PATT43: The 43rd International Pupils' Attitudes Towards Technology Research Conference
Hosted by the Swedish National Centre for School Technology Education (Cetis) and Technology and Science Education Research (TekNaD), Linköping University, Norrköping, Sweden, June 15th to June 18th, 2026

Workforce Development for Emerging STEM Career Areas: Upper Primary Student Career Perceptions in Microelectronics

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Abstract

Microelectronics (ME) are an important part of our everyday technologies and they represent an in-demand industry in many parts of the world. Early learning experiences may help students understand ME and become interested in ME-related careers. Guided by Social Cognitive Career Theory (SCCT), this preliminary study explored how upper primary school students perceive ME-careers and how these perceptions changed after participating in ME-focused instructional units. A total of 93 students in grades 3–5 from several schools in the Midwestern United States participated in the study. Students completed pre- and post-surveys that measured their exposure to ME and their motivation to learn about ME and ME careers. As the survey responses were collected in a dichotomous (Yes/No) format appropriate for this age level, a McNemar's test was used for the data analysis. Results showed significant increases in students' exposure to ME across all the related survey items. However, only one motivation-related survey item demonstrated a statistically significant increase. While a significant difference was found on only one motivation items, there was no indication of reduced motivation toward ME careers. These findings suggest that ME-focused instruction can increase elementary students' awareness of ME. However, short-term lessons alone may not be enough to strongly change motivation. Longer and repeated learning experiences may be desired to support early career development in ME.

Key Words: STEM Education, Microelectronics, Career Perception, Social Cognitive Career Theory

1 INTRODUCTION

In recent years, nations worldwide have invested heavily in microchip manufacturing to build innovative, resilient supply chains. In the United States, for example, the *CHIPS and Science Act of 2022* has channelled resources toward strengthening the domestic microelectronics (ME)

industry (U.S. Congress, 2022). With growing national interests in microchip development and manufacturing, there is a predicted talent shortage for the industry. Industry forecasts project that by 2030 approximately 67,000 semiconductor jobs in the United States could go unfilled if current education trends persist (Semiconductor Industry Association & Oxford Economics, 2023). Addressing this workforce concern will likely require earlier, and more intentional, K–12 engagement with ME concepts and careers.

As a result, a K–12 workforce development initiative focused on increasing awareness and engagement around the emerging ME industry has been initiated in the midwest region of the United States. While schools have seen a surge in STEM education activities, such as robotics and coding, over the past decades (Bybee, 2013), the ME industry presents an opportunity to create novel STEM-career focused curriculum and a rich site for research to understand children's career perceptions. However, given the novelty of ME integration within K-12 education, little is known about how students perceive this industry and the related careers, particularly at the elementary level. Elementary schooling typically occurs at a time in a child's life before their career choices become clear, and exposure to potential career fields during this time can influence motivation and learning choices (Super, 1990; Eccles & Wigfield, 2002; Hidi & Renninger, 2006). For this reason, this study focused on exploring the career perceptions of students in grades 3-5 before and after their experience with a ME-focused instructional unit.

The study is framed within the Social Cognitive Career Theory (SCCT), which links early self-efficacy and outcome expectations to emerging occupational interests (Lent et al., 1994). Within this framework, exposure to ME learning experiences is expected to influence students' motivation toward future engagement with the field.

- RQ1. How do children, across grades 3-5, perceive careers within ME industry?
- RQ2. To what extent does participation in a ME-focused, engineering design-based unit influence children, across grades 3-5, perceptions of the ME related careers?

Gaining insight into student experiences with ME and their perceptions of ME-related concepts and careers can inform K-12 workforce development initiatives aimed at students' exposure to, and motivation toward, the ME industry.

2 LITERATURE REVIEW

ME encompasses the knowledge, processes, and resources that enables the production and use of microchips which is a foundational technology that supports many systems and industries in society. The demand for workers in the ME field continues to grow with the expansions of the industry in the United States. The importance of introducing and teaching ME concepts to students beginning at the K-12 level has been seen as a strategy to motivate and prepare the domestic ME workforce (U.S. White House, 2025). To help begin to develop the ME workforce,

curriculum has been designed and implemented in the K-12 space in an effort to increase interest and knowledge of the ME industry (Lee et al., 2025).

While the K-12 range of schooling is vast, the goal of curriculum development and implementation across the grades is to provide students with different entry points to learn about ME. Prior research suggests that elementary school years are not a period for making concrete career decisions, but rather a critical stage for the development of interests, attitudes, and learning motivation related to future fields of study and work (Super, 1990). Early exposure to science and technology during this period has been shown to play an important role in shaping students' interests and engagement, which can influence learning, participation, and educational trajectories (Eccles & Wigfield, 2002; Hidi & Renninger, 2006). Therefore, this preliminary study was conducted to better understand students' perceptions and interests toward the ME industry in grades 3-5. Social Cognitive Career Theory (SCCT)

Lent, Brown, and Hackett (1994) proposed the SCCT, which is based on social cognitive theory and explains academic and career interests, choices, and performance through three key components: self-efficacy, outcome expectations, and goals. According to this theory, learning experiences help build individuals' self-efficacy and outcome expectations, which are central to the development of interests and career choices. Self-efficacy refers to an individual's belief in their ability to successfully perform specific tasks or activities. Self-efficacy is shaped through learning experiences, observing others, encouragement from others, and emotional states, and it plays an important role in determining which activities individuals choose to pursue and continue. Outcome expectations refer to beliefs about the expected results of performing a particular behavior, including material rewards, social recognition, and personal satisfaction. Together with self-efficacy, outcome expectations are key factors that influence the development of interests and career choices. Lastly, goals are the action plans that individuals intentionally set for themselves, ranging from short-term academic goals to long-term career goals. Within SCCT, interests lead to goal setting, and goals serve as a mechanism that guides actual choices and behaviors (Lent et al., 1994).

SCCT emphasizes the role of environmental factors as well as individual factors in career interests and choices. One of the key environmental elements highlighted in SCCT is learning experiences. Learning experiences can take various forms, including classroom instruction, participation in activities, observation, and exposure to media. These experiences can indirectly influence the development of self-efficacy and outcome expectations (Lent et al., 1994). Consistent with SCCT, the exposure items used within the context of this study—such as ME-related instruction, activities, media exposure, and teacher explanations—can be understood as forms of learning experiences. In addition, motivation in the context of this study reflects students' potential interest in ME, their willingness to learn more, and early career-related curiosity, which are conceptually aligned with interest and proximal goals in SCCT (Lent et al., 1994; Lent et al., 2000). Therefore, SCCT provides a theoretical framework for interpreting how ME educational experiences can influence students' career orientation toward the industry.

3 METHODOLOGY

3.1 Data Collection

This preliminary study explored children's perceptions of ME careers and concepts before and after an experience with an engineering design-based unit integrated with ME concepts and contexts. The study focused on children in grades 3-5 which can be a developmental stage sensitive to the formation of career perceptions. To collect the data to answer the study's research questions, a ME career-focused survey was administered as before and after the students participated in the one of the two units described in Section 3.4. The pre-survey was conducted before the instructional unit began, and the post-survey was administered immediately after the unit ended to examine changes. The surveys were completed in the classroom setting with guidance from the teacher, and students responded to the survey voluntarily after receiving their assent and parental/guardian consent. As a result, 93 student participants were a part of the pre-survey, whose ages ranged from 7 to 13. Of these, 40 participants (43.01%) identified as female, 43 participants (46.24%) identified as male, and 10 participants (10.75%) did not report their gender. For the post-survey, there were 80 participants, whose ages ranged from 7 to 13. Pre- and post-survey responses were linked using a student alias that did not allow individual students to be identified. This process enabled the analysis of pre- and post-responses at the individual student level. All data were used solely for research purposes and were managed in accordance with research ethics and student privacy protections.

3.2 Ethical Consideration

Following approved protocol from the Institutional Review Board, the students participated in the surveys. Parents and guardians received a written description of the study that outlined its purpose and explained how data was collected. They were asked to review and sign a consent form that specified the nature of the study activities, the expected duration of participation, any risks, the measures in place to protect participant confidentiality, and the rights associated with participation. Once the parents provided consent, the students were asked for their assent to participate.

3.3 Instruments

The survey instrument used was adapted from the ME exposure and motivation survey items reported by Gentry, Bermel, Holloway, and Douglas (2022). The original survey instrument was developed and administered with undergraduate students and provided evidence of content validity and reliability. However, the students in this study were in grades 3–5, and differences in developmental level and learning context were considered (authors, 2020). The items were adapted following a similar approach by (authors, 2020) that helps retains the original theoretical constructs and measurement intent while simplifying the wording and modifying some content to ensure that the items were understandable for elementary school students. While this approach has limitations, these modifications were made to preserve the core meaning of each item and align the language and examples with students' developmental level and lived experiences.

The survey items, which can be found in Appendices A and B, were designed to measure students' exposure to, understanding of, and interest toward learning about ME. The exposure items (Q1–Q6) asked whether students had experienced ME-related content through reading, watching videos, listening to teacher explanations, participating in related activities, and learning how microchips are used in everyday life. The motivation items (Q7–Q9) focused on students' intentions to learn more about ME and their willingness to continue participating in related learning activities.

All survey items (Q1–Q9) were presented in a dichotomous (Yes/No) format. The same survey instrument was administered to the same students at both the pre- and post-survey stages, allowing for comparison of responses before and after participation in the instructional unit. dichotomous response formats are appropriate for surveys with children because they can improve item clarity and support reliable responses, and they are well suited for analyzing pre–post changes within the same students (Borgers, de Leeuw, & Hox, 2000; Krosnick, & Presser, 2010).

Several limitations should be noted. Motivation was assessed using dichotomous (Yes/No) items, which may constrain variability in responses and reduce sensitivity to small but meaningful changes.

3.4 Intervention

This preliminary study examined students' perceptions of ME-related careers and explored the potential influence of ME curriculum units on these perceptions. The study was conducted in the Midwestern United States where there is an expanding ME industry. The curricular units were designed to engage 3rd through 5th grade students in solving real-world problems through engineering design while learning about ME and meeting the designated disciplinary-specific learning standards (Lucas et al., 2025). The two curricular units at the center of this research emphasized authentic, context-based problem situations and supported students in developing solutions that involve ME. These units were collaboratively developed by elementary teachers and faculty, staff, and students at a partnering university. The 2 different units (referred to as the *Integrated STEM Unit* and the *Engineering & Literacy Unit*) will be discussed in the following sections.

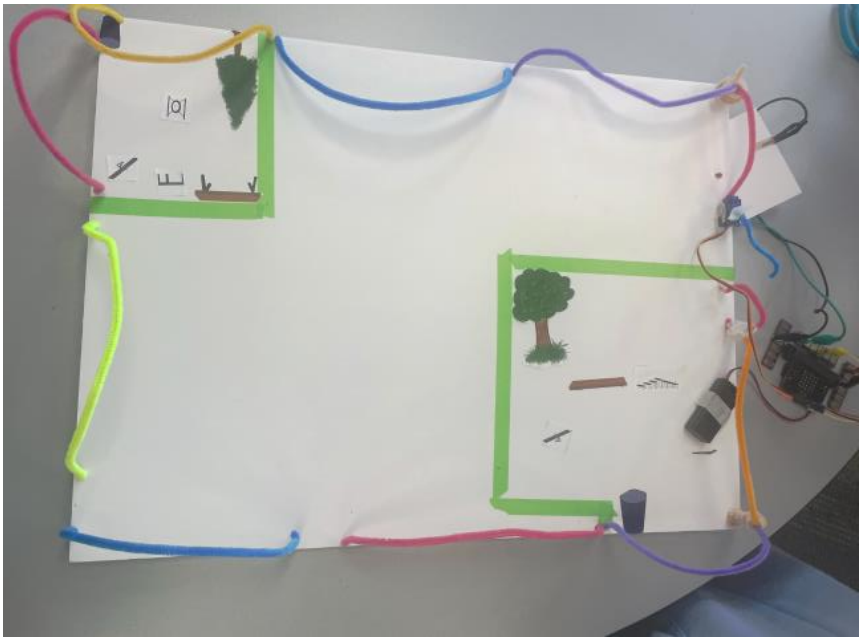
3.4.1 Integrated STEM Unit

The integrated STEM unit guided primary students through redesigning a community dog park, combining engineering design, circuits, and mathematics in a real-world context with authentic community connections. Students progress from creating simple circuits to make illuminated dog portraits to building automated safety features using micro:bits (tiny computers that allow students to explore how software and hardware work together) and servo motors, while learning about urban planning, budgeting, and community needs. Students design the park to keep gates closed, turn lights on automatically, and create a safe park. Students learn about sensors and how they can be controlled within electronic systems. The unit culminated in team presentations of their designs, where they demonstrated their understanding of engineering principles, mathematical concepts, ME, and collaborative problem-solving skills through their designed park

layouts. The unit includes 9 lessons. The total instructional time is about 11-12, 40 minute class periods. Figure 1 shows and example of a dog park created by the students.

Figure 1

Example of student created "dog park"using the micro:bit, sensors, and other electronics components.



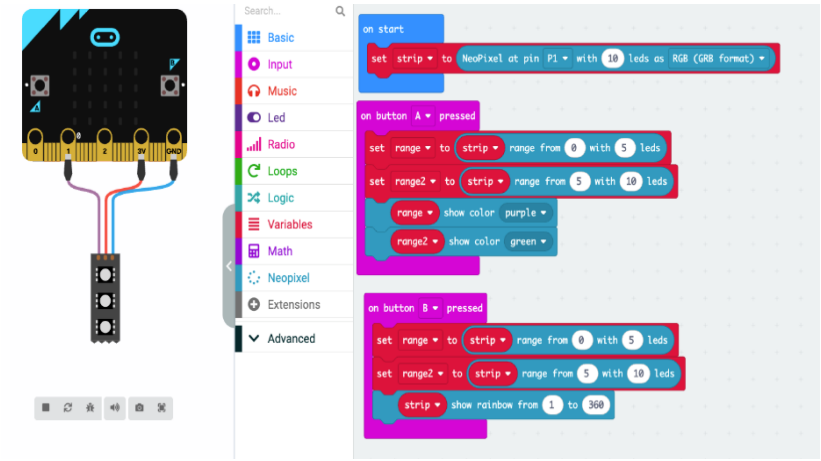
3.4.2 Engineering & Literacy Unit

The second curricular unit focused on using classroom literature as context to engage students in STEM learning through the integration of engineering and literacy. The unit was tailored to each teacher's class using their desired book for reading. Then each teacher followed an instructional approach that integrated the chosen book with engineering design. This integration involved engaging students in reading the book and identifying problems encountered by characters that could be solved in connection with ME. Students treat challenges faced by the story's characters as authentic engineering problems and address them by following engineering design practices, including problem definition, idea generation, prototyping, testing, and refinement. To support authentic problem solving, the unit incorporated hands-on activities involving computational tools and basic electronics/ME components, allowing students to explore how engineering solutions can be implemented in real-world contexts. This approach enabled students to connect engineering practices and ME-related concepts with practical applications while working

collaboratively to develop and improve their designs. The instructional unit was designed to be implemented over a 4-week period, with 2 instructional sessions per week. Figure 2 provides an example of the Engineering & Literacy Unit that centered on reading a book titled *The Hundred Dresses* by Eleanor Estes. After ready the book, students identified a problem to solve to help the main character that involved electronics and coding using the micro:bit.

Figure 3

Example of Engineering & Literacy Unit.



3.5 Data Analysis

In this preliminary study, pre- and post-survey data collected from primary school students were analyzed to examine the effects of ME units on changes in students' ME exposure and motivations. All statistical analyses were conducted using the R statistical software (R Core Team, 2024). McNemar's test was performed using the package mcnemar.test().

For survey items with binary responses, changes between pre- and post-survey responses were analyzed 'within-student level,' allowing comparisons of each student's response over time. Some students did not complete all survey items; missing responses occurred at the item level. Analyses were conducted using pairwise deletion, such that only students with complete pre- and post-test responses for a given item were included in the corresponding analysis (Enders, 2010).

To test changes in the binary pre- and post-survey responses, the McNemar test was used (McNemar, 1947). The McNemar test is a nonparametric method appropriate for analyzing changes in paired binary data collected from the same participants over time, making it suitable for the structure of the survey data in this study. For each survey item, the number of responses that changed from No to Yes and from Yes to No was calculated. These values were then used to test the statistical significance of changes in response distributions between the pre- and post-surveys.

To present patterns of response changes more clearly, descriptive statistics were calculated for each survey item, including the frequency and percentage (%) of responses that changed from No to Yes and from Yes to No. Because multiple statistical tests were conducted across survey items, a False Discovery Rate (FDR) correction was applied to the p-values to address the issue of multiple comparisons (Benjamini & Yekutieli, 2001).

Although students were recruited from schools in multiple districts, the primary unit of analysis in this study was the individual student. Therefore, statistical analyses comparing differences

across districts were not conducted. The ME units were implemented in the same manner across all regions, and school district-level effects were not a focus of the study. As a result, all analyses were performed at the individual student level.

3.6 AI disclosure

Generative AI tools (i.e., ChatGPT) were used only as a supportive tool for translation and language editing. All substantive writing, analysis, and interpretation were performed solely by the authors.

4 RESULTS

4.1 Results for RQ1: Initial Exposure and Motivation

Descriptive statistics from the pre-survey indicated that students' initial exposure to ME varied across items (see Table 1 for the results). Across the exposure items (Q1–Q6), the proportion of students responding "Yes" ranged from 24.1% to 62.2%, suggesting uneven prior exposure to ME-related concepts and experiences. In particular, fewer students reported knowing an adult who works with "microchips" (Q1 = 24.1%) or having participated in a ME-related activity (Q5 = 26.1%), whereas more students reported having learned about ME (Q4 = 62.2%) and watching a video about ME (Q3 = 53.4%).

For the interest-related items (Q7–Q9), students generally endorsed interest in learning more about ME, with 64.4% indicating interest in reading about ME (Q7) and 72.7% indicating interest in learning more (Q8). However, only 20.5% indicated wanting a future job involving ME (Q9), suggesting that career-oriented motivation was relatively low at the baseline.

Table 1

Initial "Yes" responses for exposure and interest items (Pre-test)

Item		N	Yes_N	Yes_Percentage (%)
Q1	Do you know any grown-ups whose job is to make or work with tiny computer parts called microchips (the chips that help phones and computers work)?	58	14	24.1
Q2	I have read something about microelectronics.	89	34	38.2

Q3	I have watched a vedio about microelectronics.	88	47	53.4
Q4	A teacher has talked to me about microelectronics.	90	56	62.2
Q5	I did an activity involving microelectronics.	88	23	26.1
Q6	I have learned about microelectronics.	90	50	55.6
Q7	I want to read books about microelectronics.	87	56	64.4
Q8	I want to learn more about microelectronics.	88	64	72.7
Q9	When I grow up, I want a job where I can work with microelectronics.	88	18	20.5

4.2 Results for RQ2: Pre–Post Changes in Exposure and Motivation

4.2.1 Exposure (Q1–Q6)

McNemar test results showed statistically significant pre–post changes for all exposure items (Q1–Q6). As expected, a substantially larger proportion of students changed their responses from No to Yes than from Yes to No across all of these questions. The percentage of No-to-Yes changes ranged from 41.8% to 72.7%, whereas Yes-to-No changes were minimal (0.0%–2.8%). All exposure items yielded statistically significant McNemar χ^2 values ($p < .001$), and these results remained significant after false discovery rate (FDR) adjustment.

Table 2

Pre-post changes in students' responses to exposure items

Item	N	No → Yes N (%)	Yes → N N (%)	χ^2	p (FDR)
Q1	58	17 (47.22)	1 (2.78)	12.50	< .001
Q2	89	30 (45.46)	3 (4.55)	20.49	< .001
Q3	88	30 (46.15)	1 (1.54)	25.29	< .001

Q4	90	28 (41.79)	0 (0)	26.04	< .001
Q5	88	48 (72.73)	0 (0)	46.02	< .001
Q6	90	33 (49.25)	1 (1.49)	28.27	< .001

Note. N reflects the number of students with complete pre-post responses for each item. McNemar's test was used to examine pre-post changes. P-values were adjusted using the false discovery rate (FDR) procedure.

4.2.2 Interest (Q7–Q9)

For the interest items, only Q8 demonstrated a statistically significant pre–post change ($\chi^2 = 6.72$, $p = .010$; FDR-adjusted $p = .012$). For this item, the proportion of No-to-Yes changes exceeded the proportion of Yes-to-No changes. In contrast, Q7 and Q9 did not show statistically significant changes ($p > .05$), with the majority of students maintaining the same response from pre- to post-test.

Table 3

Pre-post changes in students' responses to motivation items

Item	N	No → Yes N (%)	Yes → No N (%)	χ^2	p (FDR)
Q7	63	14 (22.22)	8 (12.70)	1.14	.286
Q8	65	15 (23.08)	3 (4.62)	6.72	.012
Q9	66	12 (18.18)	5 (7.58)	2.12	.164

Note. *N* reflects the number of students with complete pre-post responses for each item. McNemar's test was used to examine pre-post changes. P-values were adjusted using the false discovery rate (FDR) procedure.

Overall, the results indicate that participation in the ME-focused unit was understandably associated with consistent and significant increases in students' exposure to ME, as reflected across all exposure items. However, changes in motivation were more limited, with statistically significant differences observed for only one of the three motivation items. This result is related to the fact that the majority of the participants were already "motivated to learn more" about ME before the ME experience and still motivated to learn more after the experience. Therefore, there was no significant difference, and there was also no reduction in motivation toward ME.

5 DISCUSSION & FUTURE RESEARCH

The purpose of this preliminary study was to examine elementary students' exposure to and motivation toward the field of ME before and after participation in a ME-focused instructional unit. These early findings suggest that participation in the ME-focused units were associated with consistent gains in students' exposure to ME, while changes in motivation were more limited as students were already interested in learning about ME.

Results showed statistically significant pre–post differences across all exposure items (Q1–Q6), with a large proportion of students shifting from "No" to "Yes" responses and very few understandably shifting in the opposite direction. These findings indicate that the instructional unit was successful in increasing students' awareness of and familiarity with ME-related concepts and experiences. Given that microchips and semiconductor technologies are often embedded and invisible in everyday devices, such gains in exposure are noteworthy, particularly at the primary school level. These findings can suggest that instructional experiences that make underlying concepts and processes explicit can play an important role in supporting students' early awareness and understanding across complex, career-focused learning domains.

From a theoretical perspective, these results align well with SCCT, which emphasizes the importance of early learning experiences in shaping students' understanding of and engagement with career-related contexts. In this study, the ME-infused, engineering design-based activities appear to have served as meaningful learning experiences that increased students' exposure to ME, an important first step in the development of longer-term career-related interests.

In contrast to the consistent exposure gains, changes in motivation were observed for only one of the three motivation items (Q8). For the remaining motivation items (Q7 and Q9), most students maintained the same response from pre- to post-test, and no statistically significant changes were detected. This pattern suggests that students were initially motivated to learn about ME before the unit and maintained this motivation after their experience. Regarding career perceptions and interest, this can show that the topic of ME is one that is interesting to primary students and the ME learning experience does not change this interest.

The findings of this study are consistent with previous research on early STEM and industry-related learning experiences and students' career perceptions. Authors (2020) showed that industry-driven outreach programs helped broaden children's views of manufacturing careers but did not lead to clear or immediate career intentions. Similarly, Walls et al. (2024) found that STEM learning labs in industry settings improved students' career perceptions, without resulting in definite career commitments. In line with these studies, the current results show significant increases in students' exposure to ME concepts/careers after participating in an instructional units. These results can suggest that early learning experiences help increase students' awareness. However, these experiences appear to support early career interest foundations, rather than directly shaping final career choices.

Within the SCCT framework, motivation is influenced not only by exposure but also by factors such as self-efficacy, outcome expectations, and social supports. The current units may have

increased students' awareness of ME, but additional opportunities for hands-on success, reinforcement, and continued engagement may be necessary to produce broader motivational change.

The results indicate statistically significant increases in students' reported exposure to ME following participation in the ME-focused instructional activities. However, the limited motivation findings indicate that workforce development efforts should be designed as longer-term and scaffolded experiences rather than one-time interventions, particularly if the goal is to influence students' motivation toward ME-related learning and careers (Authors, 2025).

This preliminary study has a limited sample size. Therefore, future studies with larger and more diverse samples are needed to support these findings. And, future studies could incorporate multi-point Likert scales to capture more nuanced shifts in motivation. Finally, the study focused on short-term pre–post changes; longitudinal research is needed to examine whether increased exposure leads to sustained motivation and later career-related outcomes.

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Appendix A

Pre-Survey Questionnaires

3-5 Microelectronics Pre-Survey

Name : _____

Instructions: Read each question (or have a grown-up read it to you). There are no right or wrong answers. Pick the choice that sounds most like what you think or feel. Take your time, and remember—your answers are private.

Please read the definitions below before you aner the questions.

Microelectronics are tiny parts or microchips that are inside electronic devices like phones and computers. They help these devices send messages and do smart things! Parts of the microelectronics are so tiny that you can't even see them with your eyes.

Microelectronics Careers are jobs where people design, make, test, or fix the tiny computer parts—called microchips—that make phones, tablets, cars, and other electronics work.

1. **Do you know any grown-ups whose job is to make or work with tiny computer parts called microchips (the chips that help phones and computers work)?**

   ◯ Yes ◯ No ◯ I'm not sure.

2. **I have read something about microelectronics.**

   ◯ Yes ◯ No

3. **I have watched a video about microelectronics.**

   ◯ Yes ◯ No

4. **A teacher has talked to me about microelectronics.**

   ◯ Yes ◯ No

5. **I did an activity involving microelectronics.**

   ○ Yes ○ No

6. **I have learned about microelectronics.**

   ◯ Yes ◯ No

Appendix B

Post-Survey Questionnaires

3-5 Microelectronics Post-Survey

Name : _____

Instructions: Read each question (or have a grown-up read it to you). There are no right or wrong answers. Pick the choice that sounds most like what you think or feel. Take your time, and remember—your answers are private.

Please read the definitions below before you aner the questions.

Microelectronics are tiny parts or microchips that are inside electronic devices like phones and computers. They help these devices send messages and do smart things! Parts of the microelectronics are so tiny that you can't even see them with your eyes.

Microelectronics Careers are jobs where people design, make, test, or fix the tiny computer parts—called microchips—that make phones, tablets, cars, and other electronics work.

1. **Do you know any grown-ups whose job is to make or work with tiny computer parts called microchips (the chips that help phones and computers work)?**

   ○ Yes ○ No ○ I'm not sure.

2. **I have read something about microelectronics.**

   ○ Yes ○ No

3. **I have watched a video about microelectronics.**

   ○ Yes ○ No

4. **A teacher has talked to me about microelectronics.**

   ○ Yes ○ No

5. **I did an activity involving microelectronics.**

   ○ Yes ○ No

6. **I have learned about microelectronics.**

○ Yes ○ No

7. I want to read books about microelectronics.

○ Yes ○ No

8. I want to learn more about microelectronics.

○ Yes ○ No

9. When I grow up, I want a job where I can work with microelectronics.

○ Yes ○ No

10. What is your gender?_____

11. How old are you? _____

12. Which categories describe you? Select all that apply to you:

☐ American Indian or Alaska Native

☐ Asian

☐ Black or African American

☐ Hispanic, Latino or Spanish

☐ White

☐ Other: _____

☐ I prefer not to answer.

13. What did you like about this microelectronics experience?

_____

_____

_____

_____

_____

14. **What would you change about this microelectronics experience?**

_____

_____

_____

_____

_____