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The Next Generation for Manufacturing Competitiveness?: Investigating the Influence of Industry-Driven Outreach on Children Career Perceptions

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Abstract
Manufacturing is considered one of the major economic drivers in the United States. However, a challenge for manufacturing competitiveness can be the negative perception of the industry held by children, and society as a whole, which may make them reluctant to pursue manufacturing careers and fulfill the projected workforce demands. Accordingly, there have been a number of talent pipeline initiatives to address the issues related to (1) the availability of a skilled workforce, (2) the preparation of students for the jobs of tomorrow, and (3) teacher access to the tools necessary to inspire children to pursue high-demand career pathways. While these industry-driven outreach initiatives are often developed with the best intentions, research attempts focused on better understanding the influences of these initiatives on children's perceptions of manufacturing-related careers are necessary. Therefore, this study focused on investigating the career perceptions of children (Grades K-8) and the influence of an industry-led summer camp focused on robotics in manufacturing. To do so, data were collected from career-perception surveys and a "Draw-A-Manufacturer" test, which were administered before and after the camp experience. The influences of the summer camp on the participants' career perceptions and interests are presented and used as a foundation for discussions and recommendations for developing outreach initiatives and preparing children for the future of work.

Keywords Manufacturing education · STEM outreach · Career perceptions · Industry-education partnerships

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Introduction

Manufacturing continues to be considered the backbone of economic growth in the United States (Rosendin & Gielczyk, 2018). By the year 2025, due to retirements, economic expansion, and changes in skillsets needed for advanced manufacturing, it is projected that nearly 3.5 million manufacturing jobs will be open and available (The Manufacturing Institute and Deloitte 2015). However, based on an analysis of data from the U.S. Bureau of Labor Statistics, the Manufacturing Institute and Deloitte (2015) predict that approximately 2 million of these jobs will go unfilled, because of an insufficient supply of skilled workers. This concern is often touted as a result of a widening "skills gap" (National Association of Manufacturers 2019) which is connected to the belief that students leaving high school and/or college do not typically possess much, if any, of the experiences and skills necessary to qualify for employment in this sector (Adecco 2014; McMenamin 2015). Accordingly, there have been a number of education and/or talent pipeline initiatives, now often under the title of STEM education, developed to address the issues related to (1) the availability of a skilled workforce, (2) the preparation of students for the jobs of tomorrow, and (3) teacher access to the tools necessary to inspire children to pursue high-demand career pathways.

While it may be true that STEM education is growing throughout our schools, there continues to be debate about its effectiveness in preparing our youth for the current and future workforce demands, specifically within the career fields in the manufacturing industry. Within the broad term of "STEM," many implementations of curriculum lack the types of transdisciplinary practices that more closely match current and projected industry-dictated job needs (Advancing Excellence in P-12 Engineering Education 2018). This can be a concern as these approaches may limit a child's exposure to modern manufacturing within social contexts, which can be detrimental to the industry as it continues to battle a decades-old perception (dirty, dangerous, unskilled, and monotonous) held by children, parents, and teachers (Bosman and Strimel 2018; Deloitte and Touche LLP 2017; Lee 2017; McMenamin 2015). For example, Bosman and Strimel (2018) found in their study that future teachers believe that society perceives manufacturing jobs as less than desirable. The participants in this study believed this to be a result of manufacturing occurring "behind closed doors" with limited access to the general public which leaves perceptions to be based upon what was learned in history/social study courses as well as what is popularized in media.

Deloitte's 2017 report titled *Manufacturing Matters: The Public's View of US Manufacturing* suggests that while Americans value manufacturing as a strong economic sector, many are reluctant to pursue manufacturing careers (Deloitte and Touche LLP 2017). Specifically, one-third of the U.S. population would not encourage children to pursue a career in manufacturing because (a) they are worried about security and stability, (b) they do not believe manufacturing is a strong career path, and (c) they believe manufacturing does not pay enough. However, Americans that are familiar with manufacturing are almost two times as likely to encourage children to pursue a related career path (Deloitte and Touche LLP 2017). Therefore, it seems as though the biggest challenge for the next generation of manufacturing is a "perception gap," rather than just a "skills gap" (Lee, 2017). This perception gap and the negative image of the manufacturing industry may, however, be an attributing factor to the perceived "skills gap" that challenges the industry. Nonetheless, these challenges provide an opportunity to advance collaborations to better understand student perceptions of manufacturing and develop industry connected learning initiatives to meet the needs of regional manufacturing ecosystems while cultivating the employability skills necessary for the next generation workforce. Consequently, research attempts focused on better understanding the influences of industry-driven outreach initiatives on children's perceptions of manufacturing-related careers are necessary. Therefore, this study focused on investigating the "perceptions gap" of children and the influence of an industry-led summer camp, focused on robotics in manufacturing, on their career perceptions.

Literature Review

This research investigated the career perceptions related to the broad range of occupations within the manufacturing sector held by children in grades K-8 (ages 5 through 14) and the potential influence that an industry-led outreach initiative had on these perceptions. This age group was the focus of this investigation as studies conducted by Deloitte and the Manufacturing Institute (2018) have recommended to establish industry-education partnerships starting as early as primary school to (1) address looming workforce concerns and (2) expose children to concepts (robotics, automation, and programming) necessary to align with the shifting skillsets needed for the future of work. This recommendation was based on their study results that revealed that manufacturing executives believe there to be three main factors contributing to the workforce concerns which are (1) the retirement of the baby boomer population, (2) the shifting skills sets related to the digitalization of manufacturing, and (3) the misperceptions that children and their parents hold of manufacturing jobs. While recommendations to increase career exposure and awareness at an early age are often well-intentioned, there is a lack of research focused on how such initiatives influence a child's perception of manufacturing. Accordingly, a foundation for this study and the resulting discussions was established through a review of literature on (a) *manufacturing in K-12 schools*, (b) *children career interest and development*, and (c) *approaches toward building interests in manufacturing career pathways*.

Manufacturing in K-12 Schools

In 2000, the professional organization for the school subject of technology education released the *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007) to outline the content for the study of technology from Kindergarten to twelfth grade. These standards were positioned to enable <u>all</u> students, regardless of career path, to experience the practices of design and study the human-made world. The content specifically included topics of manufacturing and manufacturing technologies. The standards state that in order to be technologically literate students should "develop an understanding of and be able select and use manufacturing technologies" (ITEA/ITEEA, 2000/2002/2007, p. 182). However, technology education as a school subject has had a rather short history when compared to the total history of education. It is a field of study that emerged from the evolution of former school subjects titled manual training, manual arts, and industrial arts (Strimel et al. 2016). But, likely due to these continual changes along with the rapid advancements of technology as well as the lack of updated standards, the school subject has continued to face a positioning problem within a schools general curriculum (Starkweather 2015). As a result, technology education is not often part of a student's general education requirements—leaving most students without opportunities to study manufacturing and its impact on the world, thus potentially furthering the perceptions gap.

While the general population of K-12 students in the U.S. may lack exposure to manufacturing through technology education, there continues to be manufacturing programs provided through *Career and Technical Education* (CTE). CTE programs are designed to provide students the technical and academic skills necessary for success in the future workforce. There are 16 nationally recognized career clusters within CTE, one of which, being manufacturing. The teachers of these programs often come from a background in industry through alternative routes to teacher licensure instead of through a bachelor's degree program in education. While the lack of an educational background may limit the pedagogical knowledge of these teachers, their industry experience may provide them with a solid foundation of content knowledge that translates to the workforce. More recently, CTE has experienced a renewed interest through national initiatives and legislature in alignment with the changing nature of work and a perceived growing deficit in the STEM skills of our students (Asunda 2012). These issues have sparked calls for action to increase STEM education with enhanced connections to career pathways (Asunda 2012; Carrie 2018; National Science and Technology Council 2018a, b). However, these CTE experiences are often reserved for when a student reaches high school, which limits a child's exposure to related career fields at an early age when they are developing their career interests. In addition, CTE pathways are the programs in which students must opt into and therefore, results in many students receiving little to no instruction related to the industry of manufacturing. Consequently, it seems as though informal learning environments are necessary to provide career awareness and exposure to all students, specifically at a young age, to address the perceptions gap around manufacturing.

Children's Career Interest and Development

The literature provides some evidence that education providers are focusing on developing career goals and interests with elementary age students through both informal and formal learning environments. For example, Tyler-Wood et al. (2012) investigated the offering of an after school program targeting 4th and 5th grade girls titled, "Bringing Up Girls in Science (BUGS)." The longitudinal study suggests girls that participated in the BUGS after school program have higher positive perceptions of science careers in comparison to a control group. Cotabish et al. (2013) assessed the implementation of a one-year program for elementary students using a rigoruos science curriculum. The key program interventions, which included ongoing professional development for teachers and inquiry-based science instruction, resulted in science knowledge gains related to concepts, content, and skill development. Welde et al. (2016) implemented and assessed a teacher-training program aimed to integrate career education projects into elementary classrooms. The findings imply that elementary students benefited most from experiences promoting engagement in self-exploration toward potential career interests. Chapin et al. (2015) conducted a study to increase student exposure to career and educational opportunities related to food science and food safety. The data collected from 61 students showed an increase in interest and content knowledge related to science in general, and food science and safety specifically. Mahoney et al. (2010) analyzed career development skills associated with after-school program workers. The results were dismal, suggesting these types of workers, who are critical to the success of programs, often do not receive the necessary training to adequately provide high quality programming and support. Finally, Knight (2015) conducted research to explore current approaches to elementary school counseling for career development. The author makes five recommendations for improving career counseling at the elementary level: (1) develop university–elementary school partnerships, (2) incorporate resources relevant to elementary school-age children, (3) require consultation and collaboration around career development, (4) teach students how to develop and evaluate career interventions, and (5) introduce specific methods for delivering classroom guidance. These findings suggest that career interests and perceptions can be influenced at an early age and that schools are searching for “best practices” for doing so in the appropriate way. However, when reading this synopsis, one can see a need for developing interventions to support those involved in career development for youth that is based on a better understanding of the career perceptions of children and the influence that informal learning environments, such as summer camps, have on these perceptions.

Approaches toward Building Interest in Manufacturing Career Pathways

In general, the literature provides limited examples of approaches toward developing and building manufacturing career interest and skill development, especially prior to high school. The few studies that could be found are highlighted here. While these studies may have limited focus toward investigating career pathways specifically in manufacturing, they do include aspects of manufacturing through robotics, makerspaces, and technology skill development.

Bers et al. (2013) worked with 32 early childhood teachers during a 3-day intensive professional development workshop with the goals of increasing instructor knowledge and teaching abilities related to robotics, programming, and engineering. Findings show significant improvements in attitudes toward and self-efficacy in technology, suggesting that these types of workshops have the potential to engage young students early on in life. Another robotics intervention, completed by Nemiro et al. (2017), was titled, “School Robotics Initiative (SRI).” The analysis used observations as well as student-written journals to provide recommendations for integrating social, psychological, and physical elements into curriculum to support creative thinking. Furthermore, Barton et al. (2017) investigated the implementation of a makerspace program, “Making 4 Change,” as a means to engage young underrepresented students in STEM using the ethnographic research approach. The authors conclude that there is a need to balance play with just-in-time learning modules, incorporate aspects of self-identity, and address affordances and constraints associated with community-organized makerspaces. Li et al. (2016) used Legos and an engineering design-based approach to engage fourth-grade students in the problem-solving process. Results suggest that the use of Lego bricks, applied within a cognitive game-based learning experience, showed significant gains in students’ problem-solving ability in comparing an experimental group to a control group. Berry and colleagues (Berry III et al. 2010) investigated the integration of digital fabrication and engineering design principles on elementary mathematics curriculum. The findings of this preliminary study suggest a critical need to conduct additional research to further assess and validate the viability of thoughtfully re-designing existing mathematics curriculum to incorporate the engineering design aspects of creating, building, and inventing. Matsumoto et al. (2016) assessed the implementation of a brush coating training system using the hands-on and engaging PHANTOM Omni system, in comparison to traditional manufacturing education approaches in elementary and secondary schools that use videos to showcase manufacturing career opportunities. Because of participating in this training, students received feedback on brush coating motion and achieved skill improvement.

While these studies may have highlighted some potential successes toward building student capabilities and enhancing early experiences with aspects related to manufacturing, investigations related to children’s career perceptions specifically related to manufacturing career pathways and approaches to influence these perceptions through informal learning are limited. For example, the Center for Advancement of Informal Science Education (2019) has highlighted that a research gap remains in understanding the connection between informal learning experiences, such as learning through makerspaces and tinkering, and being engaged in STEM pathways, which can include manufacturing. Therefore, research attempts are needed to better understand student perceptions of manufacturing and how industry connected learning initiatives are created to meet the perceived needs of the next generation workforce.

Problem Statement

The literature on children’s career perceptions and interest development related to the broad range of occupations with the manufacturing sector is limited. Furthermore, while manufacturing outreach and talent pipeline efforts are typically designed to engage youth in activities related to manufacturing careers through informal learning environments, such as *Manufacturing Day*, research attempts to better understand the influence of such initiatives on children’s perceptions of related careers and educational pathways seem to be lacking. Therefore, this study focused on investigating children’s perceptions of manufacturing before and after a summer camp titled *Robotics in Manufacturing*, that was developed through a regional commerce group and co-hosted by several manufacturers in one Midwestern town located within a vibrant manufacturing ecosystem.

Research Questions

The research questions that guided this study are as follows:

> RQ_1: What influence, if any, does an industry-led summer camp focused on robotics in manufacturing have on the perceptions of careers in manufacturing for children in grades K-2?
>
> RQ_2: What influence, if any, does an industry-led summer camp focused on robotics in manufacturing have on the perceptions of careers in manufacturing for children in grades 3–8?

To answer these research questions, data were collected from career perception surveys and a “Draw-A-Manufacturer” test, which were both administered before and after the summer camp experience. The research questions were divided by grade-level as the camp activities were separate for each age group and designed to be developmentally appropriate for the students. Also, the survey questions were written to account for the different reading abilities of the participants.

Methodology

Study Context

This study was focused on investigating children’s perceptions of manufacturing careers and the potential influence of an industry-led summer camp focused on robotics in manufacturing on their career perceptions. The study took place in a Midwestern town situated within a vibrant manufacturing community. The summer camp was developed by the local commerce group, co-hosted by the region’s manufacturers, and operated through the local YMCA organization. The summer camp activities were held within the facilities of the region’s three largest manufacturers and the summer camp participants were bused to these locations throughout the duration of the camp. While the majority of the activities were held in these locations, other local manufacturers provided camp activities, resources, hospitality, and funding to support the camp activities.

The summer camp spanned two weeks during the month of June in 2018. The first week was designated for children in grades 3 through 8 (ages 8 through 14), while the second week was dedicated to children in Kindergarten through 2nd grade (ages 5 through 8). The weekly schedules involved (1) transporting participants to the manufacturing facilities that were hosting the activities for the day, (2) conducting the pre-camp data collection, (3) introducing the daily manufacturing theme (teamwork, continuous improvement, lean manufacturing, problem solving, and leadership), (4) implementing daily hands-on manufacturing activities, (5) providing a mid-day “brain break” which included games/challenges, (6) recapping the learning objectives of the day, and (7) visiting local community/technical/four-year institutions. The daily hands-on manufacturing activities revolved around teaching participants coding skills, basic electronics, prototyping, and general robotics within the contexts of the local manufacturers. The activities used products such as Lego Mindstorms™, LittleBits™, and Dobots™ that are designed for K-12 STEM education. Throughout each day, participants rotated to different stations, working at each station for about an hour before moving on to the next activity. Some activities, like the station with the Lego Mindstorms™ were scaffolded throughout the week, so that at the week’s end, participants created a robot capable of exploring their cityscape and performing tasks related to logistics and the local supply chain. Other activities involved day-to-day tasks, with no weeklong goal, so participants could explore different aspects of an activity or skill throughout the week. Week 1 (3rd-8th grade) participants, over the age of 10, had the opportunity to go on tours of the manufacturing facilities. Participants under the age of 10 were not provided with this opportunity due to liability and safety concerns.

Participants

Following approved protocol from the Institutional Review Board, all of the children participating in the *Robotics in Manufacturing* summer camp were recruited for this study. To do so, the parents/guardians were provided a letter that offered an overview of the study purpose as well as the data collection process. Then, the parents/guardians were provided with a consent form that detailed the purpose of the study, the study procedures, the length of the study, any potential risks, the protocol for participant confidentiality, and their rights if they chose to participate. Once the parents provided consent, then the children were asked for their assent to participate. The participants from grades K through 2 were asked for only verbal assent while the participants from grades 3 through 8 were required to provide signed documentation for their assent. As a result, 40 participants (26 male, 13 female, and 1 undisclosed) from Week 1 were enrolled in the study, whose ages ranged from 8 to 15. For Week 2 of the camp, there were 23 participants (13 male and 10 female), whose ages ranged from 5 to 8. The majority of the participants for each week reported themselves as Caucasian/white or other. The complete demographic data are provided in Table 1.

Procedure

To better understand the participant's perceptions of manufacturing and determine the potential influence of the *Robotics in Manufacturing* summer camp on their perceptions, two data collection instruments were used. First, pre- and post-surveys were administered to the participants. These surveys were developed, based on outcomes from the Deloitte (2017) study, to assess children's perceptions of manufacturing. This approach also aligns with the survey methodology used by Mawyer (2016) for obtaining information on student perceptions of manufacturing. Each survey consisted of a series of manufacturing perception questions that included a "Yes/No" and sometimes an "I Don't Know" response option which was aligned to standard conventions for the participant's age level (Bell 2007). While the dichotomous response options can sometimes be considered too constricting, the questions in this study were refined to a single quality of manufacturing with only the minimum number of response items to avoid placing excessive cognitive demands on the children, facilitate the easiest possible choice for their perception as they could get confused by subtle differences between a range of options, and to not discourage them from expressing their view by offering them an "easy way out" by selecting an "I don't know" response (Bell 2007; Borgers and Hox 2000, 2001; Borgers et al. 2000). Also, to further address the limitations of the survey, a second source of data was collected from the "Draw-A-Manufacturer" test (detailed later) to further uncover the participant's perceptions. The surveys also included questions to determine each participant's prior experiences with manufacturing. To account for the cognitive development of the participants, different versions of these surveys questions were created for each age group. Also, the questions were read aloud to the students to help ensure comprehension. Lastly, the post-survey for the older participants included open-ended questions to allow them to provide additional details about their summer camp experience. The Appendix provides the questions for each version of the survey.

The second data collection instrument was the "Draw-A-Manufacturer" test. This test was developed based on the "Draw-A-Scientist" test used in previous studies to

Table 1 Summer camp participant demographics

	Grades K-2 Participants	Grades 3–8 Participants
Gender		
Male	13	26
Female	10	13
Undisclosed	0	1
Race/Ethnicity		
African-American	3	0
American Indian/Alaskan Native	0	1
Asian	0	0
Caucasian/White	14	33
Latino/Hispanic	0	1
Other	6	5
Undisclosed	0	0
Age		
5	4	0
6	8	0
7	10	0
8	1	14
9	0	7
10	0	8
11	0	2
12	0	5
13	0	2
14	0	0
15	0	1
Undisclosed	0	1
Total	23	40

examine children's perceptions of scientific careers (Huber and Burton 1995; Langin 2018). The "Draw-A-Scientist" test has been successful in showing general themes children have about scientific careers and how they change after an intervention such as an introduction to scientist role models (Huber and Burton 1995; Langin 2018). Based on these studies, the researchers asked the participants to draw what they thought a manufacturer looked like before and after their participation in the summer camp. Participants were prompted to think about what they thought the workers would look like, what kind of equipment they might have, and what might be surrounding them in the manufacturing facility.

Data Analysis

The surveys were given to participants on paper and the resultant data were entered into a Microsoft Excel© file to sort by participant and pre-and post-question. The data were kept in word form and a second sheet was generated that used a numerical code to identify the responses instead of words in order to aid with analysis. Demographic information was counted individually, and the percentages were calculated from the individual counts. For each non-demographic question a “perception change table” was developed. These tables divided the participant responses to the yes/no questions provided in both the pre- and post-surveys into the following quadrants: yes-yes, yes-no, no-no, and no-yes. These quadrants represent the change (or lack of change) in perception as a result of their response changes. Based on the number of participants in each quadrant of the table, it is easy to visualize the potential influence of the summer camp on the participants’ responses to each question. Ideally, the table would be the first step in organizing the data to perform a McNemar’s test to determine statistical significance of the changes made. However, the population for this study was too small, especially when partitioned into the quadrants, to be able to accurately perform meaningful statistical analysis. Nevertheless, these data in combination with the “Draw-A-Manufacturer” test can provide a detailed picture of children’s perceptions of manufacturing related careers before and after the summer camp experience.

The drawings collected from the “Draw-A-Manufacturer” test were analyzed using the Nvivo qualitative analysis software. This enabled the researchers to qualitatively code each drawing for specific themes. First, the drawings were reviewed by the researchers to establish a set of themes. The theme set was then used as a basis for the codes used to mark each drawing. The number of times a specific code was used in the pre- or post-drawing was counted. The pre- and post-drawing codes counts were then used to determine, overall, if there was a thematic change in the drawings.

Findings

Following data collection, all data were analyzed with the guidance of the research objective. The objective was to use the collected data to explore children’s perceptions of manufacturing careers and the potential influence of an industry-led summer camp focused on robotics in manufacturing on their career perceptions. The findings, from both quantitative and qualitative data, are presented here in alignment with the two identified research questions.

Research Question 1

To investigate the influence, if any, that an industry-led summer camp focused on robotics in manufacturing had on the perceptions of careers in manufacturing for children in grades K through 2, a “Draw-A-Manufacturer” test as well as a pre- and post-survey were administered to each participant. The data related to each instrument are presented here.

Drawings A total of 18 participants in grades K through 2 completed the pre-drawing activity while 19 participants completed the post-drawing activity. During this activity, the participants were prompted to think about what they believe the workers would look like, what kind of equipment they might have, and what might be surrounding them in the manufacturing facility. From the drawings generated by this test, several themes could be identified and coded. The codes for the identified themes are described in Table 2. Upon reviewing these drawings, it can be noted that on the pre-drawing tests some of the participants drew unoccupied, "block" buildings, that is they represented manufacturing by sketching a large box that often did not have any signs of work occurring within (see Fig. 1). However, after the summer camp the number of these unoccupied "block" buildings decreased and the participants drew more people in their representations of manufacturing. Additionally, the "people" they drew after the camp were more involved in manufacturing processes (See Fig. 2), had more identifiable features (See Fig. 3), continued to appear happy, and mostly resembled men. The participants also drew safety equipment on the workers they depicted in their drawings after the camp. The K-2 participant drawings had little evidence of safety gear before the camp but safety was a prevalent theme in the drawings after the camp. Furthermore, the K-2 group drew "humanoid robots" before the camp, which can be described as

Table 2 Codes for the themes identified in the drawings from the participants in Grades K-2

Parent Code	Sub Code	Description	Frequency Observed	
			Pre	Post
People	Happy	The people drawn in images look happy and have smiles.	8	9
	Man	The people drawn appear to be men.	2	7
	Woman	The people drawn appear to be women.	3	4
	Teamwork	There are people in the drawings working together on tasks.	2	2
	Unhappy	The people drawn in images look unhappy or have frowns	0	1
	Other	There are people in the drawings.	12	17
Building	Unoccupied	The building is empty and has no evidence of activity.	2	0
	Block	The building drawn is just a box, may not have doors or windows.	4	2
	Other	There is a building in the drawing.	4	3
Automotive	Truck	There is a truck being built or used in the drawing.	4	4
	Car	There is a car being built or used in the drawing.	5	4
	Other	There is a component of automotive industry in the drawing, such as steering wheels or a car door.	8	8
Unidentifiable		It is unknown what the participant is trying to display in this drawing.	1	1
Tools		There are tools (hand tools, computers, etc.) in the drawing.	3	1
Safety		There are elements of safety (such as safety glasses or steel toed boots) in the drawing.	1	5
Robots	Humanoid	There are robots that appear to be emulating humans in the drawing.	4	3
	Industrial	There are robots such as robotic arms in the drawing.	0	1
	Other	There are robots, not necessarily industrial or humanoid, in the drawing.	4	4
Production		There are elements of creation in the drawing.	0	6

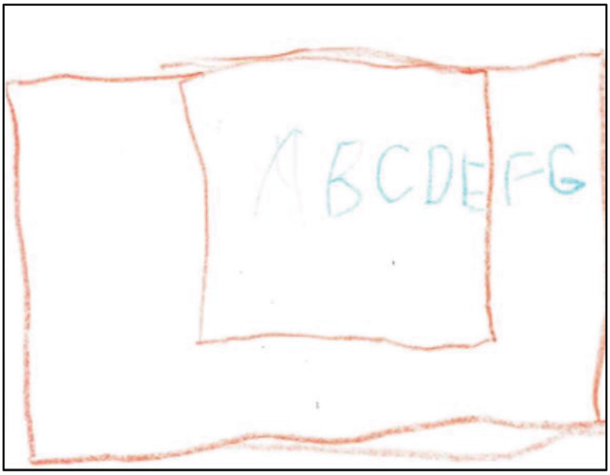

Fig. 1 An example drawing from the K-2 group showcasing a block, 'unoccupied' building

robots that had human-like features (See Fig. 4). After the camp, the amount of people using hand tools, like hammers or screwdrivers decreased, while there was an increase in the presence of robots that were involved in production.

Surveys A total of 23 participants from grades K through 2 were enrolled in this study. Based on their survey responses 6 reported that they had parents/guardians who were employed in manufacturing, 4 reported having other relatives working in manufacturing, and 7 reported knowing someone else working in manufacturing. While there was a total of 23 participants enrolled, only 14 participants completed both the pre- and post-survey. Therefore, the data from these 14 participants are highlighted in Table 3. This table provides the number of participant responses to each question on both the pre- and post-survey to determine their perception changes, if any.

As seen in Table 3, there are some notable items related to the participants' career perceptions. First, the majority of the participants' responses (8 of 14) on the pre-survey indicated that they would not be interested in working in manufacturing. Following the

Fig. 2 An example drawing from the K-2 group showcasing a person involved in the production process

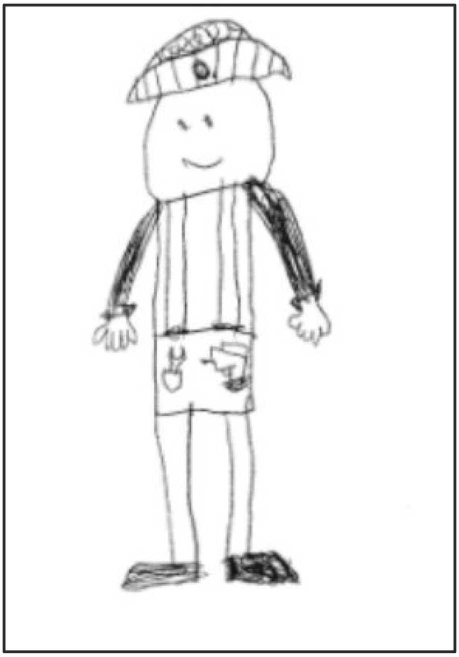

Fig. 3 An example drawing from the K-2 group showcasing a person with distinguishable features, rather than a stick figure, that is also wearing safety gear

summer camp experience, seven participants continued to express no interest in a manufacturing career, four participants who originally expressed interest no longer did so, and only one changed their response from no to yes. Therefore, after the summer camp experience only three of the 14 participants were interested in a manufacturing career. When the participants were asked about needing a college

Fig. 4 An example drawing from the K-2 group showcasing a humanoid robot

Table 3 Number of participant responses in each quadrant: Yes-Yes, Yes-No, No-Yes, and No-No

Question	Pre – Post Yes-Yes	Pre – Post Yes-No	Pre – Post No-Yes	Pre – Post No-No
Do you think you would want to work in manufacturing?	2	4	1	7
Do you think that there are lots of jobs in manufacturing?	6	1	4	2
Do you think manufacturers need to have lots of education, like a college degree?	10	0	1	3
Do you think manufacturing jobs are safe?	4	0	5	5
Do you think manufacturing jobs are clean?	1	1	4	8
Do you think manufacturing jobs let you be creative?	9	3	2	0

education to work in manufacturing, nearly all of them believed a college degree to be necessary and they maintained this belief after the summer camp. In regard to workplace safety in manufacturing, a total of nine participants viewed the workplace as safe after the camp, with five participants changing their view from unsafe to safe. In regard to workplace cleanliness in manufacturing, a total of nine participants viewed the workplace as dirty after the camp but with four participants changing their view from dirty to clean and one maintaining their perception of cleanliness.

Research Question 2

Drawings A total of 35 participants in grades 3 through 8 completed the pre-drawing activity while 28 participants completed the post-drawing activity. During this activity, the participants were prompted to think about what they thought the workers would look like, what kind of equipment they might have, and what might be surrounding them in the manufacturing facility. From the drawings generated by this test, several themes could be identified and coded. The codes for the themes identified are described in Table 4. Similar to the K-2 participants, several of the participants from grades 3 through 8 drew unoccupied, “block” buildings. As such, they represented manufacturing by drawing a large box that often did not have any signs of work occurring within (see Fig. 5). After the summer camp, however, the number of these unoccupied ‘block’ buildings decreased. Additionally, before the camp, participants drew a mixture of humanoid robots, industrial robots, and hand tools. However, after the camp, there were no hand tools represented but there was an increase in robots, specifically industrial robots involved in production (See Fig. 6). Lastly, in the 3–8 drawings, safety became a more prevalent theme after the camp as the participants drew more safety equipment on the workers (See Fig. 7).

Survey A total of 40 participants from grades 3 through 8 were enrolled in this study. Based on their survey responses, 7 participants reported that they had parents/guardians who were employed in manufacturing, 1 reported having siblings working in manufacturing, 10 reported having other relatives working in manufacturing, and 13

Table 4 Codes for the themes identified in the drawings from the participants in Grades 3–8

Theme	Sub Code	Description	Frequency Observed	
			Pre	Post
People	Unhappy	The people drawn in images look unhappy or have frowns	1	0
	Diverse	The people in the drawings are diverse; they are not just men or one race/ethnicity.	2	0
	Happy	The people drawn in images look happy and have smiles.	16	15
	Man	The people drawn appear to be men.	12	11
	Woman	The people drawn appear to be women.	5	6
	Teamwork	There are people in the drawings working together on tasks.	5	1
	Other	There are people in the drawings.	26	21
Building	Smokestack	The building in the drawing has a smokestack.	2	0
	Block	The building drawn is just a box, may not have doors or windows.	7	3
	Active	There is activity in the building, it is clearly occupied or has production.	1	0
	Other	There is a building in the drawing.	7	3
Automotive	Truck	There is a truck being built or used in the drawing.	1	0
	Car	There is a car being built or used in the drawing.	3	5
	Other	There is a component of automotive industry in the drawing, such as steering wheels or a car door.	7	8
Unidentifiable		The drawing is unable to be coded because it is unclear.	3	1
Tools	Hand	There are hand-tools such as hammers or screwdrivers in the drawing.	7	0
	Computer	There is a computer being used as a tool in the drawing.	2	0
	Other	There are tools besides robots, hand tools, or computers in the drawing.	9	2
Safety		There are elements of safety (such as safety glasses or steel toed boots) in the drawing.	8	12
Robots	Industrial	There are robots such as robotic arms in the drawing.	5	8
	Humanoid	There are robots that appear to be emulating humans in the drawing.	1	1
	Other	There are robots, not necessarily industrial or humanoid, in the drawing.	3	6
Production	Logistics	There are elements of items being planned and created in the drawing.	2	2
	Other	There are elements of creation in the drawing.	8	8

reported knowing someone else working in manufacturing. While there was a total of 40 participants, only 35 completed the pre-survey and 29 completed the post-survey. The students who participated in the pre-survey responded to whether or not they had previously had any experience in manufacturing. Of the 35 students who completed the pre-survey, 18 stated they had no previous experience with manufacturing, one said they had participated in a manufacturing learning activity, five said they had been on a manufacturing tour, and 11 said they had done both a manufacturing activity and tour.

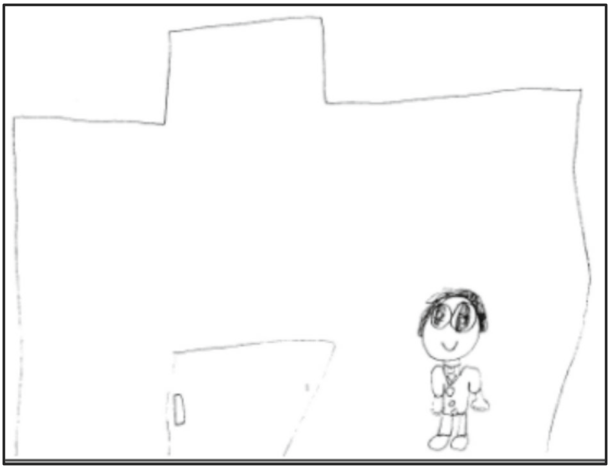

Fig. 5 An example drawing from the 3–8 group showcasing a block building

Of these participants, 23 completed both the pre- and post-survey. The data from these 23 participants are highlighted in Table 5. This table provides the number of participant responses to each question on both the pre- and post-survey to determine their perception changes, if any.

As seen in Table 5, there are some notable items related to the participants' career perceptions. First, only five of the 23 participants reported being encouraged to consider a career in manufacturing. Next, the majority of the participants' responses (12 of 23) on the pre-survey indicated that they would be interested in working in manufacturing. Following the summer camp experience, only seven participants continued to express interest in a manufacturing career while five participants who originally expressed interest no longer did so and two changed their response from no to yes. Therefore, after the summer camp experience only nine of the 23 participants were interested in a manufacturing career.

Fig. 6 An example drawing from the 3–8 group showcasing an industrial robot involved in a production task

Fig. 7 Example drawings from the 3–8 group showcasing safety equipment

However, when asked if manufacturing jobs paid well following the summer camp experience, 20 of the 23 participants responded yes. When the participants were asked about needing a college education to work in manufacturing, nearly all of them believed a college degree to be necessary and they mostly maintained this belief after the summer camp. In regard to workplace safety in manufacturing, only three participants changed their view from unsafe to safe, leaving a total of 14 participants perceiving the workplace as unsafe after the camp. In regard to workplace cleanliness in manufacturing, only two participants changed their view from dirty to clean and only four maintained their perception of cleanliness, leaving a total of 17 participants perceiving the workplace as dirty after the camp.

The 29 participants who completed the post-survey all answered the open-response questions. Unfortunately, several of the responses consisted of only one to two words, or were indecipherable. However, three main themes were identified in the final open-ended responses: bathrooms, lunches, and favorite activities. While these following

Table 5 Number of participants who responded in each quadrant: Yes-Yes, Yes-No, No-Yes, No-No

Question	Pre – Post Yes-Yes	Pre – Post Yes-No	Pre – Post No-Yes	Pre – Post No-No
Has anyone ever told you to consider a manufacturing job/career?	3	7	2	11
Do you think you would want to work in manufacturing?	7	5	2	9
Do you think that manufacturing jobs pay well?	17	1	3	2
Do you think there are lots of jobs in manufacturing?	16	2	1	2
Do you think manufacturers need to have lots of education, like a college degree?	17	2	4	0
Do you think manufacturing jobs are safe?	5	2	3	12
Do you think manufacturing jobs are clean?	4	2	2	15
Do you think manufacturing jobs let you be creative and innovative?	15	2	5	0
Do you think there is a lot of technology involved in manufacturing?	18	2	2	0
Do you think manufacturers need to be highly skilled?	17	2	2	2

items may seem trivial, they can influence a participant's perception of working in a manufacturing environment. This will be addressed later in the discussion section. First, in regard to restroom facilities, some participants mentioned that they felt the bathrooms were very far away from where they were participating in activities and that they felt they could not go to the bathroom as often as they would have liked. The location of bathrooms at some of the manufacturing facilities involved a long walk from the activity area and, due to child-safety regulations for who can be in a bathroom at the same time as the participants; the bathroom breaks were regulated to prevent long disruptions for the workers in the building. Some participants also mentioned that they wanted lunch-time to be sooner. This is likely because the post-survey was given directly before their lunch break. Many participants likely had this on their mind during the survey, which may have caused a distraction. Finally, many participants wrote the names of activities they found enjoyable during the week, including the LittleBits and coding using Scratch.

Discussions

While this study was exploratory in nature and limited to a small sample of participants, who mostly reported themselves as Caucasian, the findings can provide some insights for discussions around the manufacturing "perceptions gap" and recommendations for developing talent pipeline outreach initiatives.

To begin this discussion, the analysis of the data collected before and after the *Robotics in Manufacturing* summer camp does support the idea that there is a "perceptions gap" among children in regard to manufacturing careers. For example, when reviewing the results from the "Draw-A-Manufacturer" test collected before the camp, one can see several participants representing their view of manufacturing by drawing unoccupied, block buildings. Furthermore, there were limited depictions of people involved in actual production processes in the participant drawings. While some drawings did show some representation of fabrication by including basic hand tools, others included robots that were more science fiction-oriented rather than industrial.

Also supporting the idea of a "perceptions gap," the pre-survey data showed that the majority of the K-2nd grade participants were not interested in a manufacturing-related career, over half of the 3rd-8th grade participants were not encouraged to explore manufacturing, most of the K-2nd grade participants viewed the jobs as unsafe, almost all of the K-2nd grade participants saw the jobs as dirty, and the majority of the 3rd-8th grade participants perceived manufacturing as an unsafe job as well as unclean. However, the pre-survey results did show that most of the participants believed there were a lot of available jobs in manufacturing and nearly all of them thought that manufacturing careers require a college degree. While this can be viewed as a positive perception of the industry, it can also highlight how there is an apparent societal perception that "everyone still needs a 4-year college degree." This can then be viewed as a potential misalignment between the industry and career perceptions as manufacturing jobs are often times accessible through associate degrees and high school diplomas and can provide options for tuition reimbursement to obtain further credentials.

Compellingly, the pre-camp data indicate that either the participants held a potentially "negative" perception of the industry or, more likely, they had no conception of it at all. But, to answer the study's research questions, the data analysis does show that children career perceptions can be influenced through industry-driven outreach initiatives. However, the data demonstrate that people should "proceed with caution" when developing and implementing such outreach activities as the influence can be perceived as oppositional to the goals of talent pipeline development efforts. For example, when examining the pre- and post-surveys, the data suggest that the experience actually influenced the participants to "not consider" a career in manufacturing. Based on the post-survey data, only three K-2nd grade participants and nine 3rd-8th grade participants reported interest in a manufacturing career after the camp experience. In addition, the post-survey showed that many participants left the experience perceiving the manufacturing workplace as unsafe and dirty.

While these results may seem counterintuitive, a few observations may provide some additional items for thought. First, it is likely the participants had little to no preconception of manufacturing when completing the pre-camp survey. Therefore, they may have been more likely to consider a career in this industry before they actually knew what all it entailed. This may portray that the camp influenced the participants to have a negative perception of manufacturing, when in reality, it actually gave them their first look at the industry. This is why the researchers believe it was important to add the "Draw-A-Manufacturer" test to the study. This test seemed to offer a more rich description of the perception changes. For example, by comparing the pre- and post-drawings, the following perception changes were identified, (a) participants placed an increased emphasis on safety after the camp, (b) they had an enhanced understanding of the actual activities happening within the "mysterious block manufacturing buildings" after the camp, (c) they increased their depiction of industrial robots in the manufacturing process, and (d) they focused their attention toward the human element of the manufacturing employees. These perception changes can be viewed as a more positive influence of the camp as the children are now aware of what this industry actually involves. While these perception changes can be viewed as positive, it is yet to be determined whether such changes are specifically linked to increasing or decreasing their interest in manufacturing-related careers.

In regard to the perceptions of a safe work environment, there were some observations during the camp that likely influenced the participants. As these camps were hosted at manufacturing facilities, liability was always a concern. This resulted in an associate from each manufacturer beginning each camp day explaining their facility's safety protocol. In addition, the participants were placed in personal protective equipment designed for adults and then often told of the dangers of not properly wearing the equipment. This could be an intimidating experience for children, which may provide a rationale as to why more participants viewed the environment as unsafe after the camp and why they drew more people wearing safety equipment in the post-camp drawing test. Furthermore, only participants that were 10 years of age or older were given the opportunity to tour the factory floor which left many participants without the full experience of the operations. These observations and results can warrant the following questions: (1) how early is too early to expose children to manufacturing, (2) what is the best way to introduce safety to children, and (3) what is the physical context in which they are experiencing the manufacturing workplace.

Lastly, the drop in interest in manufacturing may be linked to the activities provided at the camp and their alignment with the daily activities of those working in manufacturing. Manufacturing can span a wide range of careers in regard to the individuals who work to design, produce, transport, and support the company's products. However, most of the camp events focused on activities related to digital manufacturing, such as programming, robotics, electronics, additive manufacturing, and computer-aided design. As such, the participants may have seen a disconnect between the camp activities and the day-to-day activities of the manufacturer employees. On the post-drawing test, many participants drew “what they thought manufacturing looked like” based on the small activities that they completed during the camp (Legos, LittleBits, Scratch, etc.) and what they were told about manufacturing, since many were not allowed to go on tours. Therefore, it may be important to continually check whether or not manufacturing careers are accurately depicted to children. On one hand, we may expose a child to something called manufacturing that they dislike and therefore never explore the actual field and, on the other, we may mislead children as we provide manufacturing activities that they enjoy that have little relation to the career field. Furthermore, another explanation for the decline in interest could be that the camp activities may have challenged participants to a level where they decided that manufacturing careers are not for them.

While it may be important to show participants what manufacturing looks like on a day-to-day basis, another viewpoint is that the camp activities (robotics, programming, electronics, automation, additive manufacturing, etc.) are actually beginning to prepare children for the future of work in the realm of digital manufacturing rather than the current job openings. Whereas some projections show that millions of manufacturing jobs will go unfilled in the next decade, a recent report by Oxford Economics (2019) forecasts that industrial robots could displace approximately 20 million manufacturing jobs globally. Therefore, it remains important to continue industry-driven outreach initiatives while understanding their influence on children to best prepare them for the future of work.

Recommendations

To address some of the concerns highlighted through the results, the researchers have assembled some recommendations for developing and implementing future manufacturing outreach that align to talent pipeline development goals.

Curriculum, Training, and Language

First, it is recommended that future manufacturing camps and other associated activities develop training for all volunteers/staff associated with the event. To do so, curriculum could be developed to ensure learning objectives for the camp are outlined and that the instructional activities are aligned. This can help to support meaningful manufacturing activities that support the goal of informing children about manufacturing careers. A potential “best practice” for developing this curriculum can be to involve pre-service and in-service teachers in the planning process for the camp. This can provide the camp directors and associated manufacturing industry leaders with specialists in the development of curriculum and instruction. Additionally, it can help provide teacher experiences in manufacturing that they can bring back to their classrooms in a meaningful way. It can also help to bridge the gap between industry and education, which is often difficult to achieve as both fields often use different means to communicate their goals.

Accordingly, a training program for volunteers/staff could be established to help them implement the developed curriculum and instructional activities. As part of this training, the staff/volunteers could learn to use similar language that is age-appropriate when discussing various key topics. Many manufacturers have company-specific, technical language, which can be confusing and intimidating to children and obscure the overall of message/goal of the outreach initiative. However, by providing the staff/volunteers with a common taxonomy of age-appropriate language along with imagery depicting relevant associations of these concepts to a child's everyday life, everyone could discuss the same topics in a manner to minimize confusion. As mentioned, this common language could also assist in orienting the children to manufacturing concepts in an age-appropriate manner. Sometimes discussions about safety or cleanliness can be oriented toward "scaring" people into following the proper protocols. This "scary" language (ex. Put on your safety glasses or you will lose an eye) can cause the participants to feel negative toward the general safety and cleanliness of manufacturing. Using language that reinforces that "manufacturing careers are safe and clean by established procedures such as wearing steel-toed boots," can make the experience less intimidating. In this manner, safety can be "shared" with children rather than following the approach of "scaring" them into following safety protocol.

Finally, a common training can help to provide a unified message to the participants and may help to extend take-home messages to parents/guardians as well. When a few key points are repeated throughout the course of the camp, it is more likely that those key points will be remembered by the children. This means that, when confronted about manufacturing in the future, they are more likely to remember the key points they learned at the camp. Additionally, when they talk with their parents/guardians they are more likely to repeat those key points, which could assist in changing the parent/guardian's perception of manufacturing careers as well.

Establishing the Appropriate Context

Based on the results of this study, it is recommended to continue to think critically about the environment in which the children are engaged and whether this environment is child friendly and contextually relevant. While some of the open-ended question responses may have seemed trivial, such as the bathroom locations, the environment may have influenced the participants' interest in working in the field. For example, the young children did not get to tour the factory floor and see what actually happens in the work environment. However, at one of the manufacturers, to use the restroom, the children had to walk an extended distance that happened to parallel the noisiest and traditional parts of the factory. The children noted this in their open-ended responses as a concern about the work environment as this felt overwhelming to them. Also, it seems important to ensure that the manufacturing environment in which the children are immersed is contextually relevant to their lives and engaging. This way the children can see why the industry is personally and socially important. At the young ages, it does seem that manufacturers of food products are engaging. For example, the camp brought novelty frozen treats from one local manufacturer and used it as a context to teach about manufacturing processes. This seemed to be a favorite experience among the children.

Continued Research & Development

As the shortage of Americans with the knowledge, interests, and technical skills necessary for advanced manufacturing jobs seems to underlie many of the nation's challenges for innovation and competitiveness, appropriate educational experiences seem to be important for children. This aligns with objectives from the *Strategy for American Leadership in Advanced Manufacturing* (National Science & Technology Council, 2018b) which includes (1) attracting tomorrow's manufacturing workforce by addressing the decades-old perceptions gap of the industry and (2) growing tomorrow's manufacturing workforce by establishing foundational K-12 STEM experiences that foster a the computational literacies necessary for digital manufacturing. While achieving these objectives may help to promote a "better" public perception of manufacturing, allow students to explore careers within the manufacturing industry, and create joint industry-education environments in formal and/or informal settings, it will be important to continue to investigate the influence that related initiatives have on children. Accordingly, continued research and development efforts related to industry-driven outreach initiatives are recommended. First, the findings of this study provide a rationale for further investigating the ways in which outreach activities can influence career perceptions and interests. Also, the "Drawing-A-Manufacturer" test proved to be a valuable tool for collecting a rich-description of children's perspectives. Therefore, it is recommended that this tool be applied to other outreach contexts. Lastly, it is recommended that the results of this study be used to refine the survey questions to enhance the age-appropriateness of the instrument and to improve its validity.

Conclusion

While the strength of manufacturing as a career maintains, it seems that the lack of encouragement and overall negative perceptions of the industry continues to turn students away from pursuing these careers. Therefore, this study was conducted to better understand the influences that industry-driven outreach initiatives can have on influencing a child's (Grades K through 8) perceptions of, and interests toward, manufacturing-related careers. While manufacturing outreach and talent pipeline efforts are typically designed to engage young students in activities related to manufacturing careers, research attempts to better understand manufacturing outreach influences on children's perceptions of related careers and education pathways seem to be lacking. Therefore, this study focused on investigating children's perceptions of manufacturing before and after a summer camp titled *Robotics in Manufacturing*, which was developed through a regional commerce group and co-hosted by several manufacturers. The analysis of the collected data did support the idea that there is a "perceptions gap" among children in regard to manufacturing careers. However, the changes seen between the pre-camp and post-camp data do seem to indicate that an industry-led summer camp experience can influence the manufacturing perceptions of children. While the survey responses showed that interest in manufacturing careers waned after the camp, the children's drawings indicated that the participants moved from having limited, to no understanding of the industry, to more realistic perceptions of manufacturing. For example, the data showed that (a) participants placed an increased emphasis on safety after the camp, (b) they had an enhanced understanding of the actual activities happening within the "mysterious block manufacturing buildings" after the camp, (c) they increased their depiction of industrial robots and people in the manufacturing process, and (d) they focused their attention toward the human element of the manufacturing employees. Therefore, an experience, such as a summer camp, can provide children with an understanding of what happens within manufacturing-related careers. However, while the students did see manufacturing as a creative pursuit, their seemingly "negative perceptions" of safety and cleanliness did continue, potentially discouraging their pursuit of such careers. This highlighted the need to provide proper training for the outreach staff and age-appropriate ways to introduce ideas of topics, such as safety. If these items are not provided, then industry outreach experiences, as seen in the data, may not achieve their intended goals related to increasing their talent pipeline.

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Compliance with Ethical Standards

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Table 6 Grades K – 2 pre- and post-survey questions

Question	Response	Question	Response
1) What is your race/ethnicity?	African-American/Black American Indian/Alaskan Native Asian Caucasian/White Latino/Hispanic Other	**2)** Are your parents or guardians employed in manufacturing (local examples provided)?	Yes No I don't know
3) Are your siblings employed in manufacturing (local examples provided)?	Yes No I don't know I don't have any siblings	**4)** Do you have any other relatives (aunt, uncle, grandparents, etc.) employed in manufacturing (local examples provided)?	Yes No I don't know
5) Do you know anyone else employed in manufacturing?	Yes No I don't know	**6)** Do you think you would want to work in manufacturing?	Yes No
7) Do you think that there are lots of jobs in manufacturing?	Yes No	**8)** Do you think manufacturers need to have lots of education, like a college degree?	Yes No
9) Do you think manufacturing jobs are safe?	Yes No	**10)** Do you think manufacturing jobs are clean?	Yes No
11) Do you think manufacturing jobs let you be creative?	Yes No		

Table 7 Grades 3–8 pre- and post-survey questions

Question	Response	Question	Response
1) What is your race/ethnicity?	African-American/Black American Indian/Alaskan Native Asian Caucasian/White Latino/Hispanic Other	**2)** Are your parents or guardians employed in manufacturing (local examples provided)?	Yes No I don't know
3) Are your siblings employed in manufacturing (local examples provided)?	Yes No I don't know I don't have any siblings	**4)** Do you have any other relatives (aunt, uncle, grandparents, etc.) employed in manufacturing (local examples provided)?	Yes No I don't know
5) Do you know anyone else employed in manufacturing?	Yes No I don't know	**6)** Have you been on a manufacturing tour or participated in manufacturing activities before?	Yes, I've been on a tour and participated in activities No, I haven't done either. I've been on a tour, but I haven't participated in activities. I've participated in activities, but I haven't been on a tour.
7) Has anyone ever told you to consider a manufacturing job/career?	Yes No I don't know	**8)** Do you think you would want to work in manufacturing?	Yes No
9) Do you think that manufacturing jobs pay well?	Yes No	**10)** Do you think there are lots of jobs in manufacturing?	Yes No
11) Do you think manufacturers need to have lots of education, like a college degree?	Yes No	**12)** Do you think manufacturing jobs are safe?	Yes No
13) Do you think manufacturing jobs are clean?	Yes No	**14)** Do you think manufacturing jobs let you be creative and innovative?	Yes No
15) Do you think there is a lot of technology involved in manufacturing?	Yes No	**16)** Do you think manufacturers need to be highly skilled?	Yes No
17) What did you learn about manufacturing?	Open response	**18)** How do you think your idea of what manufacturing jobs were	Open response

Table 7 (continued)

Question	Response	Question	Response
		like changed since you last took this survey?	
19) 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	**20)** List one thing you liked and one think you would change about the camp.	Open response

All multiple-choice questions were the same on pre- and post- survey. The open response questions were only asked on the post-survey

Appendix

Survey Questions

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