

1.7 Limitations

The scope of this thesis was limited in the following ways:

1. The researcher was involved in prior research projects related to the topic of this study and may be subject to issues with data interpretation and bias. In order to mitigate these biases, the researcher used data collection instruments that have been used previously, as well as other validity-ensuring tools for qualitative research (Gay, Mills, & Airasian, 2017), which will be discussed further in Chapter 3.
2. Interviews were conducted within a designated time frame of 60 minutes which may have led to omissions of certain responses that would have otherwise been offered if the interviewee had unlimited time. This limitation was considered when developing the interview questions so that the time allowed was sufficient for the responses to properly answer the research questions. Also, the researcher conducted member checking in alignment with suggestions by Berg (2004), to help address any biases or underlying assumptions that may have impacted the data analysis.
3. Using surveys limits the responses that participants can give. To allow for a more complete view of the themes, 5 free-response questions were included in the post-survey, which were thematically coded and used along-side the survey data to help triangulate themes.
4. While the Draw-a-Manufacturing Test might be useful for capturing younger participants' perceptions, the method required the researcher to infer what each drawing portrayed. To address this limitation, the data were analyzed by members of a research team, while practicing peer debriefing and reflexivity (Gay et al., 2017).
5. To answer research questions 1a and 1b, pre-existing data were accessed and analyzed. These data were collected and by the manufacturer. As such, the researcher did not have control over the methods of data collection and the overall quality of the data. Also, as the data were de-identified, the analysis methods were limited to treat pre- and post-data as independent samples. To account for this limitation, the study employed the Mann-Whitney U statistical test to identify significant shifts in the data between the pre- and post-survey samples.
6. The focus of this study centered around the influence that industry-situated learning environments have on students' perceptions of manufacturing. This learning environment was embedded within the tour of the manufacturing facilities. While these learning environments are never intended to be separated from the facilities in which they are embedded, it is difficult to pinpoint the exact part of the experience that influences a student's perception. However, to account for this concern, multiple sources of data were triangulated

to determine the sources of the influence, whether being the learning environment specifically or the tour of the facilities. This included leveraging the data from the drawings, open-ended responses, and stakeholder interviews.

1.8 Delimitations

The following statements set the boundaries of this thesis:

1. This study only focused on one novel application of an industry-situated learning environment embedded within a manufacturing facility tour of one large automotive manufacturer in the Midwest. This research did not examine student learning and skill development; it narrowly focused on student perceptions of careers in manufacturing.
2. This research did not focus on investigating students' prior educational experiences.

1.9 Summary

This chapter touched on the context of the problem under investigation, the purpose for the research, and the research questions that guided this study. This section also briefly discussed the procedures of the study, as well as the assumptions, limitations, delimitations, and useful definitions. In the following chapter, a literature review will provide a more in-depth analysis of the current state of the manufacturing skills gap, the framework used in this research to understand how students form career perceptions, and a few of the current industry-education initiatives that aim to address the manufacturing skills gap, as well as the learning environments that can be positioned to connect industry and education.

REVIEW OF LITERATURE

CHAPTER 2.

2.1 Introduction

The Manufacturing Skills Gap involves both industry and education, and has many contributing factors that have developed over the past 50 years. However, this research focuses on student awareness, interests, and perceptions of careers in manufacturing as they relate to industry-driven outreach within industry-situated informal learning environments such as a STEM lab. Therefore, in order to best situate this research, this chapter will first explore the current workforce problem related to manufacturing, how this problem formed and who it involves, what has been done to address this challenge, and the K-12 learning environments related to this issue. In addition, this chapter will provide a theoretical framework for understanding how students choose careers, the supports and barriers that influence them in these decisions, and the adaptive career behaviors that help students navigate uncertain pathways in the process. Lastly, this chapter will include a discussion on how students form career perceptions at different developmental stages as well as current educational initiatives and learning environments designed to expose students to the careers and skills related to the manufacturing industry.

2.2 The Manufacturing Skills Gap

> *"The [manufacturing] industry has failed to compete with technology for their interest. Unfortunately, the industry hasn't fully explained the dynamic, technology-driven environment of the modern plant floor. With Gen Z just moving into the workforce, we need to encourage their participation in modern manufacturing. If we don't, I'm afraid the industry will be hit with the negative effects of the Silver Tsunami." (2019 L2L Manufacturing Index)*
>
> *-Keith Barr, President and CEO of L2L (Leading2Lean)*

The rationale for this study can be found in the *2018 Deloitte and The Manufacturing Institute* report titled the *Skills Gap and Future Work Study*. The fourth study of its kind, this report attempts to detail the current state of manufacturing in the US and predicted problem areas surrounding talent shortages within the manufacturing workforce. Findings from this report include, but are not limited to: 1) qualified employees in the manufacturing ecosystem are leaving at a higher rate than new employees can replace them, causing what is colloquially known as the “Manufacturing Skills Gap;” and 2) despite interventions from governments and industries alike, this gap is widening year over year (National Science & Technology Council, 2018). Deloitte and the Manufacturing Institute have been monitoring and researching the skills gap for over 17 years and have used the information that they have gathered to produce reports that aim to inform stakeholders in industry, government, and education of the extent of the problem. After interviewing over 500 manufacturing executives, industry leaders, and other relevant stakeholders, two of the top causes for the skills gap cited by the 2018 report were 1) the “shifting skill set due to the introduction of new advanced technology and automation,” and 2) the “negative perception of student/their parents toward the manufacturing industry” (Deloitte, 2018, p. 4-5).

The “state of the art” for manufacturing is constantly changing, with respect to both technology and processes. This makes it difficult to teach specific technologies to students, because 1) it can be expensive, and 2) it may be outdated by the time the students are employees. That said, there are still ways to prepare students for manufacturing careers through self-efficacy and foundational skills. There are foundational technical skills, as well as soft skills, that will prepare students regardless of the specific manufacturer or career they end up in (Partnership for 21st Century Skills, 2019; Heckman & Kautz, 2012). None of those may matter, though, if students do not have any exposure to, or interest in, a career in manufacturing due to poor perceptions of the field (Bosman & Strimel, 2018; Krause & Strimel, 2019; Strimel et al., 2020a; Deloitte, 2018; L2L, 2019).

According to the 2019 *L2L Manufacturing Index (2019)*, an annual report on the American public’s perception of manufacturing in the U.S., the next generation (Generation Z) has better resources and better perceptions of manufacturing than the previous ones. L2L worked with a 3rd party to interview over 1000 participants that reflect the nation’s demographics. The survey asked questions related to manufacturing perceptions and the results were segmented to compare results between Generation Z (born between 1997-2012), Millennials (born between 1981-1996), and the general population as related to the United States (Dimock, 2019). Four key takeaways from the results include: 1) "One-third (32%) of Generation Z has had manufacturing suggested to them as a career option, as compared to only 18% of Millennials and 13% of the general population" with, "75% of Americans having never had a counselor, teacher, or mentor suggest they look into attending trade or vocational school as a means to a viable career" (p. 4); 2) "A majority (56%) of Generation Z would consider working in the tech industry, while only 27% would consider working in the manufacturing industry" (p. 5); 3) "Generation Z is twice as likely [as both millennials and the general population] to have family or friends working in manufacturing" (p. 9); and 4) "over half (53%) of the general population assumes the average salary of a mid-level manufacturing manager is under $60,000. In reality, the average salary for a manufacturing manager in 2018 was $118,500" (p. 4). Despite the majority (73%) of L2L's participants' disinterest in careers in manufacturing, the findings from L2L's Manufacturing Index show encouraging signs that current students (Generation Z) are better positioned to pursue careers in manufacturing, due to a greater number of students with family members and friends in the field, and a more informed support structure through guidance counselors, parents, and teachers. Another promising element discovered in this survey has to do with the improved support and encouragement for students through key individuals, based on research and psychology surrounding modelling and learning (do Ceu Taveira, Oliveira, & Araújo, 2017; Bandura, 1986; Lent, Brown, & Hackett, 1994; Lent & Brown, 2013), which will be revisited in the next section. These generational differences, combined with the Skills Gap Report's recommendation on early intervention and exploratory experiences (Manufacturing Institute, 2019; Deloitte, 2018), suggests the potential for a culturally and environmentally primed audience for a career perception change. As such, this research aims to understand how industry-situated learning experiences might influence shifts in perceptions of, and interests in, manufacturing careers. In order to maximize the effectiveness of these industry-situated learning experiences, it is important to understand how students choose a career, what learning experiences and environmental factors play a role in that selection, and how students adapt to life changes with regards to their career choices. This understanding may help provide a framework around which the goals of an industry-situated STEM lab can be properly aligned, and potentially provide some insight as to the influence that such an experience may have toward shifting student perceptions; leveraging established psychological principles to build an effective experience in terms of the stakeholder's goals. It may also help provide a frame for understanding just how complex career choice is, and how many underlying factors play a role in how students decide what to do with their adult lives. By adding that frame, the hope is that the researcher (and the reader) can dampen some of the hope that this type of initiative be a silver-bullet for solving the manufacturing skills gap.

2.3 Theoretical Framework: Social Cognitive Career Theory

The literature on the formation of career perceptions is expansive, with a number of theories that cut across many situations, relationships, and epistemological frameworks. Adapted from more broad psychological research, this field is referred to as vocational psychology; studying human behavior with regards to career selection, performance, and mobility (Walsh, Savickas, & Hartung, 2013). Though this field is generally applied to career counseling, the models developed by vocational psychologists have practical uses for understanding how students form career perceptions, as well as perceptions of their own abilities in specific domains and realistic career goals (Marcus, 2017). As a whole, modern literature emphasizes the dynamic nature of career perceptions and how the process is not one specific moment, but a series of events and choices that develop over an extended period of time (Walsh et al, 2013; Bandura, 2001, Lent et al, 1994). The main theory that this research centers around is Social Cognitive Career Theory (SCCT), which is an adaptation of Albert Bandura's General Social Cognitive Theory (1986) with a tightened focus on how people choose, maintain, and advance their careers (Lent et al, 1994). This section will briefly explain what SCCT is, how the different elements relate, what improvements have been made to the framework, and finally, highlight the specific ways of learning that apply (or could apply) to this research.

SCCT was developed by Lent, Brown, and Hackett in 1994 and uses Albert Bandura's Social Cognitive Theory (1986) to create a framework to, "understand three intricately linked aspects of career development: (a) the formation and elaboration of career-relevant interests, (b) selection of academic and career choice options, and (c) performance and persistence in educational and occupational pursuits" (p.1). The foundation for this model is based on the paradigm that behavior is a byproduct of the person and their environment and tries to account for the role of human agency in behavior through active psychological processes like self-efficacy, outcome expectations, goal-setting, and reflection (Bandura, 1986; Bandura, 2001).

Self-efficacy is how a person views their own skills and competencies in a specific domain and may be a better predictor for success than actual abilities (Lent et al, 1994; Bandura, 2001; Thompson & Dahling, 2012). For example, if you think that you are a good endurance athlete, you may be more inclined to participate in a marathon, and because you think you can do it, you may stick with it longer and through more setbacks than someone that views themself as more of a sprinter, even if they have the same mile time as you. Self-efficacy is molded by learning experiences and influenced by external factors and learning opportunities (Lent et al., 1994). Outcome expectations are another important psychological principle working in concert with self-efficacy (Bandura, 1986; Lent et al, 1994). Whereas self-efficacy might be, "Do I think I can do it?", outcome expectations hypothesize the potential outcomes of a chosen activity and identify positive and negative potential results; sounding more like, "if I do it, what will happen?"

For some important life choices, like career selection, the combination of self-efficacy and outcome expectations can lead to goal-setting; leading the individual to articulate a desired outcome and make concrete choices toward achieving that outcome (Lent et al, 1994; Lent & Brown, 2013). According to IResearchNet (2016a), the SCCT model, personal goals are explained as, "one's intentions to engage in a particular activity (e.g., to pursue a given academic major) or to attain a certain level of performance (e.g., to receive an A in a particular course)" (para. 5). People generally set goals that factor both interests (intrinsic motivation) and perceived personal aptitudes (Thompson & Dahling, 2012), as well as the rewards they expect to receive, both internal and external (Lent et al, 1994). Articulation of major goals, such as career or field choice, may also help an individual understand the smaller, performance goals and actions that will need to be performed along the way. After a person sets an expectation for specific activity involvement and participates in it, those experiences are reflected on and create learning experiences, which in turn refine the individual's self-efficacy and either reinforce or dissuade the development of specific interests (Lent et al, 1994). That said, interests are also influenced by a number of other factors, both internal and external, such as learning environment, support structure, and downright chance.

SCCT posits that personal interests are dynamic and developed through activities and observational modelling that are differentially reinforced through experiential, social, and cultural feedback (Lent et al, 1994). SCCT delineates those initial, somewhat random interests that a child would get from activities they either participate in or observe, from what Lent et al. (1994) refer to as enduring interests; citing that enduring interests form when a person has self-efficacy and positive outcome expectations in a specific domain that have been previously reinforced. This iterative cycle means that a child might try a task at random, for example, playing with LEGO's™, enjoy it, and receive feedback from his parents telling him that he was good at following instructions and building, and would make a good engineer. SCCT then takes it a step further by using those enduring interests to create goals and drive choices and behavior. Lent et al (1994) also talks about the role of timing and proximity; stating, "[goals] are more likely to be dubbed expressed choices, plans, or decisions when they involve specific intentions, (e.g., determination to engage in a particular field or role), are assessed near or at career entry, and require commitment" (p. 85). That said, not all goals are created equally. Goals can carry different personal weights, commitments, or choice actions and are dynamic in that changing circumstances or new learning experiences can influence not only the degree of the goal, but the goal entirely (Lent et al, 1994; Bandura, 2001). This can happen often with students. A student may make the choice goal to be an engineer based on their interests, self-efficacy, and outcome expectations, then set performance goals like passing calculus. Then if that student fails calculus, that learning experience may change their self-efficacy and outcome expectations, potentially resulting in a change in major. That said, direct experiential learning is not the only way for students to build self-efficacy and predict outcomes. Observational learning, one pillar of Bandura's original Social Cognitive Theory (1986), allows people to learn through observing the actions or words and related consequences of "models" and then modelling that behavior. Research has shown that observational learning is strengthened when the model is similar in some way to the observer (Bandura, 1986; Bandura, 2006; Bandura, 2001). The specific steps of this learning process are attention, retention, reproduction, and motivation (Bandura, 1986). These modeled behaviors can be both good and bad, with encouragement and other forms of feedback either reinforcing or deterring the behavior. Similar to course grades, feedback can be both positive and negative and can come from both internal and external factors. SCCT posits that positive feedback, given through the right channel, would lead to improved self-efficacy, and thus more favorable outcome expectations in that domain, and could even form enduring interests (Lent et al, 1994).

SCCT extends this process by articulating values and the role they play in weighting different aspects of specific anticipated outcomes. Values are, simply put, the mode of reinforcement that people prefer (Lent et al, 1994). Values are learned at a young age. As Lent et al (1994) state, "Interactions with or observations of family members, peers, teachers, other significant persons, cultural or religious institutions, and print and electronic media sources provide much of the context for imparting values and personal standards of behavior" (p. 91). In SCCT, values are manifested through outcome expectations and influence the weight of the different anticipated outcomes. For example, if a student values intrinsic, internally-oriented feelings of accomplishment and self-satisfaction, they may value that type of reinforcement more out of all of the potential elements that come with an expected result. This supports Bandura's (1986) notion that outcomes can be divided into three categories; social, material, and self-evaluative. A person's values might impact which of those three categories is most important, and act accordingly. SCCT further explains how subpersonal attributes and external situations can potentially impact self-efficacy and outcome expectations (Lent et al, 1994).

Personal abilities can be both hereditary and learned and impact how a person sees their self-efficacy and anticipates potential outcomes. Lent et al. (1994) says that, "our approach acknowledges the influence of genetic endowment, special abilities, and the environmental conditions on career decision making" (p. 85). The internal abilities, learned through personal experience and observational learning, alongside the external realities of life, often dictate the career that students actually choose. It is also worth noting that individuals often have to choose between the job they want, and the job they can get. These concessions and their associated behaviors will be discussed in a later section. Other personal factors, like ethnicity and gender, might impact career choice through culturally sanctioned modelling and encouraged/discouraged activities. Lent et al (1994) says, "For example, educational access issues can influence the quality and types of learning experiences one receives, and certain cultures may selectively reinforce particular occupationally relevant activities" (p. 105). These external influences can build these personal factors and affect students' access and influence of experiences directly (e.g., access to positive models in different careers) as well as internally through self-efficacy and outcome expectations (Lent et al, 1994).

Aside from the personal factors, SCCT also accounts for contextual influences. Although these influences can be environmental, Lent et al (1994) say, “Supports, opportunities, and barriers -- like beauty -- lie at least partly in the eye of the beholder” (p. 106). In a study done by Thompson and Dahling (2012), 380 college students were asked to self-report on perceived social status using questionnaires that look at self-efficacy, learning experiences, social status, and occupational outcome prediction. The study found that higher perceived social status was associated with enhanced learning experiences in specific domains, even after controlling for gender. This study also showed results that support and are consistent with past research on the relation between learning experiences and self-efficacy and outcome expectations. Essentially, people play an active role in how environmental factors are perceived. SCCT categorizes contextual influences for opportunity structures into 2 types: background influences in which people tacitly participate, like available role models and feedback structures; as well as distinct structural supports or barriers in key moments (Lent et al., 1994). An example of the latter might be an individual’s career network contacts or discrimination in the hiring process. These opportunity structures might not predict career choice, but instead might predict how a person views their own control over their situation/choices/environment; either enhancing their self-efficacy or constraining it. Lent et al (1994) state, “In our scheme, contextual factors (a) help shape the learning experiences that fuel personal interests and choices, and (b) compromise the real and perceived opportunity structure within which career plans are devised and implemented” (p. 107).

For this research, perhaps the two most pertinent propositions put forward by SCCT, Propositions 10 and 11, have to do with learning experiences.

> Proposition 10. Self-efficacy beliefs derive from performance accomplishments, vicarious learning, social persuasion, and physiological reactions (e.g., emotional arousal) in relation to particular educational and occupationally-relevant activities.
>
> Proposition 11. As with self-efficacy beliefs, outcome expectations are generated through direct and vicarious experiences through educational and occupationally-relevant activities (Lent et al, 1994, p. 103).

Two important assumptions/distinctions in these propositions look at the impact of the learning experience/modality and the activity itself on self-efficacy and outcome expectations. Keywords are, “educational and occupationally-relevant activities,” and the learning can happen through different channels. Therefore, a direct tie can be made to this research as the activities in which students engage and how their alignment to the relevant occupations in which they are situated as well as the environment in which they are delivered, can play a role in shaping their self-efficacy which can in turn shape their career interests and perceptions.

Essentially, the process that leads to forming career interests is driven by self-efficacy, intrinsic motivation, external supports and barriers, and outcome expectations, all put through a unique lens of feedback and reflection. That said, one criticism of this model is that it assumes an ideal circumstance for people. As stated by Lent et al (1994),

> We should also note that this model is intended to depict a set of normative processes taking place under conditions of optimal voluntary control. However, we fully recognize that, in the ‘real world,’ a variety of important factors, such as cultural and economic conditions, will moderate the explanatory power of the model. (p. 96).

This initial assumption of ideal circumstances has since been addressed by updated research that focuses on adaptive behaviors and non-ideal scenarios, as well as accounts for different human developmental stages (Lent & Brown, 2013). These are referred to as Adaptive Career Behaviors.

2.3.1 Adaptive Career Behaviors

Recent work on SCCT has revised the initial 1994 model created by Lent et al. to include and assign greater relevance to processes and environmental/personal barriers or supports (Lent & Brown, 2013). Reflecting on the original SCCT framework, Lent & Brown (2013) say,

> The original content focus of SCCT has encouraged inquiry on factors that foster or hinder people’s interests and entry into certain fields (e.g., science, technology, engineering, mathematics careers and majors). However, it has offered less clear guidance for investigators seeking to understand how people negotiate life transitions

> (e.g., shift from school to work) or engage in common career development tasks (e.g., career exploration and decision making) across fields (p. 559).

Much like Piaget's developmental philosophy, this development of SCCT focuses on the processes that lead to redefining goals and the approach to learning; including factors that apply in dynamic ways over the course of a person's lifetime (Lent et al, 1994; Lent & Brown, 2013). This research acknowledges the cultural shift in work and the recent rise in the prevalence of non-linear careers through a person's life (Lent & Brown, 2013). This consideration might be important for this specific research in that students might not pick careers in manufacturing as their first choice; harkening back to the shortcomings of the previous iterations of SCCT. The focus of this updated model revolves around what are referred to as "Adaptive Career Behaviors."

Lent and Brown (2013) define these as, "behaviors the people employ to help direct their own career (and educational) development, both under ordinary circumstances and when beset by stressful conditions" (p. 559). These behaviors have to do with the broader processes that people employ when undergoing important, developmental changes to their career or life. As Lent & Brown (2013) state,

> We find it helpful to conceptualize career adaptability in terms of a collection of behaviors that can be learned, rather than only as traits that people possess. However, as we discuss below, the performance of these behaviors may be facilitated by certain traits as well as by environmental supports (e.g., friends, bosses, family members) and social cognitive factors (self-efficacy) (p. 561).

The behaviors are broken down into Super, Savickas, & Super's (1996) developmental stages and provide process-oriented, acquirable skills that aim to identify common checkpoints in behavior for different developmental stages. The subjects in this research fall within the first two stages: Growth and Exploration. IResearchNet (2016a) describes the Growth stage (roughly ages 4 to 13,) as,

> the period when children develop their capacities, attitudes, interests, socialize their needs, and form a general understanding of the world of work. This stage includes four

> major career developmental tasks: becoming concerned about the future, increasing personal control over one's own life, convincing oneself to achieve in school and at work, and acquiring competent work habits and attitudes (para. 5).

A few of the adaptive career behaviors in this stage have to do with developing foundational skills like problem-solving, decision-making, and social skills, with specific behavioral examples like, "developing preliminary work-relevant interests and values and forming provisional vocational aspirations and self-concept" (Lent & Brown, 2013; p.560). The following stage, according to IResearchNet (2016b), is Exploration (roughly ages 14 to 24). The Exploration stage is defined as,

> the period when individuals attempt to understand themselves and find their place in the world of work. Through classes, work experience, and hobbies, they try to identify their interests and capabilities and figure out how they fit with various occupations. They make tentative occupational choices and eventually obtain an occupation. This stage involves three career development tasks. The first one, the crystallization of a career preference, is to develop and plan a tentative vocational goal. The next task, the specification of a career preference, is to convert generalized preferences into a specific choice, a firm vocational goal. The third vocational task is implementation of a career preference by completing appropriate training and securing a position in the chosen occupation (para. 6).

Examples of adaptive career behaviors in the exploration stage are, "exploring possible career paths (e.g., through reading, observing, undertaking informal and formal self-assessment of interests, abilities, values)," "making career-relevant decisions (e.g., regarding leisure activities, elective courses)," and "forming more specific vocational goals and plans" (Lent & Brown, 2013, p. 560). Changing someone's perception (which might equate to interests, values, or self-efficacy) about a broad, abstract concept like a career is hard, and it gets harder as they get older and their interests solidify (Lent et al, 1994). As previously stated, the reasons that someone pursues a specific career are not static or confined to personal choices, but dynamic and influenced by both internal and external supports and barriers. As Bandura (2006) argues, "People do not operate as autonomous agents. Nor is their behavior wholly determined by situational influences. Rather, human functioning is a product of a reciprocal interplay of intrapersonal, behavioral, and environmental determinants…" (p. 165).

In order to better understand the factors at play and how they relate to each other, Lent and Brown (2013) rather cleverly divided the factors into two categories: 1) the proximal person and contextual factors, and 2) the distal antecedent and experiential sources. The first category has to do with direct personal influences, such as domain-specific self-efficacy, coping efficacy (one's belief in their ability to negotiate obstacles), and process efficacy (perceived ability to manage specific tasks necessary for different career stages); as well as contextual and personal factors proximal to the individual. Lent and Brown (2013) state that, "People are more likely to set and implement goals to engage in adaptive career behaviors when they are buoyed by environmental (e.g., social, financial) supports and relatively free of barriers that can constrain their exercise of agency" (p. 562). They also state, "Contextual influences (e.g., reactions of important others, having access to environmental resources) can also directly affect the outcomes that follow adaptive behaviors and moderate action-outcome relations" (p. 562). This updated model of SCCT delineates personal factors from specific interests with a process-driven approach; using the latter to account for developmental presses, personal goals, and environmental considerations (Lent & Brown, 2013). That said, research has been done on how personal attributes, such as the big five personality traits, impact the effectiveness of different adaptive career behaviors (Brown & Hirschi, 2013). The second category discusses the preexisting, passive, and distal influences that might shape an individual's ability to conduct adaptive career behaviors. These influences can play out through culture, feedback, and societal norms, and take into account both personal inputs like race and gender, as well as contextual affordances, like access to a support system (Lent & Brown, 2013). Lent and Brown (2013) state, "Distal person and contextual variables covary in the sense that educational and career-relevant resources are often differentially conveyed to children and adolescents on the basis of how key social agents respond to their gender, race/ethnicity, and other person characteristics" (p. 563). Again, this framework/theory accounts for the social interactions and the role of others in the development of perceptions. Lent and Brown (2013) further this point by saying, "Contextual influences (e.g., reactions of important others, having access to environmental resources) can also directly affect the outcomes that follow adaptive behaviors and moderate action-outcome relations" (p. 562). They then incorporate these models into the cognitive affects to offer a more complete view of how different learning modalities can impact learning, saying, “More specifically, such socialization or learning experiences convey four types of information relevant to self-efficacy and outcome expectations: personal performance accomplishments, observational learning (or modelling), social encouragement or persuasion, and physiological and affective states and reactions” (Lent & Brown 2013, p. 563).

Understanding how students build and grow career perceptions and navigate the school-to-work transition can provide key insight as to where misperceptions currently exist with regards to manufacturing, as well as provide a framework for implementing proper research techniques, learning experiences, and intervention strategies to address those misperceptions. Keeping that point in mind, the next section will look at current initiatives in place that aim to educate students and promote careers in manufacturing, who they are reaching, and where the gaps might be.

2.4 Current Industry-Education Initiatives

As manufacturing careers grow increasingly technical and complex, so too do the education and training strategies of both schools and industries. Manufacturing education has come a long way from the industrial arts of yesteryear, placing a stronger emphasis on engineering principles (Strimel et al, 2016). There are manufacturing classes in high school, as well as engineering classes that incorporate manufacturing concepts; drawing on both national and state standards (Strimel et al., 2016). These high school classes are often electives, and many students may only learn about manufacturing in a history class unit. Other initiatives focus on improving perceptions and awareness of the manufacturing ecosystem. For example, there are extracurricular camps that students can attend in the summer that help them better understand manufacturing through activities, tours, and lessons. In addition, Manufacturing Day, promoted by the Manufacturing Institute (Manufacturing Institute, 2019), has both primary and secondary students nation-wide interact with local manufacturers to teach them about the careers, skills, and opportunities in the manufacturing ecosystem. However, research on the influence of such activities is still limited (Strimel et al., 2020a).

One recent study conducted by Strimel et al. (2020b) looked at a week-long application of Manufacturing Day, in which three groups of students (K-5th, 6-8th, 9-12th grade) participated in varying activities presented by local manufacturers, a community college, and a community-based workforce development committee. Each of the different age groups had a field trip in which they got to talk to manufacturers, participate in activities, and potentially address some misperceptions of manufacturing careers. It is noted that students only spent a single day at any of these events, and the event took a week because of the volume of students that participated (*N* = 1592). The students in grades K-5 group (ages 5-11) participated in a *Manufacturing Workshop*, which was 2-hour session located at a local community college that focused on manufacturing awareness, comprised of four 30-minute, rotating activities in which employees of local manufacturers had students participate in activities that, "showcase how production occurs, the concept of lean manufacturing, and how the local supply chain works" (p. 5). The 6-8 grade group (ages 11-14) participated in a *Manufacturing Expo*, which was a 4-hour event in which students rotated through four 45-minute activities aimed at career exploration. The *Manufacturing Expo* had local manufacturers set up booths, in which students could, "explore what their company does and perform activities related to the careers within their organizations" (p. 6). Activities included (but not limited to) a virtual reality forklift simulation, a LEAN processes LEGO™ activity, and additive manufacturing (3d Printing) introductions. The grades 9-12 group (ages 14-18) participated in *Manufacturing Tours*, in which students toured multiple local manufacturing facilities (either two 90-minute tours or three 60-minute tours) with the intention of displaying what work in a manufacturing setting really looks like, with the overall goal of addressing issues of career perceptions.

The participants of these events were administered a *manufacturing career perceptions survey*, that was differentiated by grade level, before and after the event. The surveys included a series of Likert scale questions adapted from a Deloitte survey used to measure parent's perceptions of manufacturing careers (Deloitte, 2017; Deloitte & Touche LLP, 2017). For the two older groups, the post-survey also included 5 open-response questions that aimed to provide additional insight about the experience. For each age group, the data analysis looked at the individual change in the 5-point Likert scale answers (i.e. 'Strongly Disagree' = 1 to 'Strongly Agree' = 5) from pre- to post-survey and used qualitative thematic coding (Saldaña, 2016) to analyze the open-response questions. For all three groups, "the greatest change in perception was related to participants increasing their consideration of a career in manufacturing, followed by an increased belief that many job opportunities exist and that manufacturing jobs are clean" (Strimel et al., 2020b, p. 12, 14, 16). It should be noted that while the average change for the "I would consider a career in manufacturing," statement was the greatest, the actual change diminished for the older students. This aligns with findings in SCCT research and supports the need for early intervention when attempting to influence career interests (Lent et al, 1994; Lent & Brown, 2013). All three groups (Strimel et al., 2020b) also saw the least change in perception regarding manufacturing careers being safe and creative. As for the open-response questions, the 6-8th grade group, "showed that the participants learned topics such as diversity in work, high salaries for manufacturers, and low education requirements, and were surprised by the cleanliness of the manufacturing facilities" (Strimel et al., 2020b, p. 13). The 9-12th grade group, "learned topics such as safety measures in manufacturing facilities, the skills needed for manufacturing, multiple job opportunities, and were surprised how manufacturing uses a variety of technology" (Strimel et al., 2020b, p. 17). Based on the research, Strimel et al. (2020b) suggest that it could be helpful to train the industry participants on how to interact with students of varying age; specifically citing that, "the language used can be frightening to students when discussing safety and personal protective equipment" (p. 22). Another suggestion presented had to do with the authenticity of the activities as they relate to the products. In the free response, multiple students referenced the activities that they were allowed to participate in; drawing on personal connections to the products or processes.

Barger, Gilbert, and Boyette (2013) examine a similar industry-driven manufacturing education initiative in Florida, in which the Florida Advanced Manufacturing Technological Education Center of Excellence (FLATE) aligned local manufacturers with students in the area in order to provide tours of advanced manufacturing facilities. According to Barger et al (2013), FLATE started facilitating tours in 2005 and up to the point of publication has "conducted 167 tours to 75 different Florida manufacturing sites, introducing 3917 middle, homeschooled, and high school students and 435 teachers and parents to the world of modern manufacturing" (pg. 2). Their report looked at anecdotal evidence gathered from stakeholders in both education and manufacturing, as well as survey results (N = 2369) gathered over an 8-year period. The purpose of their research was to provide a model based on FLATE's approach to organizing, facilitating, and evaluating tours, in order to help set up similar outreach structures. FLATE differentiates four unique styles of tour they provide and specify the participants and structure; stating that it is important to "know your 'customer'" (Barger et al, 2013, p. 2). The five different tour models that FLATE developed include 1-to-1 (one school class to visit one site for half a day), 1-to-many (one school group to visit two or more sites for a full day), many-to-many (two or more school classes to visit two or more sites for a full day), home school (one groups to visit one site for half a day), and many-to-1 (two or more school classes to visit one site for half a day). FLATE then gives some suggestions for setting up the tour, conducting it, and following up with stakeholders afterwards. Their process starts 6-8 weeks before the tour with finding a good match between school program and manufacturer, stating that it is important to, "Know what the company does, what it makes, how much time they need or want to have the students visit (usually 60-90 minutes), what areas of the plant students will see, and generally, what the host can offer for the tour" (p. 3). FLATE also suggests that the tour facilitator involve the teacher in preparation by sending the teacher information, educational resources, and even lessons on manufacturing, as well as the specific company they will visit, a few weeks before the tour. During the tour, Burger et al (2013) suggest that the tour facilitator help the students and teachers formulate questions, make sure giveaways are distributed, and ensure surveys are completed before the tour is over. After the tour, FLATE encourages both companies, as well as tour facilitators, to send follow-up emails thanking the participants, sharing the survey results, and sharing any photos that were taken (if permitted) during the tour. Perhaps an important distinction, in this application, the manufacturing companies are also encouraged to provide feedback through a short, online survey. Barger et al (2013) also explain the tours themselves and how FLATE attempted to optimize the experience, citing their outreach website (www.madeinflorida.org) as a method to distribute information about the tours, as well as informational handouts for the participants that included, "job, education requirements and wage information, information about what is manufacturing, list of local companies and what they make, [and] handout about robotics in manufacturing" (p. 5). After the tours, students were encouraged to take a survey, similar to those referenced above, in which students answered questions like, "I was considering a career in manufacturing before the tour," and "I am now considering a career in manufacturing or related technical industries" (Barger et al, 2013; p. 6). The results from these surveys (*N* = 2369) "show a 36% positive change in *agree* responses toward consideration of a career in high tech manufacturing after the tour" (Barger et al, 2013; p. 6). Another interesting result is that 61% of surveys stated that the tour gave them important information about manufacturing careers. FLATE also denotes the importance of parents in students' career decisions, and encourages manufacturers to provide parents with accurate, pertinent information regarding careers in manufacturing. One key suggestion from parents found through the surveys has to do with who actually gives the tour, citing that tour guides that did not work on the plant floor, "did not provide any insight about the particular jobs or required education and skill sets of any of the production jobs the touring students and parents saw on the floor" (p. 8). FLATE then offers recommendations for future tours; with tour extensions like *Industry Day*, or the *STEM Goes to Work* model, as well as hosting tours from summer camps and increasing the number of teachers/classes that participate. FLATE also suggests the tour facilitator survey the teachers, and encourages classes to do post-tour lessons, activities, and debriefing. FLATE also encourages industries to use the tours as a jumping-off point for long-term, self-sustaining, industry-school relationships. Finally, FLATE suggests that the tour facilitator align the tour to specific learning objectives, and provides a list of tips for industry tour hosts.

Another technique for teaching manufacturing concepts to students is to bring the technology to them, in the form of STEM labs and/or makerspaces. However, the trouble with teaching cutting-edge technology is that it is expensive (Sheridan, Halverson, Litts, Brahms, Jacobs-Priebe, & Owens, 2014). There are a few strategies for mitigating this problem. Among them is the implementation of STEM labs and/or makerspaces, so that technology can be consolidated to one area that people can visit in order to learn, play, and make (Vossoughi & Bevan, 2019). Throughout this research, different names have been used to describe the space in which students will participate in activities and learn through doing, but how do all of these different environments vary, and where does the industry-situated STEM lab that is the focus of this study fall in relation to them? While a STEM lab is not necessarily a makerspace, they are similar and makerspaces are becoming more frequent in our communities (Roy & Love, 2017; CAISE, 2019; Vossoughi & Bevan, 2019), leaving an opportunity to use the research on the subject to potentially draw parallels to see how these spaces are set up, used, and maintained in many different contexts.

Individuals working in STEM education and related industry recognize the term makerspace, but what exactly is the maker movement focused on doing? According to Vossoughi and Bevan (2019), the maker movement has three main categories: "making as entrepreneurship and/or community creativity, making as STEM pipeline and workforce development, and making as inquiry-based educational practice" (p. 5). The latter two categories are the focus of this research and are shared qualities with the concept of a STEM lab (Roy & Love, 2017). Currently, the STEM pipeline and workforce development focus heavily on high school and college students; providing them with both the skills that will help them become the workforce of tomorrow, as well as the confidence and interest to pursue careers in STEM fields (Vossoughi & Bevan, 2019). The third category, inquiry-based education, does not require expensive tools or a defined space, but rather focuses on supporting the students' interests and agency through curriculum and pedagogy. This last category can extend down to younger students and provide them with a context to build their confidence, identities, and knowledge as potential future manufacturing employees. These learning opportunities also provide students with an opportunity to interface with experts in the field and provide a meaningful context to the artifacts that they are making (Vossoui, Escude, Kong, & Hooper, 2013). Perhaps equally important to this equation is the pedagogical strategies used by instructors/facilitators in these spaces. Vossoughi et al. (2013) pose that instruction in these spaces should be a hybrid of formal and informal learning, focusing on building community, fostering creativity and courage to try new things, and using intellectually inclusive language, based on the age and ability of the students. In their review of the literature, Vossoughi and Bevan (2019) discuss student experiences in makerspaces, the pedagogy used, and the tensions and opportunities of makerspaces. They offer examples of research on makerspaces in schools, both primary and secondary, universities, museums, and community-center settings. This leaves a gap in the research in a specific area: how can the STEM Lab or makerspace paradigm be used in industry settings?

The manufacturing industry is no stranger to STEM labs or makerspaces. Both engineering and research and development efforts often use areas similar to spaces to design, prototype, and test products, but these differ from STEM labs and/or makerspaces because of the intended use (Hira & Hynes, 2018). Learning factories are another industry application similar to STEM labs or makerspaces and are more prominent in Europe. Learning factories are generally school-like environments built by companies in order to train their future workforce in a context similar to the environment they will be working in one day, with similar tools, procedures, and equipment as the actual company (Abele et al,, 2017). Abele et al. (2017) explain that, though they are not very prevalent in the United States, they have become widespread in Europe, with a wide variety of size, scope, and function. Learning factories are focused on secondary students and act as a bridge from school to a manufacturing job. As is discussed in this section, there are limited examples of this type of connection between industry and education in the United States, leaving a gap for initiatives similar to the focus of this research to fill.

Museums represent another potentially helpful example to look at when trying to understand how to create an influential learning experience in a shorter time frame (Wilkerson & Haden 2014). The Chicago Museum of Science and Industry (MSI), for example, has a "Welcome to Science Initiative," which aims to,

> "help children achieve their full potential in science by creating learning experiences inside and outside the classroom by removing barriers that exclude them from participating. Our unique youth-centered approach means we support students, and everyone involved in their success – families, educators, schools, and communities- in these ways:
>
> 1. Improve the quality of science teaching in schools. We provide skills and resources to teachers, administrators and schools through graduate-level professional development courses and support for whole-school improvement in science.
> 2. Connect science to children wherever they are. We support science programming in neighborhoods and outside the classroom with out-of-school-time programs like after-school science clubs, weekend youth programs and summer learning opportunities, along with engaging field trip experiences such as curriculum-linked Learning Labs and hands-on workshops that inspire creativity and innovation.
> 3. Showcase diversity in STEM Fields. We introduce youth to a range of STEM professionals -- people who look like they do, and come from communities like theirs -- at intimate discussions, large-scale events, specialized programming and throughout Museum exhibits" (2020, para. 1-4).

It may be helpful to look at museums, because structurally, the initiatives, activities, and exhibits are similar to the STEM Lab experience offered within a manufacturing facility. The rationale for likening the structures has to do with the time that students are involved and the informal learning environment. At the MSI, students come for one day and tour the museum and participate in activities led by museum employees. One difference, and potential improvement, is that the MSI "Learning Labs" has pre-and post-visit activities for students to do; effectively extending the impact on students beyond a limited time frame. The MSI is also useful because they have been doing research on their initiatives for over 5 years, and have published on the effect of their program on student learning and perceptions of science (Price & Vaishampayan, 2018; Falk, Koke, Price, & Pattison, 2018; Price & Chiu, 2018; Chiu, Price, & Ovrahim, 2015; Price, Pernot, Segovia, & Gean, 2015). While research has been done on informal learning environments such as museums, it should be noted that by their nature, these informal learning environments may be difficult to research due to their informal nature. As Naomi Berman says in *A Critical Examination of Informal Learning Spaces* (2020), "Despite a focus on the behaviors and perceptions of students in relation to their use, preferred attributes and qualities of these spaces and the social experiences they promote, the matter of causality in the relationship between different spaces and their impact on teaching and learning is an empirically contentious one" (p. 131). Moving forward, this would be an area of research that could prove helpful and apply to both research methods and out-of-school programs similar to the focus of this research.

2.5 Summary

This chapter attempted to consolidate and explain some of the pertinent literature relating to this research. The literature review starts with the problem; identifying contributing factors that play a role in the Manufacturing Skills Gap. Deloitte and the Manufacturing Institute (Manufacturing Institute, 2019; Deloitte, 2018) have highlighted the issues that pose problems to the future manufacturing workforce; giving some key areas that need to be addressed in student perceptions and awareness of careers in manufacturing. Similar large-scale research done by L2L reinforces the specific issues mentioned above, but provides hope that the next generation is in a position to improve (L2L, 2019). The next section lays out a theoretical framework for the research; explaining what Social Cognitive Career Theory is, the elements within the theory that pertain to how students develop interests and career perceptions, and how it might apply to this research. The final section of this literature review looks at some of the current strategies and initiatives that aim to improve both perceptions and awareness of manufacturing careers. These existing initiatives were used to benchmark both the strategies and the instruments used to evaluate this research. In the following chapter, the research methods, context, and data sources will be discussed.

CHAPTER 3. METHODOLOGY

3.1 Introduction

This chapter focuses on the specific data collection techniques employed in this research. The chapter starts by discussing the context of the research; providing a clear explanation of the environment in which this research takes place, the process that the students participate in, and a description of the student participants. This chapter then explains the research questions, the data collection procedures for each, and the instruments used to gather the data. After the data collection process for each research question is described, the data analysis methods will be explained in detail. Finally, the potential biases will be addressed, as well as the strategies that were used to mitigate these biases and enhance the trustworthiness of the study's results.

3.2 Study Context: An Industry-Situated STEM Lab

The focus of this study is to investigate one novel application of a STEM lab within an industry setting, a large automotive manufacturing facility, located in a Midwest state. The state in which this informal learning environment is located is a leader in manufacturing by percentage of jobs (Bureau of Labor Statistics, 2019) and has taken some concrete steps toward addressing the issues that contribute to the manufacturing skills gap. One such step was to create a state-sponsored organization, focused on creating a stronger and more competitive manufacturing ecosystem. This organization focuses one of its core tenants on education and workforce development to provide programs and services to enhance the talents and capabilities of Indiana's present and future manufacturing workforce. Though this organization has many manufacturing-related initiatives, the focus of this research project is tied to the implementation of an industry-situated STEM lab that was supported by this organization. The partnering automotive manufacturer now uses this STEM lab as an informal learning environment for students to engage in activities that tie to relevant concepts (i.e., programming, robotics, automation, assembly, computer aided design, 3D printing) in advanced manufacturing while experiencing their manufacturing facilities through a tour. When students participate in this experience, they visit with their class, take a catwalk tour of the manufacturing facilities where they can see production occurring (assembly lines, industrial robots, automated guided vehicles, etc.), and participate in a series of hands-on activities/stations within the lab for approximately two hours. The activities, which include virtual forklift operations, computer aided design and 3D printing, LEGO[tm] assembly lines, teaching/programming robotic arms, and modular robotic vehicles, have been developed to align with processes/practices that occur within the facilities. For example, the computer aided design and 3D printing is aligned with the manufacturers research and development process and provides examples of how engineers and industrial designers prototype and create new parts. A few more examples include a LEGO[tm] assembly line activity, which is aligned to their lean production processes, the modular robotic vehicles, which represents their automated guided vehicles, and the robotic arms, which align to their industrial robots. These activities are aimed at showing students the high-tech side of manufacturing, the careers that are available within the manufacturing ecosystem, and situating the manufacturer within the community, with the goal of improving student and teacher perceptions about careers in the field. The students that come through the STEM lab are anywhere from 5th to 12th grade (ages 10 – 18) and have varying levels of interest and prior knowledge about manufacturing. Teachers schedule the experience well in advance, and communication is facilitated through an employee whose job it is to run the space and give the tours. The students fill out a pre-survey or pre-drawing test prior to taking the field trip to the manufacturer, which is administered by the teacher and collected by the tour guide/facilitator upon arrival. The students spend about 4 hours at the site. They start by meeting in the lobby and walking through the facility to the STEM lab. From there, students (and hopefully teachers) participate in four, 30-minute activities as described above. The activities are run by the tour guide, as well as volunteers and interns, and the group of students are divided into four roughly equal groups, and cycle through each activity. After the activities, students are guided back through the facility to get lunch in the cafeteria for 30 minutes, and then given a standard 30-minute tour, and if time allows, possibly a longer 60 or 90-minute tour. Accordingly, this research aims to study what influence, if any, the tour, combined with the activities in the STEM lab, have on students' perception of manufacturing. It is the hope that through this research, different challenges to operating such a space in an industry setting will be identified, as well as opportunities to improve the activities, tour, and experience as a whole, alongside the data collection methods. To do this, data collected from the first year of implementing this STEM lab, were analyzed and interviews were conducted with the relevant stakeholders responsible for the implementation/operation of this lab.

3.3 Research Questions & Data Sources

This research centers on one specific application of an industry-situated STEM lab within the facilities of a large automotive manufacturer in the Midwest. The research questions that guided this study were:

1. What influence, if any, does an industry-situated learning environment (STEM Lab) have on the perceptions of careers in manufacturing for students?
    1. What influence, if any, does an industry-situated learning environment have on the perceptions of careers in manufacturing for students in grades 5 through 6 (ages 10-12)?
    2. What influence, if any, does an industry-situated learning environment have on the perceptions of careers in manufacturing for students in grades 7 through 12 (ages 12-18)?
2. What are the challenges and opportunities involved with establishing and operating an informal learning environment (STEM Lab) within a manufacturing facility?

3.3.1 Research Question 1 Data Sources

Research Question 1 is divided into two sub-questions. The purpose for dividing the questions by age has to do with the data collection instruments and the sources of the data. For each sub-question, the data were requested from the manufacturer following the institutional review board's protocol for pre-existing data. Following these protocols, the data, which were collected and de-identified by the manufacturer, were shared with the researcher. The data were collected from students living within the American Midwest and, because the manufacturing facilities will not give tours to any person under 10 years old, their age ranged from 10 to 18 years old. Both sub-questions for Research Question 1 followed the same timeline in regard to data collection. Either the pre-survey (designated for students in Grades 7-12) or the pre-drawing test (designated for students in Grades 5-6) was given by the teacher in their classroom up to a week before visiting the manufacturer and students were given the appropriate time and materials to complete it. On the day of the visit, the teacher delivered the pre-surveys or pre-drawing tests to the tour coordinator. As the students arrived in the morning and after some brief instruction, they participated in guided activities in the STEM lab, had lunch in the cafeteria, and then went on a tour of the facility. After the experience, the tour coordinator gave the teacher a stack of the blank post-surveys/post-drawing tests, and the students then left to go back to the school. Within a week timeframe, the teacher then administered the post-instruments in their class and returned the results to the manufacturer. It should again be noted that the researchers were not involved in the data collection. Each of the measures used are discussed in-depth in the following section, as well as why the instruments were used by the manufacturer, and what each instrument attempts to measure.

3.3.2 Research Question 2 Data Source

Following Institutional Review Board approval, Research Question 2 was answered by conducting, recording, and transcribing semi-structured interviews with the five stakeholders responsible for designing ($N = 1$), implementing ($N = 1$), supporting/funding ($N = 1$), and operating/maintaining ($N = 2$) the industry-situated STEM lab. Because these data were collected by the researcher and not a pre-existing dataset, the collection process will be discussed further in the following section.

3.4 Data Collection

3.4.1 Research Question 1 Data Collection Methods

For Research Question 1, de-identified data collected by the manufacturer were requested and analyzed following the appropriate Institutional Review Board protocols. These data consisted of responses to a *Manufacturing Career Perceptions Survey* and drawings from a "Draw-A-Manufacturer" test that were administered to students both before and after their industry-situated STEM lab experience. These data were collected by the manufacturer to help evaluate the implementation of their program and used by this study to gauge perception changes with regard to manufacturing. The following subsections will explain the two instruments used to gather data from student participants in order to answer Research Questions 1a and 1b.

3.4.2 Research Question 1a Instrument: The "Draw-A-Manufacturer" Test

Research Question 1a targets students in Grades 7 through 12 (ages 10-12) and used a pre- and post- "Draw-a-Manufacturer" test, in which students were asked to draw their thoughts about manufacturing. The pre-drawing test was provided to the students' teacher by the manufacturer to administer to the participants before the experience. In the pre-drawing test, students provided demographic information, and were given the prompt of:

> Draw what you think a manufacturing environment looks like. Who works there? What are they wearing? What objects do they have? There are no '*right*' or '*wrong*' drawings. Draw what you think is the best representation of manufacturing to you.

The "Draw-A-Manufacturer" test was adapted from the "Draw-A-Scientist" test used in previous studies to examine children's perceptions of scientific careers (Huber & Burton, 1995; Krause & Strimel, 2019; Langin, 2018). One rationale for using a drawing-based evaluation is based on the ages of the participants and their limited experiences with the manufacturing as well as the rich data it can provide in regard to their mental perceptions of the industry (Krause & Strimel, 2019). After the industry experience, student participants were given the same prompt to respond to with a drawing depicting their perceptions of manufacturing.

3.4.3 Research Question 1b Instrument: Manufacturing Career Perceptions Survey

Research Question 1b targets students in Grades 7 through 12 (ages 12-18) and utilizes a pre-and post-*Manufacturing Career Perceptions Survey*. This instrument included a series of Likert-scale questions adapted from a Deloitte survey that was used to measure parents' perceptions of manufacturing careers (Deloitte, 2017; Deloitte & Touche LLP, 2017). The specific survey used in this research was developed to look for specific criteria that pertains to student perceptions and aims to highlight potential causes for the perceptions (Strimel, Krause, Bosman, Serban, & Harrell, 2020). The *Manufacturing Career Perceptions Survey* starts with basic demographic questions and the main Likert scale questions has participants assess how much they either agree or disagree with certain statements on a 5-point scale. These questions are created to help determine each participant's perceptions, interest in, and prior experiences with manufacturing. The survey questions can be found below in Table 1. For the post-survey, 5 open-response questions have been added, in order to further understand the student's experience and to allow participants to provide additional details about their experience. The responses to these surveys were analyzed to understand the potential influence of the industry-situated STEM lab experience on the participants' perceptions towards careers in manufacturing. This approach also aligns with the survey methodology used by Mawyer (2016) for obtaining information on student perceptions of manufacturing.

Table 1

Pre- and Post-Manufacturing Career Perception Survey Questions/Statements

Question	Response Type
1. I have been encouraged to consider a job/career in manufacturing.	Likert Scale
2. I would consider a career in manufacturing.	Likert Scale
3. Manufacturing jobs pay well.	Likert Scale
4. There are many job opportunities in manufacturing.	Likert Scale
5. Manufacturers need to be well educated.	Likert Scale
6. Manufacturers need to have a college degree.	Likert Scale
7. I think manufacturing jobs are safe.	Likert Scale
8. I think manufacturing jobs are clean.	Likert Scale
9. I think a manufacturing career would let me be creative and innovative.	Likert Scale
10. I think manufacturing careers use new technology.	Likert Scale
11. I think a manufacturer needs to be highly skilled.	Likert Scale
12. I think manufacturing is important to the United States economy.	Likert Scale
13. I think there is a need for more manufacturers in the United States.	Likert Scale
*14. List what you learned about manufacturing.	Open-Response
*15. What surprised you about manufacturing?	Open-Response
*16. How would you explain manufacturing jobs to a friend who has not done a tour of a manufacturing plant or another manufacturing-related activity?	Open-Response
*17. What did you like about this experience?	Open-Response
*18. What would you change about this experience?	Open-Response

Note. The Likert scale question responses included; Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree.
*These questions were only asked on the post-survey.

3.4.4 Research Question 2 Data Collection: Semi-Structured Interviews

To collect data to address Research Question 2, the researcher conducted 60-minute, semi-structured interviews with five relevant industry stakeholders. The five different stakeholders held distinct roles related to the conception and operation of the STEM lab. To determine these stakeholders, the researcher worked with the manufacturer to identify 1) who was involved with designing the environment, 2) who was responsible for funding the initiative, 3) who was involved with scheduling/maintaining/operating the space, 4) who was responsible for planning and implementing the STEM lab activities, and 5) who was involved with making the decisions/hiring for the initiative. By looking at the different stakeholders involved with this space, this research technique fostered a richer understanding of how different stakeholders view the goals, challenges, and opportunities of implementing a STEM lab within a manufacturing facility. The semi-structured interviews consisted of a set of three preset, open-ended questions, with the opportunity for further clarification or follow-up questions (Saldaña, 2016). The semi-structured interviews included 3 main questions that related to each of the original research questions, as well as a question to clarify who is being interviewed, and their role in relation to the STEM lab experience. For each of the three main questions, the researcher also created a few sub-questions to help clarify the interviewee's responses and probe deeper if the responses were not complete. The exact questions can be found below in Table 2, though the semi-structured element allowed for tangents to be followed and additional questions to be asked for clarification and additional understanding (Berg, 2001). In order to maintain consistency in the results, the same initial questions were asked to each interviewee, before delving further as necessary. The researcher recorded the audio of each interview. The audio was then transcribed, analyzed, and coded using the NVivo Qualitative Analysis Tool to look for trends and common issues that might lead to improved understanding of the challenges and opportunities of running a space such as this. Emergent coding was employed to categorize the participant responses, and thematic coding was used to organize the codes around central themes related to the specific research questions as well as the Social Cognitive Career Theory framework that this research is situated within.

Table 2

Semi-structured Interview Questions

Questions
Who is being interviewed? What is their job title? What are their responsibilities?
1. What are the challenges associated with the Industry-situated STEM Lab?
2. What are some opportunities for improving the Industry-situated STEM Lab?
3. How do you think the Industry-situated STEM Lab and tour of the manufacturing facility impacted student perceptions of careers in manufacturing?

3.5 Data Analysis

3.5.1 Research Question 1 Data Analysis

The data that were analyzed to answer Research Question 1 were collected by the manufacturer in order to evaluate their program. These data were then requested by the researcher following Institutional Review Board exemption protocols. Accordingly, the surveys/drawing tests were de-identified by the manufacturer and then delivered to researchers in PDF format using a temporary and secure storage system for sharing files. Both the drawing-test and the surveys included questions on participants' demographics. These questions looked at participant age, race, and gender, and were compiled to better understand the participants. However, the analysis for the drawings and the surveys differed, which is explained in the subsequent sections.

3.5.2 Drawings

The drawings collected from the “Draw-A-Manufacturer" test were analyzed using the NVivo qualitative analysis software. First, both pre- and post-drawings were reviewed by the researcher and the assembled research team, which included faculty (1), undergraduate researchers (2), and graduate students (2) actively involved in research and practice related to manufacturing outreach and education. This process was used to establish a set of themes; creating a list of keywords or phrases that describe the theme and its relationship to the research questions. It should be noted that previous work has been done with these instruments (Strimel et al, 2020a), so there was an existing set of codes that were leveraged to inform the coding process. This previous work served as a starting point for refining the codes. To set up the research, the coding categories were divided into pre-test, post-test, and demographics. By adding these categories, it was easier to examine how many times a particular code appeared in each pre- and post-test; which assisted in understanding the potential broad shifts in students' perceptions. The demographics category was added for ease of understanding who the participants were. When establishing the codes and, in turn the themes, the research team worked together; using peer debriefing to mitigate potential biases. The research team looked through several drawing samples together, and using the previous list of codes, determined where the coding list needed to be expanded or further explained. In addition, this peer debriefing process enabled the research team to identify the prevalent themes in the drawings and determine the specific elements of the drawings that pertained to those themes as well as the potential relationship of these drawings to the STEM lab experience. The research team then looked at each of the drawings and highlighted specific elements to sort them into the appropriate codes. This process was completed for both the pre- and post-drawings, to account for the interpretations that needed to be made when analyzing the drawings, the research team was used to reach a consensus in regard to the coding of the data. Additional measures for reliability and trustworthiness were also enacted which are discussed in the following section. The pre- and post-drawing code counts were then used to determine, overall, if there was a thematic change in the drawings from before the industry-situated STEM lab experience to after, as well as highlight any other interesting themes that emerge based around the research question.

3.5.3 Surveys:

The surveys were collected, de-identified, and shared as pdf files by the manufacturer following the appropriate institutional review board protocols. Demographic information was then counted individually, and the percentages were calculated from these individual counts. To analyze the non-demographic data, two separate methods were employed for the Likert scale question responses and the open-ended question response. For the Likert scale questions a second document was created in Microsoft Excel and the data were organized and cleaned (unusable/unanswered responses entered as NULL). The responses to the questions were also transformed to numerical values (i.e., 'Strongly Disagree' = 1 to 'Strongly Agree' = 5) in order to use statistical methods to understand potential shifts in perceptions from pre to post. As the survey data were de-identified by the manufacturer prior to sharing it with the researcher, the pre- and post-survey responses had to be treated as independent samples. Therefore, a Mann-Whitney U test was used to determine if there were any significant shifts in perceptions from before and after the experience. This method was deemed the most appropriate as the responses to the Likert scale questions are considered ordinal and discrete data within a limited range. These characteristics can violate the assumptions of parametric tests. And, as this non-parametric test analyzes the median of the samples, it is less susceptible to the influence of outliers. In addition, a study by de Winter and Dodou (2010) showed little to no difference between using parametric and nonparametric tests with 5-point Likert style questions. The researcher used the SPSS software to conduct the Mann Whitney U test with the independent sample groups being the Pre-Survey participants and the Post Survey participants. The null hypothesis for this test was that there was no statistically significant difference between the median responses to the survey questions by those completing the survey before the event and those completing the survey after the event.

For the open-response questions, the participant responses were loaded into the NVivo qualitative data analysis software and thematically coded. The codebook was generated by first looking over the participant responses and then working with the research team to determine recurring themes for each question. Additional codes were included for the open-ended responses that reflected the Social Cognitive Career Theory framework which included self-efficacy, outcome expectations, and influences. The additional codes from this framework were included to better interpret how the elements of Social Cognitive Career Theory can directly relate to students and their perceptions of manufacturing careers, as well as the learning experience directly. The researcher read each open-ended question response and coded each response into these codes. Those results were used to further understand the student’s experience, as well as provide additional data regarding the challenges and potential opportunities as Research Question 2 asks.

3.5.4 Research Question 2 Data Analysis:

Upon approval from the institutional review board, semi-structured interviews with relevant industry stakeholders were conducted. Due to health concerns and the current social climate during the public health crisis created by COVID-19 in 2020, the researcher had to interview the participants through a web service and record the interview. During the interviews, the researcher asked 3 pre-set questions and recorded the audio for the responses. Discussion of each question lasted about 20 minutes, and the researcher used additional probing questions to better understand the responses of the respondents. The resulting audio recordings were then transcribed by the researcher. Once transcribed, the files were imported into the NVivo qualitative coding software for descriptive coding, similar to the drawings in Research Question 1a. The researcher read the transcripts while also listening to the audio recording to break down the participants' answers to each question into distinct codes, describing each with a specific word or phrase. After coding the transcripts, the key phases/words were analytically coded by organizing a hierarchy of themes, parent, and child codes that relate to the research themes and main research questions (Saldaña, 2016). Those codes were totaled for each question and used to determine the trends that might help understand the main research questions.

Table 3 provides an overview of the research design of this study, including the data collection and analysis methods for each research question and sub-question.

Table 3

Research Design

Research Question	Data Collection Method	Response Type
RQ1a: What influence, if any, does an industry-situated learning environment have on the perceptions of careers in manufacturing for students ages 10-12?	Existing data collected from a “Draw-a-Manufacturer” pre- and post-test. Gathered and de-identified by the manufacturer over the course of the first year of the LDL.	Thematic coding based on revised codebook created through previous work.
RQ1b: What influence, if any, does an industry-situated learning environment have on the perceptions of careers in manufacturing for students ages 12-18?	Existing data collected from a “Manufacturing Career Perceptions Survey” pre- and post-test. Survey includes Likert scale and post-test includes open-response questions. Gathered and de-identified by the manufacturer over the course of the first year of the LDL.	Mann-Whitney U assessment for questions on Likert scale to look for a shift in broad differences on specific questions. Thematic coding for open-response questions.
RQ2: What are the challenges and opportunities involved with establishing and operating an informal learning environment within a manufacturing facility?	Five, 60-minute, semi-structured interviews conducted remotely with relevant industry stakeholders.	Emergent coding, followed by thematic coding of interview transcripts, broken up by question.

3.6 Trustworthiness

In the interest of trustworthiness and the credibility of this research, there are a few contextual elements that need to be addressed. The researcher had a background working in manufacturing-related outreach and has participated in events in the industry-situated STEM lab and the surrounding community. Members of the research team have also utilized the same instruments in this study, but in different contexts. Because of this, it was paramount that certain precautions were taken when the data were interpreted, the interviews were conducted, and recommendations were made. As the key individual conducting the interviews, it was possible that the researcher affected the way in which the questions were asked, certain data were interpreted, and how the outcomes were reached. To mitigate this potential bias, the researcher member-checked the findings throughout the interviews to ensure the results accurately reflected the participants’ views (Gay et al, 2017). As for the drawings and surveys, the researcher used code-recode strategies, peer debriefing, and previous studies (Strimel et al., 2020a) when creating the list of codes, and utilized other members of the research team to also interpret the drawings and surveys. Finally, this research was mostly qualitative in nature, and, as such, used data and observations gathered from each of the methods to properly triangulate the results (Gay et al, 2017). It was the hope that by using each of the methods in conjunction with another, the research questions were addressed in a more balanced, complete way.

3.7 Summary

The chapter opens with a description of the context in which this research took place, as well as a description of how the industry-situated STEM lab was used by the manufacturer. After explaining the context and listing the research questions, the next section covered the methods for both the data collection and analysis processes for each of the research questions. Research Question 1 was separated into 2 sub-questions due to the nature of the data collection process. To analyze the data from Research Question 1, existing data were descriptively coded and analyzed to understand how students' perceptions changed before after their industry-situated STEM lab experience. Research Question 2 used semi-structured interviews with key industry stakeholders in order to understand the challenges that come with implementing and operating an industry-situated STEM lab environment. The interviews were transcribed and analyzed with descriptive coding processes to identify themes pertaining to each of the research questions. This chapter concludes by acknowledging potential issues with bias, and explaining the strategies used to improve the trustworthiness of the results by triangulating the different methods.

CHAPTER 4

FINDINGS

4.1 Introduction

The purpose of this chapter is to report the findings from this study. This study was guided by two research questions which were addressed using three sources of data which included the draw-a-manufacturer test, the manufacturing career perceptions survey, and semi-structured interviews. The findings related to the analysis of these data will be presented in the following sections by each research question and explored for interesting insights that help to better understand the problem under investigation.

4.2 Research Question 1a Results

This section will look at the results from Research Question 1a and report out interesting or pertinent themes that were observed through shifts in the data from pre- to post-draw- a-manufacturer test. A total of 357 participants, between the ages of 10 and 14, completed the pre-drawing and post-drawing activity. The participants were roughly split between male (N = 143) and female (N = 162), with 52 choosing not to answer, and consisted of mostly 10 and 11-year-olds. The participants were mostly white (N = 232), with “other” and Hispanic being the second largest ethnicity represented. The demographic breakdown of the participants can be found below in Table 4.

Table 4

Participant Demographic Information

Gender	Male	143
	Female	162
	Did Not Answer	52
Age	10	152
	11	162
	12	31
	13	2
	14	3
Race/Ethnicity	Asian	2
	American Indian	5
	African American	25
	Hispanic	39
	White	232
	Other	53

Prior to the students' visit to the manufacturing facility, the participants were asked to complete the draw-a-manufacturer test which prompted them to think about and then draw what they believed manufacturing workers look like, what kind of equipment they might have, and what kind of environment they might work in. Following the industry-situated STEM lab experience, the participants were asked to complete the same drawing test. From the drawings generated by the pre- and post-tests, several themes were identified and coded. The codes for the identified themes are described in Table 5, as well as the number of times that each instance was observed on both the pre- and post-tests.

Table 5

Codes for the Themes Identified in the Drawings from the Participants ages 10 - 14 (N = 357)

Parent Code	Sub Code	Description	Frequency Observed	
			Pre	**Post**
Environment	Non-Production Facility	The building appears to have a section that is used for management.	2	2
	Multiple Rooms	The building is drawn with multiple rooms.	17	12
	Smokestack	The building is drawn with a smokestack.	42	9
	Inside	The view of the building is from the inside.	29	11
	Outside	The view of the building is from the outside.	34	7
	Mystery Box	A plain box is drawn representing a stereotypical factory.	95	50
Manufacturing	Stock Materials	There are stock materials in the drawing.	3	1
	Quality and Control Testing	Testing for quality is displayed in the drawing.	3	4
	Shipping and Receiving	There is a component of shipping and receiving in the drawing.	4	1
	Sub-Assemblies	There are sub-assemblies in the drawing.	38	121
	Suspended- Assembly	There are suspended assemblies in the drawing.	4	135
	Conveyor Belt	There are conveyor belts in the drawing.	58	40
	Automotive	There are elements of the automotive industry drawn.	326	329
	Repair	There are cars/parts being repaired.	49	28
	Manufacturers Logo	There are the manufacturer's logos in the drawing.	51	31
	Car Parts	There are car parts in the drawing.	226	270
People	Collaboration	There is an element of teamwork and collaboration in the drawing.	33	18
	Female	There is a female person drawn.	33	16
	Male	There is a male person drawn.	55	23
	Multiple	There are multiple people in the drawing.	102	84
	Individual	There is a single person in the drawing.	132	69
Technological Artifacts	Console	There is a console or controls in the drawing.	5	3
	Computer	There are computers in the drawing.	9	9
	Other	There are other technologies in the drawing (e.g., VR)	7	0
	Hand Tool	There are hand tools in the drawing.	79	18
	Robotic Arm	There are robotic arms in the drawing.	87	143
	AGV	There are AGV's in the drawing.	0	3
Safety Elements	Areas	There are markers or specific areas designated for working or walking.	10	21
	PPE	There are elements of PPE (safety glasses or steel-toed boots) in the drawing.	59	24
	Uniform	People in the drawing have on a uniform.	113	38

Upon reviewing these drawings, it can be noted that on the pre-drawing tests some of the participants drew what could be considered "mystery box" buildings (*N* = 95). This is where the participants represented manufacturing by sketching a large box shaped building that often had a smokestack on top (see Figure 1). However, after the experience, the number of these "mystery box" buildings decreased (*N* = 50), and the participants drew more detailed drawings of the inside of manufacturing facilities which included robots, assembly lines, car parts, and tools (See Figures 2 and 3). The participants' drawings had a stark decrease in people featured from pretest to post-test (*N* = 234 to *N* = 153) which is could be linked to the large number of interesting things, such as robotic arms, automobile subassemblies, suspended assembly lines, that are featured during the hands-on activities within the STEM lab and the tour. However, in regard to the people drawn on the post-test, the participants drew fewer individual people (*N* = 69) than people working together (N = 84) which was the opposite on the pre-test. Additionally, the participant's drawings displayed almost twice as many males (N = 55) working than females (N = 33) before the experience, and after the experience, the drawings displayed less of a gap between female (N = 16) and male (N = 23) associates. After the experience, the number of people using hand tools, like hammers or screwdrivers, decreased from 79 to 18, while there was an increase in the presence of robots (N = 87 to N = 143) that were involved in the production. Lastly, there was a noticeable shift from pre-test (N = 49) to post-test (N = 28) in regard to participants drawing the repairing of vehicles as representing manufacturing. As such, these changes in the drawings from pre to post-test (See Table 5) may highlight influences that the experience had on the participants' perceptions of manufacturing.

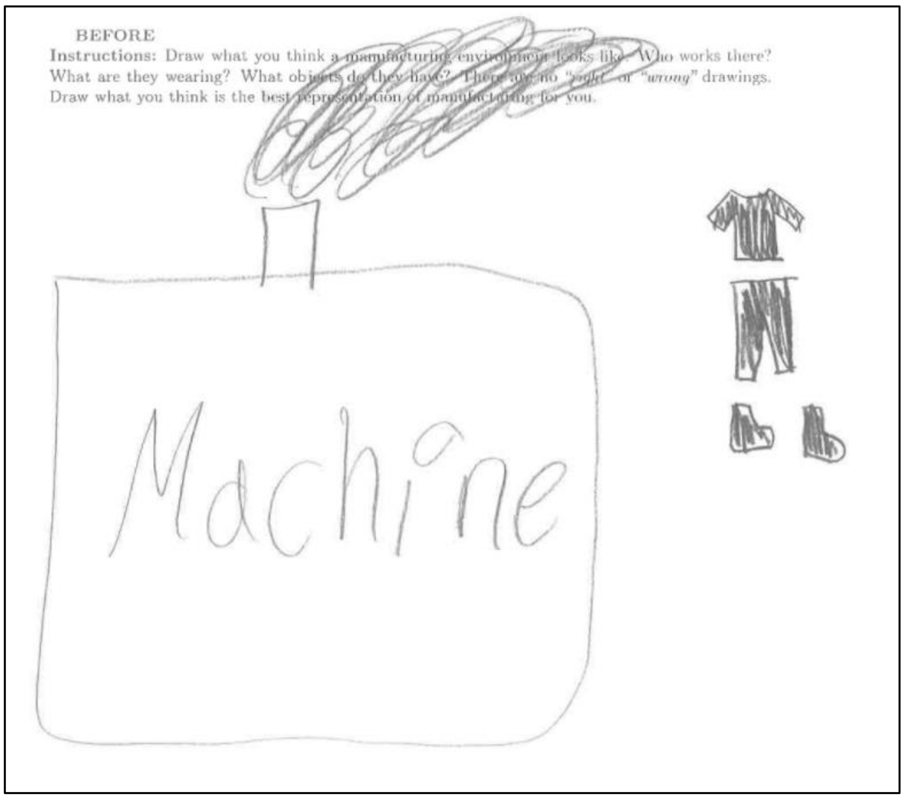

Figure 1. An example drawing showcasing a block, 'mystery box' building.

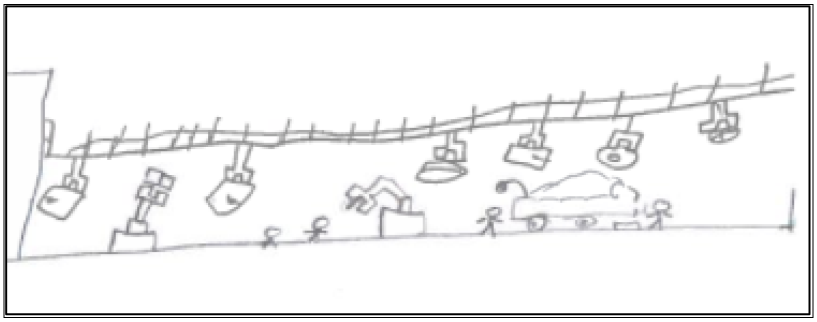

Figure 2. An example drawing showcasing a detailed manufacturing space.

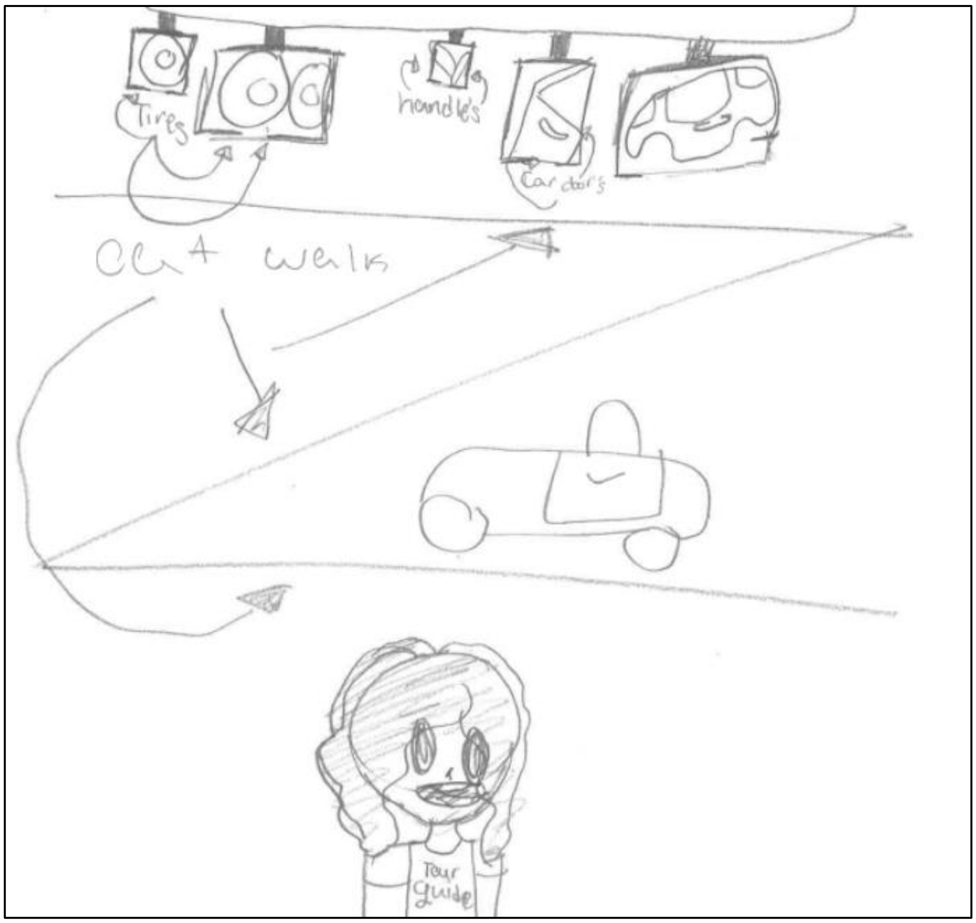

Figure 3. An example drawing showcasing a detailed manufacturing space with people and safety areas.

4.3 <u>Research Question 1b Results</u>

Research Question 1b looks at the potential influence of the industry-situated STEM lab experience on students in grades 7 through 12 (ages 12-18). This question was addressed using the dataset gathered by the manufacturer using a manufacturing career perceptions survey.

A total of 151 students from 7 local schools participated in this survey before the experience, while 106 students participated in the survey after the experience. The specific demographics for the students participating in this survey can be found in Table 6. The results for this survey are separated into two categories, Likert scale questions and open-ended responses, and each category required the use of different methods for analysis. The first section required the use of a Mann-Whitney U test to identify potential shifts in perceptions of manufacturing related to each Likert scale question. The five open-ended response questions, that were asked on the post-survey only, were analyzed using thematic coding. The results of these analyses are presented in the following subsections.

Table 6

Research Question 1b Participant Demographic Information

		Pre	Post
Gender	Male	39	21
	Female	62	65
	Did Not Answer	50	20
Age	13	1	0
	14	9	1
	15	15	20
	16	21	25
	17	45	32
	18	26	24
	19	3	2
	20	1	0
	Did Not Answer	30	2
Race/Ethnicity	African American/Black	23	1
	American Indian/Alaskan Native	1	1
	Asian	2	2
	Latino/Hispanic	41	27
	White/Caucasian	61	74
	Other	2	0
	Did Not Answer	21	1

4.3.1 Likert Scale Questions

Careers in manufacturing can span a wide range in regard to the individuals who work to design, produce, transport, and support a company’s products. However, students have shown to hold common misperceptions towards the manufacturing industry such as the lack of cleanliness, safety, and creativity. Accordingly, this study investigated the potential influence of an industry-situated STEM lab experience on the participants' perceptions of manufacturing. To do so, the participants completed a set of Likert scale questions related to careers in manufacturing both before and after the industry-situated STEM lab experience in order to determine any potential changes in their perceptions. The Likert scale questions were presented as statements to the participants while asking them how strongly they agreed or disagreed with each statement (i.e., ‘Strongly Disagree’, ‘Disagree’, ‘Neutral’, ‘Agree’, and ‘Strongly Agree’). In a spreadsheet, the responses to these questions were organized into columns by individual questions and converted into a numeric scale from 1 to 5 (i.e., ‘Strongly Disagree’=1, ‘Strongly Agree’=5) for further analysis.

After the data had been organized in spreadsheets, they were uploaded to the SPSS software to determine the statistical significance, if any, between the pre- and post-surveys responses to each question. With these types of questions and the data limitations discussed in Chapter 3, it was deemed most appropriate to use a non-parametric test for the analysis. As the goal was to compare the differences between two independent sets of data, pre-survey responses and post-survey responses, and test for significance, the Mann-Whitney U test was used for this analysis. To run the analysis, pre- and post-data were placed consecutively in columns with a corresponding column that denoted from which survey the response was found (i.e., ‘pre’=1, ‘post’=2). Once organized, the Mann-Whitney U test was run with the outcome of determining whether or not there was a significant difference between the pre-survey and post-survey responses for each Likert scale question.

The results from the Mann-Whitney U test were analyzed in accordance with the null hypothesis, or the hypothesis that two specified samples have no significant difference. For this study, the null hypothesis entails that the distribution of the given question is the same across categories of pre- and post- survey responses. If the resulting significance value was ≤ 0.05, the difference between the groups was deemed significant; if the resulting significance value was > 0.05 however, the difference was insignificant. A significant answer rejects the null hypothesis and demonstrates that the industry-situated STEM lab experience may have influenced a shift in perception among the participants from pre- to post-survey.

While the survey instrument has its limitations, the analysis did reveal that 7 of the 13 Likert scale questions were found to be statistically significant. First, the analysis shows that there was a significant difference between the pre-survey and post-survey responses toward more participants indicating that they have been encouraged to consider a job/career in manufacturing. However, there was no statistically significant shift as to whether the participants would consider a career in manufacturing. While there was no significant change between the pre-and post-survey in regards to career interest, there was a significant difference between the groups showing more students on the post-survey 1) viewing manufacturing jobs as well-paying, 2) believing there are many job opportunities in the industry, and 3) thinking that there is a need for more manufacturing in the United States. In regards to the questions related to whether or not a manufacturing career would a) allow them to be creative and innovative, b) require the use of new technology, c) require an employee to be highly skilled, or d) be important to the United States economy there were no statistically significant differences found as the participants maintained their mostly positive views on these topics. On the other hand, the analysis did reveal a shift in perceptions related to the cleanliness and safety of manufacturing jobs which has been a long-standing misperception of the industry. Lastly, there was no statistical difference found in the way the participants viewed manufacturers as needing to be well educated as the pre-survey and post-survey respondents both mostly agreed with this statement. But an interesting finding was there was a significant difference between the pre- and post-survey respondents when presented the statement that manufacturing employees need a college degree whereas more of the post-survey respondents reported a lesser degree of agreement with the statement. The complete results from the Mann-Whitney U test are provided in Table 7 and can provide insight toward the influence that industry exposure can have on student perceptions of manufacturing.

Table 7

Mann-Whitney U Analysis Results

Question	Total Responses	Median pre	Median post	Mean Rank pre	Mean Rank post	Mann-Whitney U	Standard Error	Significance	Null Hypothesis Decision
I have been encouraged to consider a job/career in manufacturing	255	3	4	112.94	149.17	10141	554.387	0.0000	Reject
I would consider a career in manufacturing.	257	3	4	122.88	137.71	8926.5	553.836	0.095	Retain
Manufacturing jobs pay well.	257	4	4	117.69	145.12	9711.5	519.093	0.001	Reject
There are many job opportunities in manufacturing.	256	4	4	110.91	152.39	10588.5	533.524	0.000	Reject
Manufacturers need to be well educated.	257	4	4	134.39	121.33	7189.5	550.153	0.139	Retain
Manufacturers need to have a college degree.	257	3	3	140.62	112.44	6248	549.244	0.001	Reject
I think manufacturing jobs are safe.	255	3	3	117.99	142.30	9377	530.372	0.005	Reject
I think manufacturing jobs are clean.	255	3	3	118.33	141.81	9325	536.883	0.007	Reject
I think a manufacturing career would let me be creative and innovative.	254	4	4	126.11	129.47	8029	534.705	0.699	Retain
I think manufacturing careers use new technology.	254	4	4	122.63	134.52	8530	520.172	0.161	Retain
I think a manufacturer needs to be highly skilled.	254	4	3.5	131.47	121.77	7204	538.56	0.268	Retain
I think manufacturing is important to the United States economy.	255	4	4	122.37	136.04	8719.5	529.573	0.111	Retain
I think there is a need for more manufacturers in the United States.	253	4	4	118.27	139.51	9049.5	536.783	0.015	Reject

4.3.2 Open-Response Questions

In addition to the Likert scale questions, the post-survey also included five open-ended questions to solicit the participants' reflections on their industry-situated STEM lab experience. Thematic coding was used to analyze 97 responses to these questions to identify prevalent themes related to the participants perceptions of manufacturing and the influence of the STEM lab experience. The results were broken down for each specific question, as well as how the overall results related to the literature on student career selection, specifically focusing on elements from Social Cognitive Career Theory. Topics that were broadly mentioned included participants' surprise at the speed of which manufacturing plants work, the importance of social interaction in the company, and misconceptions surrounding the number, diversity, and complexity of the careers in manufacturing.

The count and description of each code for each open-ended question is provided in Table 8. The first question, "List what you learned about Manufacturing," was divided into themes relating to both extrinsic and intrinsic motivation, as well as process-oriented learning and responses with a negative interest (N = 16). The extrinsic motivations (N = 4) related to pay and benefits, while the intrinsic motivation responses (N = 30) related to personal interest, relevance, and social factors. The negative interest, as a theme throughout the open-responses, had to do with the difficulty (N = 8) and the time requirements (N = 4) for the job, as well as students that were either uninterested or already knew everything. Finally, students seemed to be the most interested in the process (N = 47); noting that they learned something about the speed and complexity of the process, or the implementation of technology and safety.

The second question, "What surprised you about manufacturing?" was separated into themes that related to manufacturing processes and organization, as well as the misconceptions that participants had. Participants were surprised by the complexity and interconnectedness of the process; citing elements of assembly (N = 18), safety (N = 7), and technology (N = 9). Other participants focused on the organization itself and expressed both positive (N = 23) and negative (N = 10) surprises about the careers within. A small number of participants (N = 5) said that they were not surprised by anything throughout the experience.

The third question, "How would you explain manufacturing jobs to a friend who has not done a tour of a manufacturing facility?", yielded the least inspiring results. Students had both positive (N = 11) and negative (N = 6) perceptions, as well as defined what they saw and deferred to the tour itself.

The fourth question, "What did you like about the experience?" provided an understanding of the high points and was separated into themes that look at the environment, experience, and learning. Participants said they enjoyed the social aspect to the environment (N = 10), as well as the technology found within (N = 5). Participants also mentioned the activities (N = 19), the food (N = 5), and the tour (N = 26). Participants enjoyed learning from both the activities within the STEM lab (N = 8) and the tour (N = 18).

The final question, "What would you change about the experience?" gave participants an opportunity to suggest changes to the experience. The results for this question were divided into themes that related to general changes to the experience, and more specifically, changes to the procedure. Many participants (N = 28) had no suggestions, while others mentioned things like communication or expectations (N = 7), changes to the environment (N = 8), and making the experience more interactive (N = 9). Other suggestions focused on changing the activities (N = 7) and the tour (N = 18).

As shown in Table 9, when these open-ended responses were analyzed according to the literature on self-efficacy and outcome expectations, the experience left more students with a negative view of their self-efficacy (11 negative to 6 positive), while more students had positive outcome expectations (7 positive to 2 negative) if they chose to pursue a career in the field. Students cited self-efficacy issues like, "it takes long and hard work," showing a lack of confidence to excel in an area that requires attention to detail and repetition of hard work, which is itself a misperception identified by the literature (Deloitte, 2018). However, students referenced positive outcome expectations, citing the pay and saying things like, "I learned that a lot of manufacturing jobs have health benefits." Finally, more students identified barriers (N = 17) to entry, saying things like, "Need to provide hard work and to work 24 hours straight to provide the best cars," compared to supports (N = 13) they view (e.g., "I learned that you do not have to have a degree"). These results reinforce the perceptions that Deloitte and the Manufacturing Institute (2018) discusses in the Skill Gap Report. The complete analysis of the open-ended responses is provided in Table 4 from which can provide insight toward the influence that the industry-situated experience can have on student perceptions of manufacturing.

Table 8

Coded Responses from Open-Ended Questions

Parent Code	Sub Code	Description	Frequency
List what you learned about manufacturing.			
Extrinsic	Benefits	External Factors that motivate individuals, excluding monetary gain.	3
	Pay	Specifically refers to the pay.	1
Negative Interest	Indifference	Either answered with "nothing", "idk", or expressed that they didn't learn anything new.	4
	Challenging	Expressed that the work was too challenging.	8
	Length	Expressed that the work would take too long.	4
Intrinsic	Positive Interest	Relating to the individual personally or to why they would want to work there.	10
	Relevance	Relates to a larger scale, such as factors relating to the individual's future or the world as a whole.	10
	Social	Relating to how individuals work with others professionally or socially.	10
Process	Speed	Factors that deal with the speed of the work done.	15
	Technology	Relating to technology seen or experienced.	10
	Safety	Relating to safety and its impact on the process.	8
	Assembly	Relating to the length of the physical construction of the products.	14
What surprised you about manufacturing?			
Parent Code	Sub Code	Description	Frequency
Manufacturing - Process	Assembly	Referring to the length of the assembly process or the scale of the building.	18
	Safety	Discussing the safety precautions seen.	7
	Technology	Referencing the impact of technology on the process.	9
Manufacturing - Organization	Negative	Expressing a negative perception of the company or the work that occurs.	10
	Positive	Expressing a positive perception of the company or the work that occurs.	23
Misconceptions	Scale	Relating to the size of the building or the size of the company.	11
	Speed	Relating to the speed of production.	8
	Cleanliness	Relating to the cleanliness of the facility.	4
	Nothing		5
How would you explain manufacturing jobs to a friend who has not done a tour of a manufacturing facility?**			
Parent Code	Sub Code	Description	Frequency
General	Deferred	Answers advising an individual to go somewhere else to learn about it.	1
	Definition	An attempt at a definition.	3
Perception	Negative	Expressing a negative perception about the company.	6
	Positive	Expressing a positive perception about the company.	11
What did you like about this experience?			
Parent Code	Sub Code	Description	Frequency
Environment	Social	Relating to the social aspects of the company witnessed.	10
	Technology	Relating to the impact of technology on the process.	5
Experience	Activities	Discussing the activities individuals partook in.	19
	Food	Relating to the food eaten for lunch.	5
	Tour	Referencing the tour taken during the experience.	26
Learning	General Learning	General statements about what was learned.	8
	Interactive Activities	Specific take-aways from the hands-on aspects of the activities.	7
	Technology	Specific knowledge gained related to the technology witnessed and used.	1
	Tour	Referencing specific items seen on the tour.	12
What would you change about this experience?			
Parent Code	Sub Code	Description	Frequency
General	Communication	Relating to communication surrounding the experience.	7
	Environmental	Relating to the general environment such as sights, smells, or temperature.	8
	Interactivity	Relating to what was able to be done during the experience.	9
	No Change	No change was expressed.	28

(continues)

Procedural	Activities	Procedural changes, such as time, location, or planning, related to the activities.	7
	Lunch	Procedural changes, such as time, location, or planning, related to the food and lunch.	4
	Tour	Procedural changes, such as time, location, or planning, related to the tour.	18

**Note. This question was at the top of the second page and seemed to have been missed by a majority of participants.

Table 9

Overall Social Cognitive Career Theory Codes

Parent Code	Sub Code	Description	Frequency
Influences	Barriers	Items that would lower the odds of an individual working at this company.	17
	Supports	Items that would raise the odds of an individual working at this company.	13
Expectations	Negative	Referencing potential negative outcomes, whether intrinsic or extrinsic.	2
	Positive	Referencing potential positive outcomes, whether intrinsic or extrinsic.	7
Self-Efficacy	Negative	Implying an individual does not have the interest or skills to work at this company.	11
	Positive	Implying an individual has interest or skills to work at this company.	6

4.4 Research Question 2 Results

Research Question 2 was addressed by conducting semi-structured interviews with five key industry stakeholders to better understand the challenges and opportunities that are associated with implementing, maintaining, and operating a space similar to the industry-situated STEM lab from different points of view. The transcripts of the interviews were analyzed to identify common themes that recurred both throughout and across different interviews. This section will highlight the results of this process. The themes, as well as the specific codes, and the number of times they are observed. To align with Research Question 2, the codes were divided into challenges (Table 10) and opportunities (Table 11), with each category containing codes relating to environment, the activities, the process of operating the lab, and the research elements associated with the lab.

Table 10

Codes for the Themes Identified from Semi-Structured Interviews - Challenges

Parent Code	Sub Code	Description	Frequency
Environment	Size	Indicated a challenge with the size of the environment or number of students.	8
	Acoustics	Challenge with being able to hear and provide instruction.	2
	Infrastructure	Problems with the AC, Location, or Internet.	8
Activities	Technology	Challenges with specific technology upkeep, and maintenance.	10
	Participation	During activities, challenges with number, age, or difference of ability of different types of participants	8
	Curriculum	Challenges with creating and implementing activities and educational material.	6
	Differentiation	Challenges with applying learning materials to diverse age/ability range.	8
	Meaningful- Learning	Challenges with creating meaningful learning due to limitations with time and technology.	8
Process	Scheduling/ Coordination	Challenges with logistics of scheduling and coordinating the experience.	7
	Stakeholders/ Responsibilities	Challenges with specifying communication between stakeholders from education, industry, and support (Higher-Ed).	11
	Time	Challenges with time allotted for the experience.	5
	Staffing	Challenges with staffing the LDL for activities and support for creation of educational materials.	8
Research	Perceptions	Challenges with anticipating initial misperceptions.	4
	Goals	Challenges with clear goals and metrics for success.	23
	Data Gathering	Challenges with tracking ROI.	1

Table 11

Codes for the Themes Identified from Semi-Structured Interviews - Opportunities

Parent Code	Sub Code	Description	Frequency
Environment	Alternative Location	Opportunity to move to alternative space for various reasons.	5
	Integrated MFG Principles	Opportunity to integrate manufacturing principles into the design of the lab.	2
	Multiple Rooms	Opportunity to isolate activities in different rooms.	5
Activities	Technology	Opportunities for improving, maintaining, and utilizing technology within the lab.	13
	Participation	Opportunities for involving different stakeholders to utilize the lab.	15
	Curriculum	Opportunities for improving, diversifying, and creating new educational materials.	17
	Differentiation	Opportunities for aligning activities and experience to different users.	22
	Tour	Opportunities to improve the tour process.	5

(continues)

Process	Additional Time	Ability to use extended time to further educational experiences.	5
	Stakeholders/ Responsibilities	Opportunities to create communication network that better aligns stakeholders.	19
	Data Gathering	Opportunities to articulate and obtain specific metrics.	8
	Staffing	Opportunity to provide meaningful learning for all stakeholders.	18
Research	Perceptions	Opportunities to utilize research to identify and address current misperceptions.	12
	Depth & Complexity	Opportunities to illustrate diverse career fields in manufacturing.	5

The environment theme pertains to the physical elements of the Lab and display challenges with the size (*N* = 8) of the lab, the acoustics (*N* = 2) and resulting distractions, and the infrastructure (*N* = 8) such as air conditioning, location within the facility, and WiFi connection. The opportunities identified with the environment either suggested changing the location (*N* = 5), adding additional rooms (*N* = 5), or altering the environment itself to align with industry standards (*N* = 2); reflecting safety and workplace conditions with Six Sigma principles.

The next theme identified relates to the activities that students participate throughout the experience. The challenges represented through the interviews were coded into issues with limitations of the technology (*N* = 10), the diverse number and age of the participants (*N* = 8), creating and implementing new educational materials (*N* = 6), adapting materials to different potential users or age groups (*N* = 8), and challenges with creating meaningful learning experiences (*N* = 8) within the existing context. With regards to the activities, opportunities were identified relating to improving the technology (*N* = 13), diversifying the participants (*N* = 15), creating new learning materials (*N* = 17), differentiating existing materials to account for context (*N* = 22), and improving the tour (*N* = 5).

The next theme identified related to the procedure of establishing, scheduling, and staffing the lab. The issues identified in this theme include challenges with communicating with participants and coordinating the schedules and transportation (*N* = 7), with many noting the lack of time for the experience (*N* = 5), establishing and maintaining communication and involvement between stakeholders from industry and education (*N* = 11), and staffing the lab with personnel that are available and knowledgeable of the lab equipment/activities (*N* = 8). Opportunities identified for improving this process include adding more time through creative scheduling and facilitation of activities (*N* = 5), creating a channel for improved communication between stakeholders (*N* = 19), implementing and gathering relevant metrics related to the impact of the lab experience on employment (N = 8), and creating rich learning opportunities for the staff (N = 18).

The final theme established relates to the challenges and opportunities for improvements related to the research practices of the lab. Through the interviews, the challenges identified relate to the current understanding of student perceptions of manufacturing (N = 4), the lack of a concise, unified, and measurable goal (N = 23), and the current understanding of the return of investment for the STEM lab experience (N = 1). The opportunities for improving the research are separated between improving the understanding of student manufacturing perceptions (N = 12) and exploring the diversity and depth of fields in the manufacturing ecosystem (N = 5).

The complete analysis of the semi structured interviews are presented in Tables 10 and 11. These tables can provide insights toward the challenges and opportunities for implementing industry-situated STEM labs within a variety of informal learning environments, specifically within manufacturing facilities.

4.5 Summary

This chapter presented the findings that were a result of the various data collection and analysis techniques. The results were organized by research question and divided by the specific data sources used to address each question. For example, Research Question 1a looks at the pre- and post-drawing test done by participants and the results show an initial vague understanding of manufacturing on the pre-test, and a more specific focus on technology in the post-test. Research Question 1b used a pre- and post-survey, aimed at understanding student perceptions of careers in manufacturing. The results were separated into the Likert scale questions on the pre- and post-surveys, and open-response questions on the post-test. The results from the Likert scale questions show significant shifts in questions relating to encouragement to pursue a career in the field, the pay and opportunities for jobs, the education needed, safety, and cleanliness, as well as the need for more manufacturers in the US. The open response questions were thematically coded to both gain a deeper understanding of perceptions of the experience, as well as align with the literature surrounding career selection. The resulting themes showed that students learned about the complexity of the manufacturing process and both the personal and social relevance of the careers within the facility, were surprised by the complexity of both the technology and the social dynamics of the workplace, as well as the breadth and depth of the different facets of the manufacturing ecosystem, were indifferent on how they would explain the experience, enjoyed the activities and tour, and recommended better initial communication of expectations and more diverse activities. Research Question 2 was addressed by conducting five semi-structured interviews to gain a deeper understanding of how the industry-situated STEM lab was established, maintained, and operated. The chapter concludes by discussing the results of the interviews, identifying challenges associated with, and opportunities for, improving the environment, the activities, the overall process, and the research associated with the lab.

CHAPTER 5. CONCLUSION, DISCUSSIONS, & RECOMMENDATIONS

5.1 Introduction

This chapter will focus on the interpretation of the study's results, identifying and articulating some common themes found throughout the research, and providing recommendations for establishing and enhancing industry-situated STEM labs as well as conducting further research in the area. The recommendations are separated into four sections which includes 1) identifying metrics for success, 2) engaging stakeholders, 3) breadth vs. depth of experience, and 4) the industry-situated STEM lab itself and exploring additional uses.

5.2 Conclusions

The purpose of this research was to understand the influence that an industry-situated STEM lab experience has on students' perceptions of careers in manufacturing. This study analyzed participant pre- and post-draw a manufacturer tests as well as manufacturing career perception surveys that included Likert-scale items and open response questions. These measures were selected to work within an existing set of data in order to better understand student perceptions of manufacturing and the careers within. The drawing and survey data were collected by the industry, de-identified, and shared with the research team. Along with these data sources, five semi-structured interviews were conducted with industry stakeholders in order to understand the conception and operation of the STEM lab, as well identify any challenges or opportunities to improve or replicate success for other industries. From there, the data were analyzed through thematic coding for the drawings, open-response questions, and interviews, and a Mann-Whitney U test was performed on the survey results in order to look for general shifts in responses to specific questions from before to after the STEM lab experience. The results gained from the three different data collection techniques were looked at in aggregate and used to triangulate specific understandings, questions, and recommendations.

As evidenced by the data collected, the results confirmed a lack of students' awareness and understanding of manufacturing, misperceptions surrounding the careers within, and a disconnect between industry needs and educational output. Along with the data, literature on vocational psychology supports the need for students to participate in authentic learning opportunities to build self-efficacy and form more accurate outcome expectations with regards to future career selection. However, the data did reveal that the industry-situated STEM lab experience likely led the participants to an improved understanding of the manufacturing ecosystem and provided an opportunity for local educators to engage with industry. While this research looked at a novel application of a STEM lab and highlighted its influence on students' perceptions of manufacturing careers, there is obviously no "silver bullet" for fixing the talent pipeline for manufacturing and continuous work in this area needs to be done.

5.3 Discussion of Results

This section will discuss the results for each of this study's research questions; identifying interesting findings and exploring implications and possible explanations for each.

5.3.1 Research Question 1a (Drawings)

Research Question 1a used pre- and post-drawings to understand the influence of the industry lab experience on students' perceptions of manufacturing. The pre-drawings show a vague initial understanding of what happens inside a manufacturing facility. Many drawings show a box with a smokestack and a product of some kind. These initial understandings seem to demonstrate that students have either not thought about what manufacturing is, or do not understand what happens inside a manufacturing facility. The post-drawings, however, are much more focused on specifics, often depicting specific technologies shown throughout the experience. For example, the tour has students stop at the point where the car doors are being attached to the cars and students are about 10 yards from the suspended conveyor belt where doors are slowly moving along. An overwhelming number of drawings included this exact scene, as shown in Figure 4.

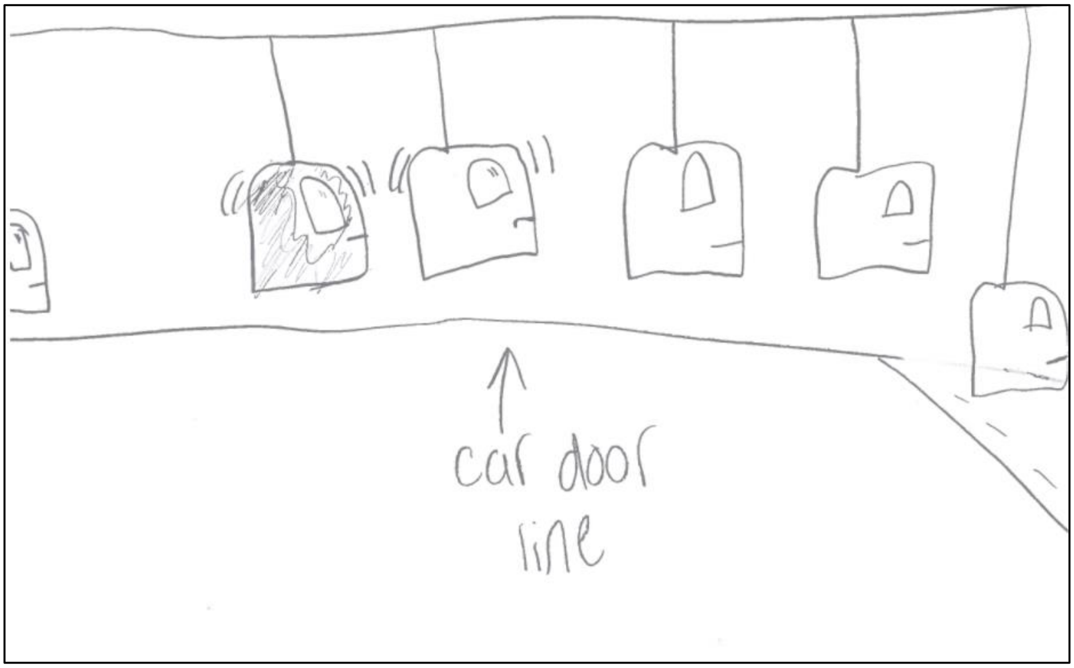

Figure 4. An example drawing showing the suspended assembly line.

It would seem that the tour itself impacted students' understanding of manufacturing more than the hands-on activities, based on the frequency of elements drawn relating directly to instances discussed on the tour. With that said, many of the robots depicted in the post-drawing looked similar to the robots used in the activities, though due to limitations with interpreting children's drawings, that could just be how they perceive robots. Another interesting finding has to do with the type and number of people depicted in the pre- and post-drawings. The post-drawings had less people, and the people depicted looked different. The shift in the number of people makes sense when compared to the number of drawings that depict specific technology, but it could be understood as one person is responsible for more work, aided by that technology. The people in the post-drawing had fewer hand-tools, more personal protective equipment, and uniforms; potentially demonstrating that students have a better understanding of what associates do there. Almost all of the people (and technology) in the drawings focused directly on the production roles. This makes sense, as it is what students observe through the tour and what relates to the activities they do. It may also mean that students still do not fully understand the different roles or fields within manufacturing that may not directly interact with production processes (i.e., administrative, managerial, finance, etc...). This may be an opportunity for improvement, as discussed in a subsequent section.

5.3.2 Research Question 1b (Likert Scale Items):

Research Question 1b used a pre- and post-survey in order to understand participants' perceptions of manufacturing careers and the industry-lab experience. The results of the survey's Likert scale items were analyzed with a Mann-Whitney U test to look for shifts in answers from pre- to post-survey. Of the 13 Likert scale questions asked, a significant difference between the pre- and post-survey samples were found in regards to 7 of the questions asked. First, the results revealed that participants in the post-survey group felt more encouraged to consider a career in manufacturing than those in the pre-survey group. This result is not surprising, considering the experience in which students took part. The results also showed an improvement of student perceptions of the pay and availability of manufacturing jobs; no doubt as a result of the experience. The only statement with a significant shift in the negative direction stated, "manufacturers need a college degree." The results of the surveys also showed a positive shift in perceptions of both cleanliness and safety within manufacturing; addressing two misconceptions identified by the literature. Finally, the last significant shift was on the statement, "I think there is a need for more manufacturers in the United States." The results showed a shift toward improving students' misperceptions, but not necessarily a shift in willingness to pursue a career in the field. Generally, participants displayed an improvement in the perceptions that they were explicitly shown or told during the experience.

5.3.3 Research Question 1b (Open-Response Questions)

The open-end survey questions yielded more interesting results. As seen in these responses, participants took note of the complexity of the production floor and the role of the associates that work there, saying things like, "building a car is a long process," and "I learned you have to be a team player." When asked what surprised them about manufacturing, many participants talked about the scale of manufacturing with regards to the physical environment or time (N = 18) and the operations and production that goes on there (N = 23). For example, participants said they were surprised by, "how many things there are to do," and, "how many different parts of the plant there were." The takeaway here is that some students had the perception that production was one-dimensional; emulating what they might have learned about manufacturing from a history class. Other aspects, such as the safety ($N = 7$), cleanliness ($N = 4$), and speed of the facility ($N = 8$) also surprised students, with one participant saying they were surprised by, "how much cleaner it actually was." Many of the response's students gave had to do with information either directly communicated with during the experience or common misperceptions that align with the literature.

The third open-ended question was, "How would you explain manufacturing jobs to a friend who has not done a tour of a manufacturing facility?" This question could probably be eliminated, because the goal is to condense an entire ecosystem down to a definition that is limited by a teenager's willingness to answer survey questions by writing with a pencil. To add to that, the way that the survey was laid out, the question was at the top of the page and many students seemed to have missed it entirely. Those that did answer gave explanations like, "you have to be able to work quickly and get things done safely," and "they are clean and safe places to work and think about their workers." Many answers made manufacturing seem unappealing or difficult, but this might be because the jobs are demanding.

The fourth and fifth open-response questions asked participants what they liked about the experience, and what they would change, respectively. Students seemed to like the social aspects of the company and careers within, saying, "it was great to see the large variety of jobs as well as hear first-hand about the experience that is to work in a manufacturing plant." Students also said they enjoyed the lab activities as a whole ($N = 19$), describing them as, "very organized and hands-on," as well as the specific things they learned ($N = 7$), such as, "building LEGO's©, using VR, using the robots, and using the 3D printers." Participants also seemed to enjoy the experience ($N = 26$) and the information given ($N = 12$) on the tour, with one participant saying, "I liked seeing all the workers putting the cars together." While these results are flattering, it must be taken with a grain of salt, as the question asked what they enjoyed. That said, the tour experience seems to be a high point for many students, and this should be validating for the current model. As for the changes that the participants would make, many students said they would not change anything ($N = 28$). Other students suggested changes to the process, saying things, "I would like to have more time for the activities," and simply, "longer lunch." Some students suggested changes to tour, but of those changes, many focused on how far they had to walk or how they could not engage and interact with the tour, saying things like, “I would have worn better shoes,” and “I wasn’t able to take pictures.” As for the lab itself, students pointed out flaws with the infrastructure and placement of the room, saying things like, “the lab room was too hot!” It seems that students seemed to cite the tour more frequently than any other parts of the experience when expressing specific likes and dislikes. This might be because the tour is more impactful than the activities, or it might be because the activities were not as effective as they could be. It is hard to say for sure, but these results do provide an interesting jumping-off point for further research and recommendations.

Another benefit to the open-response questions is that they seem to give an insight into some of the elements related to Social Cognitive Career Theory. While participants as a whole seemed to enjoy the experience, many students (N = 17) pointed out barriers by saying things like, “need to provide hard work and to work 24 hours straight to provide the best cars.” Furthermore, with regards to participants’ self-efficacy, more students felt they did not have the skills or interest to be successful in the field (N = 11 vs. N = 6), saying things like, “[manufacturing] takes lots of hard and long work,” despite higher instances of positive outcome expectations (N = 7 vs N = 2). Looking at the results of the surveys and open-response questions from 10,000 feet, there seems to be a general trend of students correcting common misperceptions, but not feeling that they are interested in or capable of being successful within the manufacturing ecosystem. This seems logical, as we cannot expect to change the entire trajectory of a student’s career goals in four hours. That said, the results show encouraging signs related to the positive impact this has on students’ awareness of what manufacturers do and the depth and diversity of careers in the field.

5.3.4 Research Question 2 (Interviews)

Research Question 2 was addressed through the thematic coding of semi-structured interviews in order to provide a better understanding of the perceptions of alternate stakeholders, as well as challenges to implementing the experience and the opportunities for improving it. The results of this section are divided into the challenges and opportunities that the participants mentioned during the interviews. One of the main challenges that came up in the interviews had to do with the technology becoming obsolete, breaking, or creating a bottleneck in the process (N = 10). This can be a common problem for group work when it comes to educational technology, as it can be expensive to have one piece of equipment per-person. When asked, “So when you say they're not interested, what makes you say that? Why do you think that is?” one participant said, “The student is sitting at the Dobot station with his friend and his friend is moving around, having fun, experimenting with the Dobot arm while they're just sitting there, kind of staring blankly either at the robot or talking to their friend at a different station or a different robot instructing someone else.” Another challenging area relates to the communication channels between the various stakeholders; saying things like, “the biggest thing with that is just the school getting here on time because the schedules are made in advance,” and “logistics on how we turn them through the lab and then also on top of that, their allotted school daytime because then when you add the bus trips and, you know, you really only get them for a handful of hours.” Many participants also pointed out the challenge of creating meaningful learning in the context provided, saying things like, “if you have a student that didn't quite grasp, understand what was going on, you just didn't have time to sit down with them and help them figure it out. So it kinda felt like a waste for them. Because they weren't able to really accomplish anything so the timing was definitely a big issue,” and, “going on a field trip is great, you go back to class and you forget about it.” The most-mentioned challenge relates to the lack of clear goals that are in place for the lab. Each different stakeholder mentioned a different goal when asked, and some even mentioned different goals throughout the same interview. One participant said the goal of the space was to, “The stakeholders, which is industry and education, need to start at the beginning together and talk about what it is that they want and what those steps are that they feel are going to take to get those students to have those skill sets to be able to work with an industry,” and when asked again later in the interview, said “For some kids that's not the goal. The goal of these labs are debated, implemented in everyday activities in their day-to-day. You know, standard of work.” Different stakeholders might have different goals, but when asked what metrics were in place to monitor those goals to determine success, one participant simply said, “none.” The lack of metrics seems to indicate that proper SMART (specific, measurable, achievable, relevant, and timely) goals were not set or communicated when the lab was created, and different stakeholders have different ideas of what the lab is for.

Through the interviews, some interesting areas were identified as opportunities for improvement of the space, activities, process, and research. One common opportunity identified had to do with extending the experience to different types of stakeholders ($N = 15$), such as teachers, administrators, or community organizations. Another area identified as an opportunity to improve focused on expanding the curriculum and creating new educational materials (N = 17), with one participant saying, “Whether it's replacing a current activity or adding a new one, I think there's always an opportunity for that. I know when we first opened it, it was just the LEGO© assembly line, 3D printing, the robots, and the virtual reality. But there's a lot of times we found that there were too many students at each activity.” That said, the existing activities also represent an opportunity to be adapted to different age groups and ability levels (N = 22). One participant said, “It was a pretty simple activity and so there's definitely ways to expand upon it, and there's definitely other opportunities out there that are more complicated that require more thought, more energy, more planning, but it's just what you want. It's just all about what you want to do. We realized there was a discrepancy and we needed a little bit more.” One interesting area that had lower numbers of instances focused on the tour (N = 5). This lack of instances is both surprising and encouraging, and along with the other data collection results, the tour seems effective and enjoyable for students. Similar to the challenges, participants identified opportunities to improve the channels and methods of communication between stakeholders from both industry and education (N = 19), with one participant saying, “there's perspective pieces that can be written in, you know, in an industry that should have a voice in that and education should as well, and there should be an obvious partnership there, but there's not.” And finally, another interesting opportunity pointed out had to do with staffing the room for activities and creating educational materials (N = 18). It seems that the staff also gains a great deal from participating in the lab, with the lab’s pre-service teacher/intern saying things like, “I didn't realize this when I first came here to [college], but manufacturing is a huge aspect of this community. There's a lot more manufacturing plants than I realized there were,” and, “I just think it was a really cool opportunity. Not only for the students, but also for me as, you know, a college age individual, I never experienced a manufacturing facility and I have, uh, multiple uncles who work at manufacturing plants, yet I had never been to one, so I think it's a super awesome experience for someone to go through no matter who.”

In summation, Research Question 2 asked about the challenges and opportunities present in the lab and overall student experience, and while the data collected from Research Question 1 had limitations due to how it was gathered and shared with the research team, the data from the interviews proved to be helpful when offering specific areas to be addressed. It is the hope of the research team that this novel application of an industry-situated STEM lab does not suffer from the “paralysis by analysis” curse, but is willing to utilize the recommendations given in the following section to not only refine research strategies, but to improve and extend the experience to more people.

5.4 Recommendations

This section utilizes the triangulation of literature and the findings from the different data collection techniques to provide recommendations for improving the industry STEM lab experience, as well as a starting point for how this concept may be adapted to other scenarios or environments. The recommendations are divided into 4 main sections and should be viewed as a starting point and are by no means comprehensive.

5.4.1 Exploring Metrics for Success and Future Research Recommendations

What is the goal of the STEM lab and tour? Based on the interviews, it seems to change, depending on who you ask. The different goals that were mentioned in the interviews had to do with career awareness and recruiting, education, and understanding perceptions. None of these goals are mutually exclusive, but there seems to be a lack of a clear, concise goal for the lab and with that, limited metrics for success. Stakeholders from both industry and education need to agree on the goals in order to define metrics for meeting those goals, so communication needs to take place between the stakeholders at all levels; including teachers, researchers, community organizations, and industry staff. If the goal is to increase the talent pipeline for manufacturing careers, then that seems like a tall order for a roughly 4-hour experience. If that is the goal, then what careers are the industry trying to fill and how can the industry track success in that mission? As previously mentioned, there seems to be a disconnect between the jobs that need filled, and the jobs that are advertised. One potential solution is to add a question to job applications that reads something like, “How did you hear about this job?” This question could include a response that lists the STEM lab experience and could be used as a metric for success and return of investment.

If the goal for the lab is learning, then “bodies through the door” does not seem like the best metric for success. Meaningful learning takes time, and time was a recurring limitation. Museums seem like the most applicable model for experience-based learning on a similar timeline, and even they implement pre- and post-visit activities (Wilkerson & Haden 2014). If the goal truly is education and learning, students need to reflect on the experience and participate in activities that are developmentally appropriate based on their age and ability, else we risk negatively impacting their self-efficacy and deterring them from careers in the field. One solution for this might be to incorporate multiple visits, pre- and post-visit activities, and a more in-depth connection to specific classes, which will be covered in a subsequent section.

If the goal is to further understand student perceptions of manufacturing, then improvements can be made to both the tools and the processes used to collect the data. One improvement that could be made is to utilize a retroactive pre-survey, so participants could more accurately gauge what they learned by reflecting on their understanding prior to the experience after they have completed it. This might offer a better representation of the learning that took place. An alternative strategy for gauging learning and perception changes would be to interview focus groups; potentially increasing the bandwidth at which feedback can be gathered and utilizing the group to reach consensus on commonalities. Another improvement to the data collection tools would be to add a simple Likert scale question to the pre-surveys that displays moods from sad to happy using either words or pictures. This solution might help to better understand how a student's mood about the experience might impact their results. Another possible question to add would be, "Have you participated in this experience before?" This question would be used to understand if students have done something similar before and might be interesting to look at how drawings/survey answers change over the course of multiple visits. One more recommendation has to do with understanding students' self-efficacy. One question could be added to the open-response, "Do you think that you would be successful in a career in manufacturing? Why or why not?" This question would aim to understand student self-efficacy and outcome expectations and how those might relate to the experience.

5.4.2 Engaging Different Stakeholders

Another area for improvement has to do with the staff involved with operating, maintaining, and improving the lab, as well as other associates that could be used to improve the experience. One solution might be to identify key personnel within the facility that are excited to talk about what they do and get them involved in the tour or activities. In order to drive home the complexity and depth of careers in the manufacturing ecosystem, participants should get the opportunity to speak with associates from diverse careers, fields, and educational backgrounds. Based on the literature around modeling and observational learning, students are more receptive to learning and imitation from those that they view to be similar in some way. To emphasize this, associates from relevant fields should be identified and incentivized to talk about their job, background, and why they chose a career in manufacturing. These associates should include new hires, associates without a college degree (preferably ones with interesting hobbies outside of work), and associates in non-production fields.

While the retirees and volunteers are low-cost and helpful, there are opportunities to improve the staffing of the lab. Based on the interviews, the preservice teaching intern is a must, and the benefits seem to go both ways. The intern learns about the complexity and depth of manufacturing, while the lab gets someone that can not only help run activities but can help create new educational materials using a background in teaching. From the perspective of the intern, this is a great opportunity to utilize the concepts they are learning in the educational courses to create activities and educational materials in a fun, novel context. That said, there are also opportunities to extend opportunities to others in education. The space could also leverage local in-service teachers through an externship program over the summer to create curriculum and prepare materials for a more in-depth connection to their own classroom, as well as more broadly. Educational and state-sponsored resources (similar to economic development committees and universities) could also provide support by covering associates' time or offering something similar to grants for associates that present plans for local educational outreach. Another way that higher education could contribute is through a practicum for pre-service teachers or a service-learning course similar to the *Engineering Projects in Community Service* program (EPICS, 2020). The practicum would not only provide the bodies to help run the activities, but would give teachers, especially non-technology/engineering teachers, an opportunity to learn and engage with the manufacturing ecosystem. The system is already in place for the practicum, but instead of shadowing a teacher in a classroom, pre-service teachers could work with students to run activities. As for the service-learning approach, this seems like a home run, and if there was only one recommendation that is utilized to make a concrete change, it should be this one. Student-led, community-based projects are already going on in the area this research took place, and even focus on similar projects and spaces. This would allow crossdisciplinary teams of both undergraduate and graduate students to solve problems and improve the effectiveness and reach of the lab, all while drawing on local talent. To create this course would take a champion within the university, whether it is a graduate student or a faculty member, but once started, the students would work with the person that runs the lab; collaborating as a team to improve the space, the activities, and the outreach strategies in the community.

Finally, if this space were to be emulated, it is recommended that the person running the space fit a certain profile. The person in charge of the space needs to have a background in education, technology, and potentially human resources, and have strong interpersonal and written communication skills. Their responsibilities would be to run the lab, coordinate and communicate with stakeholders from local K-12 and higher education, schedule the experience, engage local schools to further learning, guide curriculum development, find and utilize new educational technology, and create metrics to monitor and build a local pool of talent through different initiatives. In the interview, one participant brought up a few different potential titles, saying, “These types of positions are new to industry. Some have education directors. There are few and then you know a lot of it falls within HR,” and, “some of them have community outreach people that they'll deem as a community outreach liaison. There's not a lot of positions like that, so I'm really trying to get industry to understand that they need to invest in positions like that.”

5.4.3 Breadth Versus Depth

This section will cover perhaps the most important, and most concrete, recommendations that this research can offer. Currently, the lab experience seems to be focused mostly on career awareness but can miss out on meaningful learning as the experience is similar for all ages. This could be due in part to the limitations on time. In order to make the most of the time, pre- and post-visit materials could be given to teachers so that students are primed to learn and reflect on their experience (Barger et al, 2013; Wilkerson & Haden, 2014). Based on the literature and the themes identified in the Research Question 2 results, one opportunity has to do with the differentiation of materials, processes, and terminology based on age and goals. There should be different goals for different age groups. The breakdowns for the age groups could be as follows: 5th-8th grade, 9th-10th grade, and 11-12th grade. Younger students would focus on seeing what a manufacturing facility looks like, whereby addressing misconceptions and introducing foundational skills, while the goal for older students is to engage and retain students, as well as teachers, that are interested in the manufacturing ecosystem and will have to make important decisions regarding their future career in the near-future. For the sake of coherence, instead of thinking of future talent as a pipeline, as we've so often heard, let's think of it as a funnel, similar to the one shown in Figure 5. The following is a breakdown of what each age group could focus on and, much like a funnel, the more in-depth the content is with older students, the fewer students there will be in those groups. The subsequent paragraphs offer concrete suggestions for differentiation of the tour, activities, and additional materials, based on the grade level of the participants.

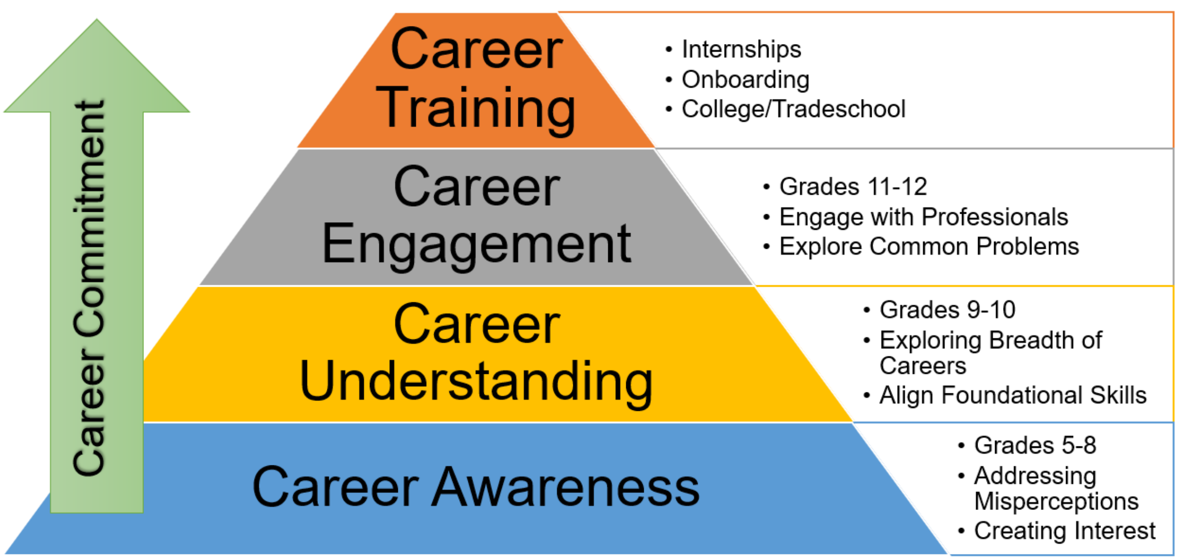

Figure 5. Infographic for the Manufacturing Talent Funnel as it relates to the Industry-Situated STEM Lab.

Younger students are often more open to changing perceptions than those about to graduate. Students might be less likely to actively take part in certain actions, and thus less likely to set goals in fields that might carry a negative perception without building those positive, self-effecous experiences, so once can't hope to change students' career choice to manufacturing without letting them explore and grow interests, because manufacturing might be a socially "risky" choice. Furthermore, once students form interests, they are less likely to change them. As Lent et al. (1994) state, "Once interests crystallize, it may take very compelling experiences to provoke a fundamental reappraisal or career self-efficacy and outcome beliefs and, hence, a change in basic interest patterns" (p 89). Basically, students are unlikely to set goals in careers that they do not think they are capable in. That sentiment is perhaps exacerbated in manufacturing specifically because students need to have early positive experiences in order to build self-efficacy if their goal of a career in manufacturing goes against a societal norm like going to college. This is where the perception can play a big role, because parents and other adults that have a poor perception of manufacturing careers can share that view with their children, and both the parents and the children may never have to interact with anyone in manufacturing, despite using manufactured products every day. Parents are, however, more likely to cross paths with employees in the service industry, as well as the entertainment, technology, or information industries through technology and culture. So, while other career perceptions can be changed naturally through exposure and time, students may never have to interact with the manufacturing industry at all. That said, grades 5-8 could focus on exploring and understanding what manufacturing is and how it relates to their everyday life. These students will have to select pathways in high school that can be difficult to transfer out of, and will often influence the career they might choose, so manufacturers should want students to make those decisions with at least a basic understanding of their options with regards to manufacturing. In order to start the funnel, manufacturers could focus on introducing relevant skills that future manufacturers might need, as well as address misconceptions about the field that students might have learned through the media and social studies classes. For the tour, this age group should focus on using easy-to-understand language to describe what a manufacturing facility does, and the types of people that work there. Tour guides should emphasize the use of technology, and break misconception of repetition and dark, dirty, dangerous environments. At this age, it is also important to engage the teacher and use them as an example, as this may be their first experience in a manufacturing facility, and they act as a model for students. Based on the drawings, the tour guide should utilize key moments that students remember to point out how different STEM fields interact with manufacturing, for example, the paint section of the facility would be a great time to introduce how chemistry is used to make sure that the paint is the right color and sticks to the car perfectly every time. The tour guide could also continue to anthropomorphize the robots on the line and make the tour fun. Granted, fun is subjective, but the facilitators should remember that these are kids, not employees, and the tour guide can be a little silly. The existing activities are perfect for this age group, but one improvement might be to gamify them. For example, the Lean LEGO© Line activity could be timed, and those times could be written on the wall as a leaderboard. The same could be done with the other activities as well. Another effective tool with this age is to send them home with something 3D printed. Because the speed of 3D printing creates a bottleneck, it prevents large numbers of students from designing and printing something that they made, so have something already printed for them ready to give out before they leave. More activities could be added for this age group, but it should be considered that there is a time limitation, and students need adequate time to participate in the activities. A possible solution to this would be to make the trip a full-day experience, lasting 5-6 hours instead of the current four. For the older grades in this group, it might also be helpful to talk about featured jobs that relate to the activities; denoting the pay, benefits, educational requirements, training needed, and the classes that they could take that might relate to it. These featured jobs might also include a profile of a person that currently works there, their contact information, and a picture of them. Attention should also be given toward diversity within these job roles.

The next group, 9-10th grade, should focus on career understanding and the complexity and diversity in the manufacturing ecosystem. This would be more than an introduction, and therefore would benefit from additional materials for the students to work through both before and after their experience. These materials could be as simple as having students prepare questions to ask during the tour. To create more in-depth materials, the manufacturer could work with the stakeholders previously mentioned through the opportunities for staffing to align content to standards and developmentally appropriate and engaging activities. For this age group, the tour should focus on the complexity of the production floor. This might mean taking the time in front of the door conveyor belt to talk about sub-assemblies and the role of the original equipment manufacturers that work with automotive facilities like this. This would also be a good time to have either materials or an associate to talk about the complexity of the supply chain. While touring the production area, the tour guide could point out how math, science, and technology concepts that are within their standards are at work, such as the trigonometry and geometry that is used in the cartesian coordinate system that the industrial robots use. In order to identify and relate these subjects to the elements seen on the tour, industry could work with teachers of different age levels and fields to identify key concepts that relate to their existing curriculum. This age could also tour the non-production areas of the facility and talk to different associates about what their role is within the organization. Within those different areas, such as engineering, finance, administrative, or quality control, associates should identify broad problems that they are currently facing in their field, and some of the solutions or tools that they use to solve those problems. This would also create an opportunity to see how non-STEM careers use math or technology concepts to do their job. For example, associates in finance might need to use an algorithm, or set of logical rules, to create a financial forecast. In order to understand this, the lab manager or tour guide would need to identify personable and professional associates from these areas and interview them beforehand to get an understanding of who to talk to and how to introduce them to the students. This age group might have expressed an interest in a particular career field, but they have likely not committed to a college by this age, so it might help them to narrow down on specific careers and understand the education that those careers require. That said, students might not have thought about the benefits of jobs in those fields. Because students are trying to form accurate outcome expectations at this age, this would be a pivotal time to explain the pay, benefits, and other practical rewards for careers that require different levels of education. This would be a good time to talk about an associate's degree, and the types of jobs that are available with it. This may mean communicating with stakeholders from colleges that have programs that align to this, answering questions they might have, and giving more information than can fit on a pamphlet. It may also help to talk to existing associates from different educational backgrounds, to break discuss tradeoffs that they might have made. For the activities, the lab manager or the intern would have to work with teachers to identify potential areas for learning and align to the age-appropriate standards. Materials would have to be created for this group, including the aforementioned pre-visit activity, as well as a post-visit lesson. After the experience, it might also be beneficial to have the associates from different fields take some time and have a remote round-table discussion in which students can ask questions, and associates from different fields can work together alongside the lab.

The final group, grades 11-12, would focus on engaging in the fields they are interested in. These students are at the precipice of adulthood, and likely have difficult decisions to make regarding their future careers, so they need to understand what those careers are like, and what they need to learn to be successful in them. This group would consist of classes with a STEM focus or with a teacher that has championed and worked with the lab to create curriculum aligned to their class, high school work-study programs, and interns. While this group would represent the smallest number of students, it would also have the most in-depth experience. Ideally, classes in this group would have multiple visits, and engage with associates to solve practical problems, either individually or in teams/as a class. The lab manager would need to work with associates from different areas to identify problems that students could effectively work on, and then either facilitate a connection with specific classrooms, or create and communicate a design brief that accurately identifies the need and context. If the associates/problems are properly selected, this might be a win-win, as it solves a problem for the manufacturers, while providing an authentic project-based learning opportunity to the students. Once the problem has been communicated to the students, the first visit would have students either interview or shadow the associate that they worked with. For this group, the lab might operate as a meeting space for students and associates to work together on framing the problem, brainstorming options, and prototyping potential solutions. This might require changes to the physical space, which will be discussed in the following section. Students would then take what they learned back to their class and work to create a solution to the problem, with opportunities to communicate with associates throughout the process. At the end of the project, students would then go back to the lab and present their solutions to relevant stakeholders. This would not only provide potential solutions to the industry, but also function as an opportunity for the manufacturer to identify and potentially recruit talent (through internships for 11th graders or scholarships for 12th grade, which are tax write-offs.) By providing an incentive/reward, these design reviews could be used to create competition between different groups, classes, or schools and could be gamified and judged similarly to a design competition by stakeholders from industry and education alike. This kind of competition also provides an opportunity to market and potentially fill key positions, provide an education-based and relevant philanthropic opportunity, and improve public relations with the local community. Because return of investment is difficult to articulate or measure for an initiative like this, the public relations elements represent an interesting selling point, which will be discussed in the next section.

5.4.4 The Space Itself and Exploring Additional Uses

This section will discuss the recommendations for improving the STEM lab's physical environment, as well as propose potential additional uses for the lab. Based on the interviews, survey results, and open-response questions, the current space represents significant challenges to student learning. The first recommendation has to do with changing the location of the lab. While this may represent a problem for the existing space, stakeholders that might attempt to recreate this experience should understand that the space itself does not need to be within the production area. Having the lab within the production area represents a few key problems. First, students under the age of 10 are not allowed on the catwalk for liability reasons, which is the only path to the current lab. This problem is specific to the subject of the research, but manufacturing facilities as a whole focus heavily on safety, so this might create a problem for others trying to replicate the process. Second, the lab is hot, loud, and small. The infrastructure of the current room drew the ire of students and associates alike, with students saying things like, "the lab is too hot!" and staff pointing to issues with the internet or acoustics. Students also communicated frustration with how far the bathrooms were from the lab, while staff talked about the size of the lab being a limiting factor. While finding a new area within an already crowded facility may be difficult, a few of the interviewee's discussed potential alternatives within the on-site training facility. On-site is key here, as students still get the opportunity to participate in the tour but have a better learning environment for the activities. It should be noted that this space is currently used for internal training and should be explored further to understand if time/space is open to schedule. If this lab were to relocate, some of the aforementioned problems might be mitigated. The training facility on site has multiple classroom-style rooms, as well as a large, open auditorium. By relocating here, students could utilize multiple rooms for different activities, limiting the distractions from poor acoustics and close proximity. Ideally, this lab would be purpose built, and provide an optimal learning environment for students of all ages.

That said, sometimes industries have to work within constraints and space is not available. Regardless, the environment itself could also reflect the industry principles that students observe throughout the tour. This would mean having industrial engineers apply Lean or Six Sigma principles to the space. For example, different areas would have marked out areas for safety, tools of equipment should utilize shadow boards, and the Lean LEGO© activity could utilize jigs for quality control.

The experience itself could also apply to a broader audience. Currently, it seems as though the lab is being underutilized. Students, and more specifically, classes, are constrained by time and logistics; operating during school hours and only once scheduled, coordinated, and agreed to by all parties. The lab is only used for activities for visiting classes, and is shut and locked when not in use. During the interviews, one participant said, “As of right now. The only time that it gets used outside of school hours is when another tour would like to see the space.” Extra-curricular groups like the Girl Scouts, Boy Scouts, Boys and Girls clubs, robotics clubs, and other community-based groups could also utilize the lab and tour experience to learn about their community and the role that manufacturing plays in it. Along with that, tours are currently offered to people that purchased a car from the manufacturer, and this might be an opportunity to engage with the lab, and maybe 3D print a personalized part that could go in their car. This could even be a stream of revenue for the lab to purchase materials and could be sold as a package for those purchasing cars with specific packages. This experience with the lab and tour should also be extended to both pre-service and in-service teachers, administrators, and school counselors and academic advisors. According to the literature, these stakeholders play a key part in students’ perceptions of different careers, and they should have a proper understanding of the types of careers that manufacturing offers, as well as the foundational skills and education required for those careers. The lab and tour could also be utilized by associates in non-production roles as a team-building exercise; focusing on teaching lean concepts and robotics to management, finance, and administrative roles. This may give associates a better understanding of the big picture of what the facility does, and potentially show the social capital that their role and company provides.

Finally, the work that is going on with the lab and local schools is a dream opportunity for public relations, marketing, and community engagement. This should be leveraged. One way to do this might be to either have a design competition for students or auction off the naming rights to the robots on the production floor. All it would take is a plaque and would make a great story, photo-op, and potentially an opportunity to fund materials and technology for the lab, depending on the direction. If the idea is to improve perceptions of careers in manufacturing and find and recruit local talent, then there needs to be a focus on promoting the work that is being done. This might mean that industry stakeholders need to pay for the marketing, but increased exposure represents a long-term return of investment for talent acquisition later down the road.

5.5 Summary

This chapter restated the problem that this research analyzed with regards to the influence that an industry-situated STEM lab experience had on students' perceptions of careers in manufacturing as well as the challenges and opportunities related to the implementation of this lab. The conclusions taken from this research are based on three data sources which included participants' drawings, survey responses, and interviews. Discussions were then formed around the results of each research question; focusing on the current misperceptions that students hold, the complexity and depth of manufacturing, and goals that different stakeholders from both industry and education espouse. Based on the literature and the triangulation of the results, recommendations were made that focus on improving the goals, communication, learning, and environment of this research's focus on industry-situated STEM labs.

It is the hope of this researcher that this study is looked at by members of both industry and education, and used to create improvements to the specific informal learning space examined in this study, as well as a starting point for emulating similar STEM labs within other industry settings and/or manufacturing facilities. It is also the hope of the researcher that both industry and education take a critical look at the pragmatic application of an informal learning space like this. The research shows that in the current form, the lab experience can improve students' awareness and understanding of careers in the manufacturing ecosystem, but may not result in scaffolded, authentic learning or influence them to change their career trajectory. Maybe the participants have always wanted to be an engineer in manufacturing because of the influence of a family member. However, not every student has the motivation, interest, or ability for a dream-job in manufacturing. While this can be considered a drawback or concern, it may not have to be. Life is not always easy or fair, and not every student achieves their dreams, so this experience might offer that career awareness that opens a door for a student to apply for a job in manufacturing after one of life's doors closes. Maybe it's sickness, maybe an unplanned child, maybe college has proven to be too much. Things happen, and students that went through this experience, or something similar, need to be aware that when one door closes in life, manufacturing can build a bridge (or a vehicle in this case) to a career that pays well and is rewarding, worthwhile, and helps the community.

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