The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #41529

Evaluation of an ErgoNomiCs and Human-Automation iNteracTion (ENCHANT) Summer Camp (Evaluation)

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I am a third-year Ph.D. student in Industrial and Operations Engineering (IOE) at the University of Michigan, advised by Dr. Xi Jessie Yang. My research focuses on Human-Computer Interaction (HCI), specifically to enhance human trust when using automation. My future goal is to conduct human factors research to improve HCI for people with disabilities and the aging population. I value engineering outreach aimed at younger students. I believe that engaging with students to introduce the world of human factors engineering and providing them with hands-on experiences can contribute to nurturing their interests and expanding their horizons. I also think this engagement makes the concept of becoming an engineer more tangible for the students. I'm confident that these outreach initiatives will ignite a passion for STEM and cultivate a diverse pool of future engineers. I currently serve as a student member of the IOE DEI Committee, in which I've been actively involved in improving outreach initiatives.

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ErgoNomiCs and Human-Automation iNteracTion (ENCHANT) Summer Camp (Evaluation)

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Abstract

To foster inclusivity and increase diversity in Science, Technology, Engineering, and Mathematics (STEM) education, ErgoNomiCs and Human-Automation iNteracTion (ENCHANT) summer camp was hosted at the University of Michigan's Industrial and Operations Engineering Department (IOE). Middle school students were introduced to IOE, Human Factors Engineering, and Robotics through four 50-minute engaging activity stations: two were specifically developed for outreach activities, and the other two were modified from current research topics. The stations included interactive hands-on activities and discussions around optimization, robotics, trust in automation, and autonomous vehicles. Post-activity evaluation questionnaires revealed that students were excited, engaged, and gained a deeper understanding of the topics covered during each station. By providing an environment where education, exploration, and enjoyment intersected, the camp created a platform for the students to get an insight into the exciting possibilities that industrial engineering holds. More summer camps should be hosted on various engineering topics, to broaden access to hands-on activities that provide enriching learning experiences to diverse student populations and encourage student interest in engineering and related fields.

Keywords - STEM engagement, Engineering Education, Women in Science and Engineering, Industrial Engineering, Human Factors Engineering

Introduction

In Science, Technology, Engineering, and Mathematics (STEM) education, fostering diversity and inclusion has been an important educational goal for institutions for many years [1]. Historically, women have been underrepresented in STEM disciplines, creating a lack of representation and overall diversity [2]. In 2019, the National Science Board (NSB) reported that women are underrepresented in the STEM workforce compared to the proportion of women within the U.S. population, only accounting for 16% of engineers and 26% of computer and mathematical scientists [3]. Improving the diversity of the STEM workforce could foster new ideas and perspectives, catalyzing the design of more inclusive and innovative engineering solutions that reflect the needs of a diverse society, similar to how corporate firms with gender-diverse boards showed higher innovation performance [4]. There has been significant progress over the years to encourage women's representation in STEM, including summer camps and organizations such as Women in Science and Engineering (WISE).

Summer camps hosted on university campuses focusing on STEM education have been proven to increase students' interest in pursuing the field, with numerous studies showing their effectiveness [5-9]. Such summer camps have demonstrated the power of interactive and collaborative activities to inspire students' passion for engineering [8, 10]. For example, individuals who participated in the Girls' POWER summer program, which aimed to enhance high school girls' confidence in their technical abilities and ability to study Computer Science (CS), felt an increase in self-confidence and interest in pursuing CS [1]. Similarly, a week-long camp at the California Polytechnic State University also observed a positive trend in students' interest in pursuing engineering academically and professionally, following participation in hands-on activities [11]. Analysis of three annual summer engineering camps at Utah State University from 2017 to 2019 with students aged 14 to 16 also revealed a positive outcome, where participation significantly increased female students' interest in STEM, advocating for future camps to emphasize female student engagement [12].

Through these outreach programs, many students have gained substantial exposure to various engineering disciplines. Researchers believe this increased exposure will contribute to the diversification of representation in STEM fields [13, 14]. However, a study examining survey responses of students in seventh, eighth, and ninth grade revealed a trend that even within STEM, girls are less inclined to pursue engineering careers compared to traditional science-related paths [15]. The interdisciplinary approach of industrial engineering integrates concepts from psychology, biology, and mathematics with engineering principles, which could bridge the interest gap among female students. As Industrial Engineering and Ergonomics are lesser-known areas within engineering, we aim to inspire students to explore the often overlooked discipline by highlighting the breadth and potential of Industrial Engineering in optimizing various systems with human-centered approaches, with the goal of contributing to a more well-rounded STEM exposure.

The Extraordinary Women Engineers Project concluded that to convince female high school students to consider engineering as a potential major/career, current engineers need to spark students' interest and help them understand the exciting and rewarding endeavors of engineering [2]. Studies also suggest that introducing students to engineering at a younger age can be beneficial because it exposes them to the relevance of engineering as a future profession in a wide variety of fields and applications, fosters problem-solving techniques that take time and practice to develop, and builds confidence in STEM activities [1, 5, 11, 16]. The ENCHANT (ErgoNomiCs and Human-Automation iNteracTion) summer camp for middle school students included engaging learning activities modified from current research projects, and activities developed specifically for outreach events and hands-on learning. The students also had the opportunity to tour lab spaces in the department to visualize real-world applications of the camp activities. Through enjoyable hands-on learning opportunities, we anticipate students will have higher retention of concepts and will grasp a deeper understanding of real-world applications, as evidenced by results from similar studies [17, 18].

Enchant Activity

On June 22nd, 2023, a WISE GISE (Girls in Science and Engineering) one-day summer camp, named ENCHANT took place at the University of Michigan's Industrial and Operations

Engineering (IOE) department. The camp was hosted by the Center for Ergonomics (C4E), the Stirling Group, and the Interaction and Collaboration Research Lab (ICRL). The camp included the Center for Ergonomics and Robotics department tour, alongside four engaging activity stations designed to expose students to a variety of systems that Industrial Engineers and Roboticists encounter. Two station activities were specifically designed and developed to challenge the students in a creative problem-solving task, and the other two were modified from current research topics.

Nineteen middle school-aged students (17 female and 2 male) participated in the camp to explore Industrial Engineering and Robotics. Though the target group was female students, male students were also allowed to participate in the camp. The participant ethnicity distribution is reported as follows: Asian (5), Black (3), Hispanic (5), White (4), Other (2), and one participant did not disclose their ethnicity. Our analysis primarily focuses on evaluating the one-day camp rather than examining gender or ethnic disparities. However, we include demographic information in compliance with a recent suggestion by Pawley [19], which highlights the importance of demographic transparency in research regardless of the research theme.

The attending students were grouped into teams of four or five to encourage teamwork and collaboration while getting enough hands-on experience. Throughout the day, the groups were on a rotational schedule to experience each of the four activity stations. Each station was a 50-minute session, during which students had the opportunity to broaden their knowledge in engineering through practical applications of Industrial Engineering concepts, specifically in Operations Research and Human Factors Engineering. This learner-centric format ensured a dynamic educational experience and kept the participants thoroughly engaged and excited about the camp. Students were also able to freely interact with graduate students, faculty, and staff coordinating the camp to ask questions and learn more about potential career paths in engineering.

A. Station 1: Optimi-Station

We initiated Station 1 with a high-level discussion about mathematics and optimization by opening the discussion with a question to the students, asking them how they arrived at the IOE building that day. The students volunteered answers about their mode of transportation, such as taking the bus or driving with a parent. This initiating question prompted a conversation about how the vehicle operator knew how to get to the destination in the most efficient way possible. The discussion about the mode of transportation transitioned into a conversation about navigation applications and their route-planning algorithms. The familiar topic of navigation applications served as a starting point for curiosity about how the “best” route is selected. Students volunteered answers about the factors that the algorithm might consider when selecting the best route, such as avoiding construction or traffic, picking the most fuel-efficient route, or picking the roads with the most beautiful scenery. This conversation also allowed us to introduce the concepts of decision variables and algorithm formation with a known concept for the students.

To transition the conversation towards the fundamentals of optimization, students were invited to answer questions about their knowledge of optimization, and what it means to "optimize" a system. After the initial introduction to the topic area, we transitioned into a discussion of interactive examples to explain optimization concepts to the students. The interactive portion of this station consisted of two activities to support this age group in grasping the concepts of optimization.

The first activity was a route planning exercise for the best path around the room. Multiple paths, divided into different segments, were marked on the floor to represent different ways the students could travel from a designated starting point to a designated ending point (Figure 1). For each segment of the path, the students were required to travel along that segment in a specific way, such as skipping, taking two steps forward and one step back, or walking backward. All the students were given time to test out each possible route from the starting point to the ending point (Figure 1). After the students had traveled along each segment of the paths multiple times, we initiated a group discussion about the level of difficulty of traveling along each path. Students were instructed to reach a group consensus for rating the difficulty of each segment from 1 to 6, with 1 indicating the least difficulty (least effort expended) and 6 indicating the most difficulty (most effort expended). Students were allowed to repeat numbers in their ranking but were encouraged to think about the difficulty level for each segment relative to the other segments in the activity. After each segment had been scored, we walked the students through the process of calculating the total difficulty score for each path from the starting point to the ending point (summing the scores along each path segment). The path with the lowest score represented the easiest path, and the path with the highest score represented the most difficult path. This activity introduced the students to optimization from a path-planning perspective.

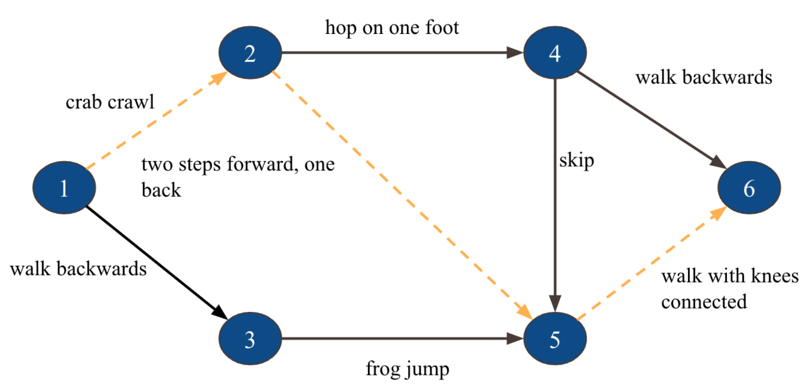

Figure 1. Map of the route planning exercise. Participants traveled along the arrow in a specific way (crab crawl, skip, etc.). The yellow dashed line indicates an example of a route from 1 to 6.

The second activity for this station involved an optimization problem with lego blocks. This activity allowed us to define different aspects of an optimization problem, such as constraints, decision variables, and the objective function. Students were asked to imagine they were in charge of a factory that produced "block Ms" and "block Us" with the legos.

Constructing a "block M" required 2 long lego blocks (4x2 blocks) and 3 short lego blocks (2x2 blocks). Constructing a "block U" required 2 long lego blocks and 2 short lego blocks (Figure 2). The students were told that they would make $5 for each "block M" that they created and $4 for each "block U" that they created. Each student was given 9 short lego blocks and 8 long lego blocks and instructed to maximize the profit that they could make. Students were given about 10 minutes to find a solution to the problem, during which the station volunteers walked around to each student and asked them about their approach to the problem.

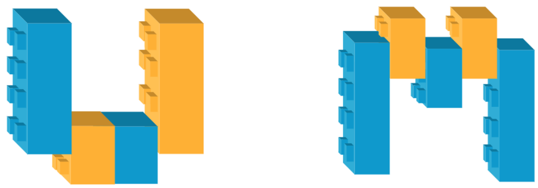

Figure 2. U and M lego blocks. U's sold for $4 and M's sold for $5. Participants were given 9 short lego blocks and 8 long lego blocks to create U or M blocks to maximize profit.

After the students were given sufficient time to devise a solution, we walked them through the problem formulation process for this optimization task. We defined the constraint equations based on the resources they were given and built an objective function to determine the best solution (Equation 1).

$$\text{Objective Function: maximize } profit = \$4\, x_U + \$5\, x_M$$
$$\text{Constraint 1: } 2\, x_U + 3\, x_M \leq 9 \quad (short\ lego\ blocks)$$
$$\text{Constraint 2: } 2\, x_U + 2\, x_M \leq 8 \quad (long\ lego\ blocks)$$

Equation 1. Mathematical formulation of the optimization task. x_U represents the number of block U's and x_M represents the number of block M's.

Taking this activity to the problem formulation step attempted to augment the understanding of the mathematics behind optimization, helping to bridge the gap between conceptualization and implementation. This activity allowed students to convert a real-world problem into a basic mathematical formulation. By completing these two activities, students were introduced to the concepts and mathematical foundations of optimization through simple and relatable experiences.

B. Station 2: Lego Mindstorms

We initiated Station 2 with a conversation on Robotics and its diverse applications in the fields of Computer Science, Biomedical Engineering, Human Factors Engineering, and the Healthcare industry. Following this discussion, we discussed the differences between robot software and hardware and how they work together to create a system that performs certain tasks. This dialogue helped shape the students' understanding of how software and hardware concepts are used to produce robotic motion, while simultaneously prompting them to think of ways a robot's actions could be organized into appropriate steps through coding.

To motivate the discussion of how a robot performs tasks using instructions written in software, the students took part in a goal-oriented exercise that drew parallels between real-life spoken instructions and robotic software processes. We paired the students, assigning one the role of a “programmer” and the other a “machine.” The machine was blindfolded to completely depend on the instructions spoken by the programmer. The programmer’s responsibility was to direct the machine to grasp a bottle that was placed at differing locations around the room undisclosed to the machine. This required programmers to give accurate instructions to their blindfolded partners by determining the distance and directions they should walk, the adjustments in orientation they needed, and the precise moment to reach for the bottle. This exercise offered students an insight into the purpose of programming and potential challenges and constraints that could arise while instructing robots to perform specific tasks.

To give the students an opportunity to apply the knowledge gained from the previous exercise to a programming task, the next activity students engaged in was using a Lego Mindstorms system, which can be built into different forms. For our station, Lego Mindstorms were pre-built into wheeled robots (see Figure 3), which were capable of sensing in an X-axis direction and moving in a Y-axis direction. These robots could be programmed using a block-based programming language (Figure 3).

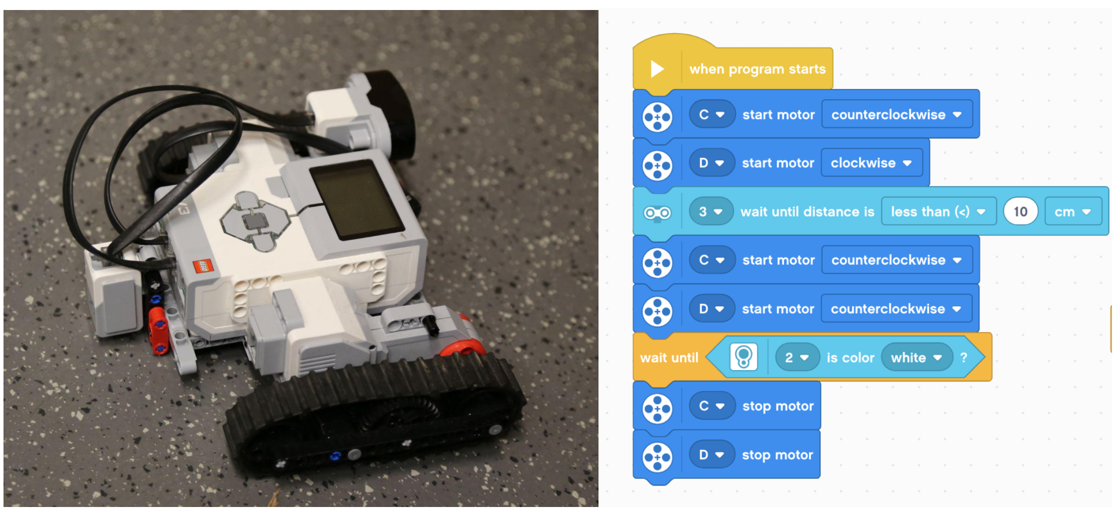

Figure 3. Lego Mindstorms robot (left) and the programming language blocks which induced a spin maneuver followed by driving in a straight line until it reached a piece of paper (right)

We first introduced the students to the fundamental concepts of the Lego Mindstorms interface, such as starting a project and accessing code blocks. We then allowed them to explore the five Lego EV3 Robots by pointing out motors, wheels, and sensors while looking at the different code blocks available on the software. Once the students gained familiarity with the robots and the coding software, we divided them up into pairs, with each pair receiving a Lego EV3 Mindstorms kit. Then we introduced different actions the robots could make, such as moving forward or backward, producing sounds, and utilizing its color sensor and infrared sensor. After acquainting each student with the various components, we challenged them to program the robot to perform a given high-level task Examples of the given tasks included "Make the robot go forward for 3 seconds, reduce its speed to 25%, and go forward for 3 more seconds" and "Make the robot say 'Hello', go forward for 2 seconds, stop, and then say 'Goodbye'". These assigned challenges were designed to allow students to come up with solutions for programming the robots on their own (with the help of a team of graduate students leading the activity and assisting the students in problem-solving).

We culminated this with a final challenge, which involved students having to program their Robots to traverse a maze we had set up, thus allowing them to put their new-found knowledge of Robots and programming to use.

C. Station 3: Can I Trust Automation? – Play games to learn trust in automation

We initiated station 3 with a discussion about automation. Our initial discussion delved into the similarities and differences between automation used in our daily lives, such as Google Home, and in workplaces, such as autopilot in a plane cockpit. This followed one area of Cunningham and Kelly's equity-oriented model [20], which suggested developing students' interest by using relatable examples in real-world contexts. During this dialogue, the students arrived at a shared understanding of automation's purpose to enhance the quality of lives of humans, both in daily lives and in workplaces. They also recognized the varying degrees of impact of failure between different types of automation: a Google Home's failure may lead to an inconvenience of the user manually performing an action, whereas an autopilot's failure may lead to a potential disaster.

Then, we introduced the concept of human factors engineering, emphasizing the importance of considering how technology is perceived and used by users and the role of human factors engineers in carefully designing the systems based on a rigorous understanding of users.

Subsequently, we shifted focus to the topic of trust in automation. One of the well-studied concepts of trust in automation is that a machine's performance can influence human trust [21, 22]. To simplify this concept for our audience, we created a scenario of the dynamics of trust among friends. We initiated the scenario by introducing two imaginary friends, A and B, and informed the students that those friends are known to speak the truth 99% and 95% of the time, respectively. Students were then asked to what extent they would place trust in each of these friends. The majority of the students expressed a higher level of trust in friend A, who is a more reliable one. Then, we introduced a twist to the scenario. We revealed that now both friends A and B will speak the truth 97% of the time. This adjustment changed many students' trust evaluations. Many students indicated that they would place greater trust in friend B, who became more trustworthy, while friend A's trustworthiness decreased. This exploration of trust dynamics in friendship scenarios served as a parallel to the concept of trust in automation. We encouraged the students to keep their understanding of trust in mind while they engaged in the two interactive activities.

Afterward, the students were provided with opportunities to perform two tasks (threat detection task, and mental rotation task) with automation aid. Throughout the activities, they could figure out how much they trust automation and how trust levels affect the way they behave.

In the threat detection task [23, 24], the students were tasked with the goal of accurately and promptly reporting threats while maintaining level flight, as if they were pilots. The automated threat detector aided the task by providing its prediction of whether there was a threat. In this situation, students could choose between relying on automation or cross-checking all the information to make sure that they do not miss any threat (Figure 4).

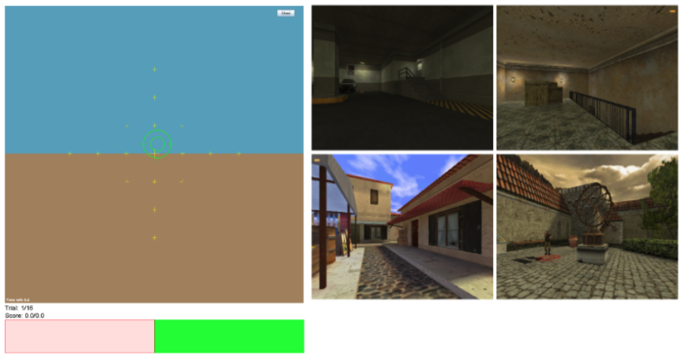

Figure 4. Threat detection task. The task display consisted of two parts: the tracking task (left) and the detection task (right). At the bottom of the tracking display (left), students could see an alert sign from the automated threat detector. The alert would be green on the right for a no-alert situation and red on the left for an alert situation.

For the second activity, students engaged in a mental rotation task (MRT) [25]. The objective was to examine a reference image and select the correct answer from a set of five options, aided by automated decision support. The correct choice was the reference image rotated either horizontally or vertically by varying degrees (Figure 5). Similar to the threat detection task, students could adjust their compliance/reliance behaviors based on their levels of trust in automation.

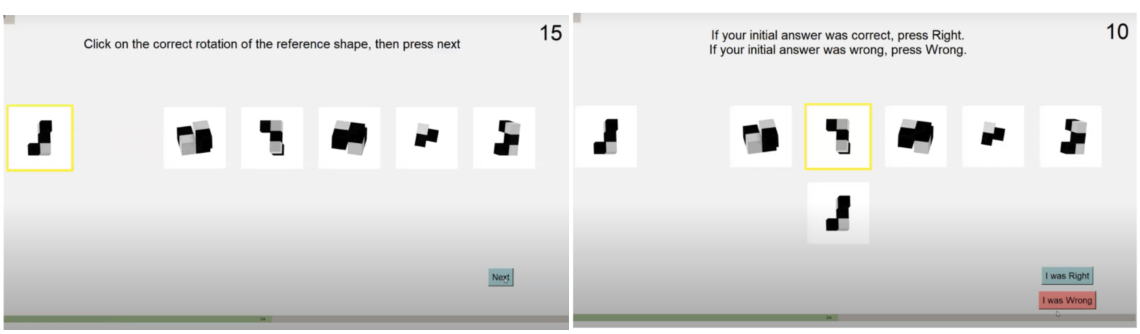

Figure 5. Mental Rotation Task example. Students first made their initial selection (left) and then confirmed whether their selection was right or wrong with the automation aid shown below their initial answer (right).

Following their participation in both activities, students gathered to discuss some pros and cons of relying on decision aids. We concluded the station by explaining the importance of understanding the capabilities and limitations of any technology we use. We also explained the concept and significance of proper trust calibration [26], to know the ability of automated systems and to put an appropriate amount of trust in the system, which could overall lead to safety and efficiency in utilizing automated systems.

D. Station 4: Experience with Autonomous Vehicles using a Driving Simulator

We initiated station 4 with an introduction to the interaction between humans and systems or processes, specifically the interactions between humans and vehicles. During the discussion, students recognized that many complex interactions could happen between vehicles and humans, involving drivers, passengers, and other road users.

We extended this discussion to the autonomous vehicle. We delved into the benefits and concerns of autonomous vehicles by showcasing the functionality of the autonomous vehicle utilizing a car simulator. Throughout the demonstration and discussion, students became aware of how unexpected events could surprise the driver, such as when pedestrians suddenly jaywalk or leading vehicles suddenly brake. We also introduced the students to the SAE automation levels [27]. To simplify this concept for the students, we separated the automation levels into manual driving, system-aided driving (featuring technologies like cruise control, lane-keeping assist), conditional automation driving (where the vehicle primarily drives but requires driver intervention when automation fails), and full automation driving (where driver never needs to intervene).

Later on, we transitioned our topic to the research tools commonly used in the field of human factors in autonomous vehicles: eye trackers and driving simulators. We invited students to participate as drivers in simulated driving activities to showcase how physiological data, such as gaze, blinks, and fixations, are collected. Initially, the volunteer drivers wore the eye tracker and followed the instructions on shifting their eye fixation locations. Then under a conditionally autonomous driving scenario, the vehicle self-navigated until an unexpected event required the driver's intervention. As the driver sat in the simulator, the other students were guided to distract the driver to observe the eye-tracking data for a few minutes. Then, the simulator vehicle encountered a sudden obstacle and asked the driver to take control by pressing the brake pedal or maneuvering the steering wheel to another lane.

By looking at the eye-tracking screen, students could see whether the driver was checking for safety (i.e. looking at rearview mirrors or side mirrors to check for approaching vehicles) before taking action. The volunteering students who wore the eye tracker could not simultaneously see how the device was tracking their eye movements. Therefore, the facilitator recorded the monitor and showed the video to the student volunteers so they could confirm whether the eye tracker had correctly tracked where they gazed.

We concluded the station with a discussion on the importance of guiding drivers' visual attention during autonomous vehicle operation and how effective communication between the autonomous vehicle and humans could prevent accidents.

E. Evaluation Questionnaire

After engaging in each station, the attendees filled out an evaluation questionnaire, which included five general questions and two station-specific questions. The evaluation measures were developed following Activation Lab's survey tools to assess STEM learning activation, which was designed to be used for middle school-aged students [28]. The first three general questions, were with answer choices of YES!, Yes, no, and NO!:

1. During this activity: I felt excited.
2. During this activity: I was focused on the things we were learning most of the time.
3. During this activity: Time went by quickly.

The next general question was with answer choices of Yes or No:

4. "Should we include this activity during next year's WISE camp?"

The last general question was an open-ended question that asked: "What could we do to improve the time spent learning about Ergonomics and Human-Automation Interaction?"

These general questions were followed by two station-specific questions, which will be discussed in the Lessons Learned section.

Lessons Learned

The results reveal that the hands-on activities kept attendees excited and engaged throughout the camp while effectively discussing the learning objectives and exposing the middle school students to new topic areas.

Excitement levels among participants were mostly positive for all stations: Station 1 ('YES!' 26.3%, 'yes' 68.4%, and 'no' 5.3%), Station 2: ('YES!' 100%), Station 3: ('YES!' 47.4%, 'yes' 47.4%, and 'no' 5.3%), and Station 4 ('YES!' 68.4%, 'yes' 31.6%).

Concentration levels among participants were mostly high for all stations: Station 1 ('YES!' 15.8%, 'yes' 78.9%, and 'no' 5.3%), Station 2: ('YES!' 63.2%, 'yes' 36.8%), Station 3: ('YES!' 47.4%, 'yes' 47.4%, and 'no' 5.3%), and Station 4 ('YES!' 47.4%, 'yes' 52.6%).

Participants also reported quick perceived time-passing: Station 1 ('YES!' 26.3%, 'yes' 68.4%, and 'no' 5.3%), Station 2: ('YES!' 68.4%, 'yes' 15.8%, 'no' 10.5%, and 'NO!' 5.3%), Station 3: ('YES!' 63.2%, 'yes' 15.8%, 'no' 10.5%, and 'NO!' 10.5%), and Station 4 ('YES!' 31.6%, 'yes' 52.6%, and 'no' 15.8%).

For the question of whether we should include the activity during next year's camp, 94.7% reported 'yes' to Stations 1 and 3, and 100% reported 'yes' for Stations 2 and 4. The results are summarized in Table 1.

In response to the open-ended questions, nine participants either responded with "nothing," "don't know," or did not provide a response. One participant offered a suggestion unrelated to the camp stations, expressing a desire for better snacks. Four participants expressed satisfaction by offering the following comments: "I really like everything!," "Loved it all!," "Not really anything. It seemed perfect," and "Nothing, it was good."

Two participants requested extended time and more activities, one suggesting "A bit more time at each station" and another suggesting "Have more GAMES! It was a good day."

Unfortunately, due to the fixed schedule of the camp, accommodating additional activities or extension of station durations would not have been feasible within the current event structure. Future iterations of such camps may benefit from spanning the event across multiple days to provide opportunities for a broader array of activities over a longer timeframe.

Three participants highlighted areas for enhancement. One participant pinpointed a technical issue with the LEGO Mindstorms proximity sensors. This may suggest the necessity of spare equipment to mitigate such errors and ensure a smooth hands-on experience for every student. Another participant recommended, “Focus on more learning activities about ergonomics rather than focusing on how fun it is.” While we aimed to deliver engaging content suitable for middle school-aged participants, individual differences in knowledge levels or preferences may have influenced perceptions of theoretical depth. In contrast, another participant suggested, “Not include the introduction or make it interesting.” The presentation of the theoretical aspects of ergonomics was the focus of the introduction segment.

Table 1. Excitement, concentration, and time-passing results (counts) are organized by station.

	Station 1				Station 2				Station 3				Station 4			
	NO!	no	yes	YES!	NO!	no	yes	YES!	NO!	no	yes	YES!	NO!	no	yes	YES!
Excitement	0	1	12	5	0	0	0	19	0	1	9	9	0	0	5	13
Concentration	0	1	14	3	0	0	7	12	0	1	9	9	0	0	9	9
Time-passing	0	1	12	5	1	2	3	13	1	2	3	12	0	2	9	6

These insights highlight the importance of finding a balance between the educational and entertainment components in future camps, striving to meet the varied interests and learning preferences within the same age-group audience.

A. Station 1: Optimi-Station

For the station-specific questions for the Optimi-Station, participants were asked to answer whether the statement, “Optimization involves mathematically finding the best solution given a situation”, is true. 94.7% of students correctly answered the first question, indicating that they had grasped the overarching concept of modeling and solving problems for the best outcome, within a given context, with mathematical equations. Next, students were asked to report whether they had an increased interest in optimization. This activity was designed specifically for industrial engineering outreach activities, and sparking students’ interest was one of the top priorities. 11/19 reported “yes,” 6/19 reported “no,”, and 2/19 wrote “sort of”.

The one student who incorrectly answered the first question also reported not having an increased interest in optimization. Interestingly, this student reported high excitement, concentration, and quick time-passing throughout the activity and reported this activity should be included in the next year’s camp.

Optimization methods are highly relevant to engineering fields, but they can be an advanced concept for students to learn. The station helped many students grasp an initial understanding of optimization by putting abstract concepts into tangible examples that pull from the young student's life experiences. Given that many students did not have previous knowledge of the concepts, the station enhanced students' understanding of how optimization functions work and why they are useful. Even though the activity was designed into tangible examples, some students still struggled with grasping the concepts through this approach. For example, in one instance a student had difficulty translating the information about equation formulation into the Lego activity and did not appear to attempt building any of the Lego designs. To assist students like this one who struggled with understanding the mathematical representation of the Lego activity, facilitators went around the room and spoke with the campers one-on-one to assess if they had the right idea. The facilitators used open-ended questions to guide the students toward the mathematical formulas for this activity. In the case of the student who did not know where to begin, the facilitator walked through the steps of a problem formulation, first asking the student to list their constraints, and then asking them to create an equation for the profit from each block "U" and block "M." By walking the student through each step of the Lego activity, the student was able to complete the activity with a better understanding about the mathematics behind optimization. Future camps should continue to explore ways to fit the concept of optimization to the appropriate age group. The result of this activity shows an opportunity to further conceptualize optimization for a young student group.

B. Station 2: Lego Mindstorms

The first station-specific question for the Lego Mindstorms station was a multiple-choice question that asked "What is the general term for any command or group of commands in a program? (In the Lego Mindstorms software, this is one or more blocks)". 94.7% correctly answered 'Code' for the question, except for one student who wrote: "I don't know". Other answer choices, "color" and "touch" were not chosen.

The second question was another multiple-choice question that asked "How does the circumference of your robot wheel relate to the distance it will travel?", which was informed by the lessons learned about the interaction between software and hardware. In this activity, distance was measured using a sensor on the robot. 12/19 students correctly answered 'they are not related', 5/19 chose 'when programmed for 1 rotation, the robot will move half of what the wheel's circumference is equivalent to', and one student answered none of the above'. The third answer choice none of the students chose was "The distance it travels with 1 rotation is close to the same as the circumference."

The Lego Mindstorms activity was a kinesthetic learning exercise. The students engaged directly with the physical and software aspects of robotic systems. The physical interaction allowed the students to better understand the connection between the software commands developed on the computer and the resulting motion of the robot. By offering a tangible way of applying the theoretical concept of robotics, students learned how a code can directly influence a robot's movements. Students experienced both successful and unsuccessful trials during the station, which encouraged a growth mindset and challenged the students' problem-solving abilities.

C. Station 3: Can I Trust Automation? – Play games to learn trust in automation

For this station, two specific questions were formulated to assess students' comprehension of the importance of understanding user characteristics and trust calibration. The first question inquired, "When designing automation, we need to consider how people will trust it." The second question asked whether "Properly trusting automation (calibrated trust) will enhance work performance and increase safety." All participating students responded to both questions, and the results indicated that the majority of them confidently answered "Yes" to both, with 94.7% providing the correct responses.

The station played a significant role in providing students with a comprehensive understanding of human factors engineering and underscored the engineer's responsibility to consider user characteristics when designing technology. Additionally, it introduced students to the concept of trust and its critical role in designing various autonomous systems. The results, specifically the high percentage of correct "Yes" responses to the station-specific questions, strongly support the idea that students derived substantial learning from this station.

Furthermore, students actively engaged in discussions about the pros and cons of automation and the importance of trust calibration, based on their real experiences with autonomous decision aids during gameplay. Through the discussion, they learned that trust is not a static or universally consistent variable. The meaningful discussions allowed them to realize that their trust perceptions toward automation can change. They also grasped that individual trust in automation is greatly influenced by personal characteristics, as evidenced by conversations with their peers about their feelings regarding the games. Some students who identified as risk-averse mentioned that they couldn't completely trust the decision aid because they were concerned about its potential imperfections. Conversely, other students disagreed with them, expressing a preference for taking advantage of the benefits of technology. It was intriguing to observe that, by the end of the game and the subsequent discussion, students could identify numerous factors contributing to individual differences in trust levels, including age, prior experience, expertise, and decision-making style.

D. Station 4: Experience with Autonomous Vehicles using a Driving Simulator

For the first station-specific question for station 4, participants were asked to answer whether the statement, "In conditional autonomous driving, the situation where the vehicle cannot drive by itself and asks the driver to drive is called a 'takeover' situation", is true. 94.7% correctly answered this question. The high correct answer rate indicated that students gained a high-level understanding of the concept of conditional autonomous driving. Through discussion, the students understood that autonomous driving is not always safe and that humans must cautiously monitor the situation and take over when needed.

Next, students were asked if "Through the eye-tracking equipment, you can see where the person wearing an eye-tracker is gazing at" is a true statement and all students correctly answered "yes" to this question. This indicates that students understood how the eye tracker helped the researchers track the driver's eye movements.

Even though the students have no driving experience and are not eligible to drive, the station allowed students to interact with the driving simulator. Through exploring the interactions, students learned the differences between manual driving and autonomous driving. While experiencing the 'takeover' situation, most of the students were interested in the simulator so they paid extra attention to it.

The students were very engaged in the discussions while exploring the simulator and eye tracker. Future camps should continue to include various research equipment to assist in enhancing the young students' learning interests in autonomous vehicles.

Overall

The station-specific questions were formatted to allow for binary responses, taking into account students' age and providing a more engaging alternative to a traditional quiz-like structure. Our approach ensured a full completion of the evaluation questionnaire after the 50-minute-long sessions. Although the simple evaluation questionnaire format yielded a 100% response rate, it's possible that the brevity of the survey answers may not have fully captured the depth of students' understanding of the concept as accurately as free-response questions. However, such simplified questions can be beneficial when introducing complex and unfamiliar concepts of industrial engineering, as the questions help reinforce key concepts. The high correct response rate to the station-specific questions indicates that participants not only explored new topics during the engaging activities but also got introduced to important concepts of each station. This suggests that the camp was successful in providing a platform for the students to get an insight into the exciting possibilities that industrial engineering holds by providing an environment where education, exploration, and enjoyment are met. For future summer camps, we plan to change the true/false questions to matching or multiple-choice to capture students' understanding more thoroughly.

Conclusions

The ENCHANT summer camp successfully introduced middle school students to concepts in Industrial Engineering and Robotics through interactive learning methods, which included both general topics and current research topics. Participants engaged in four activities that stimulated their curiosity about the field of engineering and discussed complex engineering concepts including optimization, robotics, trust in automation, and autonomous vehicles. Feedback from students revealed high excitement and engagement, along with a deeper understanding of the topics in lesser-known areas of Optimization, Human Factors Engineering, and Robotics. Our experience supports the value of hosting more outreach programs on various engineering topics, utilizing hands-on activities with enriching learning experiences to broaden access for diverse student populations and encourage interest in engineering and related fields. STEM programs should continue to focus on providing outreach programs for underrepresented populations to nurture young minds and diversify representation in STEM fields. By increasing students' exposure to engineering disciplines, these outreach programs have the potential to stimulate interest and involvement in various STEM majors, which will lead to a more diverse and versatile STEM workforce.

Acknowledgment

This work is supported by the National Science Foundation under Grant No. 2045009 and the Centers for Disease Control and Prevention Grant No. T42 OH008455. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the Centers for Disease Control and Prevention or the Department of Health and Human Services. The Optimi-Station activity was developed by an undergraduate intern, through a summer internship program supported by the IOE department's outreach development fund.

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