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Board 153: Assessment of K-12 Students' Microelectronics Understanding and Awareness (Work in Progress)

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Assessment of K-12 Students' Microelectronics Understanding and Awareness (Work in Progress)

Microelectronics and semiconductors have become vital to society due to their prevalence in personal, consumer, business, and military technologies. The microelectronics market is estimated to increase by 20% in 2024 [1], yet there continues to be a shortage in the supply chain [2]. Recognizing this need, the US is making a major economic shift from being primarily purchases of microelectronics and semiconductor components to being manufacturers [3, 4]. As the US builds its microelectronics workforce, the number of job opportunities is exponentially increasing. There will be an anticipated 114,800 industry jobs available by 2030 with training requirements ranging from certificates or two-year degrees to PhDs [5].

While the workforce continues to expand, teenagers still show disinterest in entering the microelectronics industry [6]. According to Social Cognitive Career Theory (SCCT), students' awareness and motivation of working in a certain field will only increase if multiple exposure opportunities are provided [7]. Without an increase in the upcoming generation's motivation to pursue careers in the microelectronics workforce, the plan to continue expanding our involvement in this industry will suffer.

We propose that embedding engaging microelectronics content into existing middle and high school curriculum will increase student awareness of and interest in the field. This work in progress will evaluate 11 units that are implemented during the 2023 – 24 academic year by 32 teachers. These units are embedded in courses that cover mathematics, science, engineering, English, and social studies content. The results from the content pre- and post-assessments will answer the research question: How do students conceptualize microelectronics and its meaning for engineering and society after completing an integrated STEM unit embedded with microelectronics contexts?

A measurement of change in student understanding is collected through identical pre- and post-assessments given at the start and conclusion of each curriculum unit. These content assessments contain the four prompts: *1) What does the term "microelectronics" mean?, 2) How are microelectronics used in* <u>*field*</u>*?, with "*<u>*field*</u>*" being the subject of the class in which the unit is taught, and 3) What jobs would you be interested in that use microelectronics? Provide one example of how microelectronics is used in that job.* With the increasing need for technicians, engineers, and researchers in the microelectronics industry, it is vital that students are introduced to the field as early as possible. These curriculum units will serve as an example for how microelectronics content can be embedded into existing K-12 curriculum as the US continues to invest heavily in this industry.

Literature Review

It is important to introduce students to microelectronics and semiconductor concepts as early as possible to provide them multiple exposure opportunities and foster interest in relevant career paths. As technology continues to develop, students have become complacent with their technical resources and are showing decreased interest in pursuing this field for education or careers [8, 9]. Students need to be motivated and prepared at an early age to pursue science and engineering if they are to gain interest and be successful [10]. Students who ultimately pursue scientific careers indicate this interest at a young age and are more likely to succeed if they develop STEM literacy earlier in life [11, 12]. As previously mentioned, this aligns with the highly cited SCCT to increase awareness and motivation toward a given career path [7].

Background

In the summer of 2023, through a Department of Defense funded university K12 partnership, 32 teachers from 7 districts participated in week-long professional develop to learn how to integrate microelectronics related context into their subject matter curriculum. The teachers taught a variety of subjects, including math and science, but also English, social studies, and other topics. As a result of the workshop and ongoing seminars and coaching, the teachers collaborated with the university team to write 11 units. The context for each unit was designed by a curriculum writer and the group of teachers who planned to implement the unit. The units' general format was written in alignment with the structure outlined by Douglas & Moore [13]. Each unit began with the introduction of an engineering design challenge that is proposed by a client. Criteria and constraints are provided to students by the client along with a request that they learn relevant information before designing a solution. The units then work through a series of "learn" lessons in which students learn information relevant to the design challenge. These learn lessons are essential background knowledge the students will need to design an effective solution and contain the course-specific content that are clearly aligned to learning objectives for the course. The engineering design challenge then serves as an engaging context for the content. The client then guides the students to work through the remaining steps of the engineering design process: Plan, Try, Test, Redesign, and Communicate. Along the way, students are required to use evidence-based reasoning to make their design decisions as a team. The final lesson requires design teams to communicate their design through a visual presentation given to the class. The very first and last activity in every unit is a pre- and post-content assessment. These assessments are identical and serve as a measurement of student growth in relevant knowledge. The first 7 – 9 questions focus on course content that is covered during the "learn" lessons. The last three questions are the prompts on which this study is focused as listed above.

Each unit was required to have incorporation of microelectronics content, but no specific method was provided on how it must be integrated. Many of the teachers chose to use micro:bits and block coding, especially for engineering or technology electives. Several science and mathematics teachers chose to use sensors for measurement of relevant parameters such as temperature, water quality, atmospheric carbon, or heart rate. In these units, one lesson focused on the microelectronic components of the sensor and how it takes water or air and outputs a specific value. Some teachers chose to break apart a sensor or show a cross section to help students understand how small these pieces are. Every curricular unit included the words "microelectronics" or "semiconductors" frequently throughout the text to continue fostering student recognition of and comfort with the terminology.

Setting and Participants

For this work in progress paper, two curriculum units have been fully implemented with pre- and post-content assessments available to analyze. The demographic information for the two schools can be found in Table I. Mr. B's class is a 9th and 10th grade engineering and technology elective. In his class of 11 students, 7 consented to participate in this study. The content for this curriculum unit focused on creating an electronic expansion pack for an existing robotic sphere. Students engaged in block coding, circuitry, and micro:bit content prior to designing their expansion pack. Ms. T teaches a 10th grade Integrated Chemistry and Physics (ICP) course to a class of 12 students, all of which consented to participate in the study. Her curriculum unit prompted students to design a security device for a briefcase. Students learned about electricity, circuits, sensors, and microcontrollers prior to designing their security device.

TABLE I
SCHOOL DEMOGRAPHIC INFORMATION

Teacher	Grade Level	NCES School Classification	Male Students (%)	Female Students (%)	Students of Color (%)	Students in Free/Reduced Lunch (%)
Mr. B	9th/10th	City: Small	50.9	49.1	57.8	69.2
Ms. T	10th	Town: Distant	48.5	51.5	8.7	32.4

Data Collection and Analysis

Students participated in a pre-post qualitative open-ended content assessment that was captured for all consenting/assenting students and deidentified. The responses for the final four target questions were transcribed into a single spreadsheet to analyze the content of the pre-post questions. Students who did not complete both the pre- and post-content assessment were removed from the dataset. There were a few students who copied answers from the curriculum directly rather than giving their own answer and a few that did not answer. These students' data for those questions was not included in the final analysis. In total, 14 students' responses were analyzed for 41 total questions. Answers to each questions' response were compared to benchmarked responses (such as definitions given in the curriculum or lists of careers related to the context) and then compared pre-to-post for higher fidelity to the benchmarked response. Student responses were categorized into positive, neutral, or negative change for each set of responses to each question. Positive results indicate that the student's post-content response was closer to the benchmarked answer than their pre-assessment response was, while negatively coded responses were the opposite of this. A neutral coding implies that the student's response did not improve or worsen in relation to the benchmarked response. Memoing was completed for each category within each question using a cross-response comparison to develop inferences.

Preliminary Results

Students' overall understanding of microelectronics either remained neutral or improved after the unit. Many answers in the pre-content assessment primarily included question marks or statements about not knowing the answer. After completing the post-content assessment, many students improved in their microelectronics terminology. Out of the 41 analyzed responses, 12 were categorized as positive, 27 as neutral, and 2 as negative. The two negative answers were in response to the microelectronics jobs question as the students realized they were not interested in pursuing this career path. However, no students experienced a negative trend in their answers to the questions about what microelectronics means or how it is used in their field. The unit that was taught in an engineering and technology elective had many answers categorized as neutral, which may be due to the fact that the teacher informed us that the students were already familiar with the concept of microelectronics. Nine of the positive responses were from the ICP classroom in which a great amount of growth was seen in microelectronics knowledge. None of the answers were categorized as negative to the question, "*what does the term 'microelectronics' mean?*" Out of 15 answers in the pre-content assessment, ten students answered "*small electronics*" or a variation of the phrase. In the post-content assessment, several students provided more accurate and in-depth definitions. As shown in Table II, the positive student response shows that understanding of the function of microelectronics improved, as well as how they fit into the big picture that incorporates other components of a product. Almost all of the answers in the pre-content assessment were incorrect for the second question, concerning how microelectronics are used in their classroom's field of study. Fifty percent of post-content assessment responses were categorized as positive, showing an increase in understanding of microelectronics applications.

TABLE II
REPRESENTATIVE LEVELD RESPONSES

Question	Level	Pre-Unit Response	Post-Unit Response
What does the term microelectronics mean?	**Positive Student Response**	*"I believe it means electronics that are extremely tiny and are used for smaller scale functions or more precise functions, or could be part of larger bodies*."	"*Microelectronics are electronics that are on a much smaller scale, they are essentially the nervous system to the brain of the electronic, or they can be an electronic all on their own, as with the case of raspberry pi's*."
	Neutral Student Response	*"electronics which are meant to be worked on under a microscope"*	*"electronics that are small to the eye and hard to see"*
How are microelectronics used in field? With field being the subject of class in which the unit is taught.	**Positive Student Response**	*"Microelectronics are used in the fields of chemistry and physics because microelectronics are used to perform tasks for a bigger picture."*	*"Microelectronics are used in these fields in a variety of ways, by making sensors, circuits, and etc."*
	Neutral Student Response	*"For electronic chips to be able to make devices out of it*	*"In the devices they use"*
What jobs would you be interested in that use microelectronics? Provide one example of how microelectronics is used in that job.	**Positive Student Response**	*"An electronic store. You have to be able to use microelectronics to make and fly items."*	*"Software engineer. You can use microelectronics to design new software and code it."*
	Neutral Student Response	*"cars"*	*"cars"*
	Negative Student Response	*"Electronics Quality inspector. They inspect things like the microelectronics."*	*"None, I don't like microelectronics."*

The third question that prompted students about jobs using microelectronics was the only question to have answers categorized as negative. While one of the negative responses, shown in Table II, showed decreased interest in microelectronics, it shows an increase in the student's self-awareness about their career interests. Not every student that participates in these units will want to pursue a microelectronics career. However, introducing microelectronics as a potential career path provides an exposure opportunity for students who may not have learned about it otherwise.

Conclusions

This study shows promising preliminary results for an increase in student awareness of and interest in the field of microelectronics and the results for the career interest provided insight into how students thought about microelectronics in the field. Future work will analyze the remaining units and determine if microelectronics interest is increased. Additionally, while units may broadly increase awareness or interest, studies should be conducted on individual curriculum units to determine if a certain context or subject matter is more likely to increase student engagement with microelectronics. Continued research in this field will support the US goal of increasing its participation in microelectronics by building our workforce.

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