The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #42148

Understanding the Influence of a Week-Long Electrical and Computer Engineering Summer Camp on Middle School Students' Interests in STEM (RTP)

Joshua E. Katz, University of Illinois Urbana-Champaign

Joshua E. Katz is a Ph.D. student in the Department of Curriculum and Instruction, DELTA program, at the University of Illinois at Urbana-Champaign, where his research centers on collaborative learning in engineering education and other STEM disciplines. He obtained his B.S. in Technology and Engineering Education in 2019 and his M.S. in STEM Education and Leadership in 2021, both from Illinois State University. Additionally, he holds a professional educator license for secondary education in Technology and Engineering Education in Illinois.

Mr. Robin Jephthah Rajarathinam, University of Illinois Urbana-Champaign

Robin Jephthah Rajarathinam is a Ph.D. candidate in the department of Curriculum and Instruction, DELTA program, UIUC. His research focuses on Collaborative Learning, Learning Analytics, and Human-Centered Design within STEM disciplines. His background is in mechanical engineering and education.

Yang Victoria Shao, University of Illinois Urbana-Champaign

Yang V. Shao is a teaching assistant professor in electrical and computer engineering department at University of Illinois Urbana-Champaign (UIUC). She earned her Ph.D. degrees in electrical engineering from Chinese Academy of Sciences, China. Dr. She has

Prof. Yuting W. Chen, University of Illinois Urbana-Champaign

Dr. Yuting W. Chen received the B.S. degree from University of Illinois Urbana-Champaign in 2007, and the M.S. and Ph.D. degrees from Rensselaer Polytechnic Institute in 2009 and 2011, all in Electrical Engineering. She is currently a Teaching Associate Professor in Electrical and Computer Engineering and the Director of Women in Engineering at University of Illinois Urbana-Champaign. Her current interests include recruitment and retention of under-represented students in STEM, professional development for graduate students, and curriculum innovation in computing.

Understanding the Influence of a Week-Long Electrical and Computer Engineering Summer Camp on Middle School Students' Interests in STEM (RTP)

Abstract

Student interest in engineering at the K-12 level has been shown to predict whether students of all backgrounds pursue engineering as a college major and career [1],[2]. Middle school is a critical time when student interest, identity, and career choices begin to solidify. Scientists have developed a framework based on social cognitive theory for understanding three factors that are critical in career pathway development in late adolescence and early adulthood, namely, "(1) Formation and elaboration of career-relevant interests, (2) Selection of academic and career choice options, and (3) Performance and persistence in educational and occupational pursuits" [3, p. 79]. They also point out that social and economic factors affect the level and content of career choices. Since states have been slow to adopt the NGSS (Next Generation Science Standards) and include engineering curricula in their K-12 classrooms, many universities with engineering programs have implemented informal STEM outreach programs for elementary, middle, and high school students. Thus, there is a need to better understand how outreach programs such as engineering summer camps influence engineering interest and identity in middle school students and their subsequent choice of engineering as a major and career.

In the Summer of 2023, 18 middle school students participated in a week-long summer camp that focused on electrical and computer engineering (ECE) concepts and practices. The five-day summer camp consisted of hands-on activities, tours of different laboratories in ECE disciplines, and a group project that spanned the whole week where students built circuits using the SparkFun Inventor's kit. During the group activity, the students were organized into eight groups, and each group was mentored by an undergraduate mentor who facilitated the collaborative hands-on activities. The middle school students completed validated and reliable pre and post-surveys adapted from the Student Attitudes Toward STEM (S-STEM) Survey and the Group Work Skills Questionnaire Manual. The S-STEM survey is focused on STEM interests while the Group Work Skills Questionnaire Manual Survey is centered on student collaboration. The results of Wilcoxon Signed-Rank Tests indicated positive significant impacts on 21st-century learning, Group work, student's expected class performances (in Math, Science, Engineering, and English) and student's plan to take advanced courses in the future (in Math, Science, and Engineering). Additionally, daily reflection surveys were administered to understand the impact of individual activities students participated in each day. Results were analyzed to identify activities that positively improved domains in student interests, which provided additional context to the meaning of the results from the pre- and post-survey. This approach provides valuable insights for designing more inclusive and impactful STEM education interventions, ultimately contributing to a broader and more diverse STEM pipeline. Future work

will explore the effects of socio-economic diversity on STEM engagement outcomes, and investigate which specific camp activities most effectively promote STEM interest across different student demographics.

Introduction

Cultivating student interest in engineering at the K-12 level is essential for students of all backgrounds to pursue engineering as a college major and career. To develop STEM interests within K-12 students, universities with engineering programs have implemented informal STEM outreach programs for students in elementary, middle and high schools. Research shows that middle school is a critical time for students to develop their interests, identity, and career choices. Thus, there is a need to better understand the ways in which outreach programs influence middle school students' perceptions of engineering and STEM. To this end, our research team set out to investigate the changes in middle school student's perceptions of STEM and engineering as they participated in a week-long summer camp. The purpose of this paper is to assess the impact of a week-long middle school summer camp program and how it affects students' interest. Additionally, we want to narrow down on the specific sessions in the middle school camp that led to these changes and leverage that information for future iterations of the summer camp.

Background

The Imperative of Early STEM Engagement

The landscape of modern education increasingly emphasizes STEM (Science, Technology, Engineering, and Mathematics), reflecting its integral role in fostering innovation and addressing contemporary challenges. However, a persistent issue within the engineering discipline is the insufficient number of students, particularly from underrepresented groups, who express interest in pursuing engineering as both a college major and a career path [3]. This under-enrollment phenomenon underscores the necessity of cultivating STEM interest at an early stage, particularly during K-12 education.

Research underscores the pivotal role of middle school as a critical juncture where students' interests, identities, and career trajectories begin to take shape [4],[5]. Theoretical frameworks proposed by social cognitive scientists, such as Lent et al. [6], emphasize the significance of this developmental phase, highlighting three crucial factors in the evolution of career pathways: the formation of career-relevant interests, the selection of academic and career choices, and the persistence in educational and occupational endeavors. These frameworks also acknowledge the influence of social and economic factors on the scope and nature of career choices, further emphasizing the need for targeted interventions during middle school to foster a diverse and inclusive engineering workforce.

Challenges and Opportunities in STEM Education

Despite the recognized importance of early STEM engagement, significant barriers impede the effective integration of engineering principles into K-12 curricula. The slow adoption of the Next Generation Science Standards (NGSS) and the general absence of engineering content in school curricula highlight systemic gaps in STEM education [4],[5]. Additionally, many current K-12 educators lack the requisite knowledge in engineering or the support to integrate engineering concepts into their teaching [7], further exacerbating the disconnect between theoretical STEM education and its practical, real-world applications.

The fragmented delivery of engineering instruction, often isolated from other STEM subjects, fails to present a cohesive and comprehensive view of the field to students [8]. This disjointed approach not only hinders the understanding of engineering's interdisciplinary nature but also diminishes students' ability to relate classroom lessons to real-world engineering challenges. However, the gradual introduction of NGSS and efforts to infuse K-12 science curricula with engineering concepts signal a move towards a more integrated and effective STEM education, providing a foundation for addressing these challenges.

The Role of Informal STEM Outreach in Shaping Perceptions

In response to the limitations of formal STEM education, universities and educational institutions have initiated informal STEM outreach programs, such as summer camps, to bridge the gap and stimulate student interest in engineering. These programs offer a complementary educational experience, allowing students to engage with engineering concepts through hands-on activities, real-world problem-solving, and interactions with professionals in the field. Such informal learning environments are pivotal in demystifying engineering for middle school students, a critical age group for the formation of career interests and aspirations.

However, despite the recognized value of these outreach efforts, there remains a need for a deeper understanding of their specific impact on students' perceptions of engineering and their subsequent educational and career choices. As Fairweather [4] and the STEM Perceptions: Student & Parent Study [5] suggest, enhancing K-12 students' interest in sciences and engineering requires not only improved classroom instruction but also a concerted effort from universities through targeted outreach initiatives. By focusing research on the efficacy of these programs, particularly at the middle school level, educators and policymakers can refine and expand outreach efforts to more effectively inspire the next generation of engineers and STEM professionals.

Several studies have investigated the impact of summer camps on middle and high school students' interest and attitudes towards STEM fields. Haugh et al. [9] found that a summer day camp comprising five 13-hour sessions for rising 7th graders fostered enthusiasm for pursuing engineering careers through its activities. Hammack et al. [10] reported that middle school students attending a four-day camp for 3.5 hours daily demonstrated improved understanding of technology and positive attitudes towards engineering, although the specific contributing activities were unclear. Mohr-Schroeder et al. [11] observed that a week-long summer camp enhanced motivation and interest in STEM among middle school students, with a follow-up study by Roberts et al. [12] highlighting the camp's role in improving students' understanding of STEM subjects and expanding their interest in related careers. Faber et al. [13] noted that a similar week-long camp positively influenced middle and high school students' perception of STEM, particularly benefiting those with initially low interest, and showed a greater increase in interest among female students compared to their male counterparts. Similar results were observed in a four-day engineering summer camp for girls [14], where participants had increased interest and understanding of engineering topics after camp completion. On the other hand, a mixed-method study [15] on a six-day middle school engineering summer camp showed no statistically significant change in participants' intrinsic motivation, interest in engineering careers, self-efficacy, and self-determination based on the quantitative data. Nonetheless, qualitative data indicated that camp experience positively impacted participants' outlook toward engineering and STEM careers and their awareness of STEM career requirements.

The Friday Institute of Education S-STEM survey has been used in various studies to measure middle school students' attitudes toward STEM. Students answer questions about their perception of science, technology/engineering, mathematics, 21st-century knowledge, and their interest and awareness in STEM careers [16]. Han et al. [17] used the S-STEM survey to measure high school students and teachers' self-efficacy and outcome expectancy within a 10-12 session project. This study's findings indicated that self-efficacy and outcome expectancy are crucial for teachers and students in STEM education. Hite et al. [18] used the S-STEM survey within a week-long outreach program for middle school students (6th - 8th) and considered factors of racial, ethnic, and gender minorities. For the pre-and post-test, they found statistically significant differences in their middle school populations within the engineering/technology and 21st-century learning categories. Wiebe et al. [19] used an S-STEM survey on over 15,000 public school students (4th - 12th grades). This study also includes an analysis of various demographic information of the students. Their findings indicate that students' attitudes toward STEM careers can change throughout their academic careers. In addition, students with different gender identities showed different levels of interest in STEM careers. Another study conducted using the S-STEM survey [20] also found gender differences in attitude towards STEM in 7th and 8th students who participated in a robotics curriculum at school. S-STEM survey has been validated by [21], [22] to be used in the upper elementary, middle, and high school age ranges [23].

In this paper, we studied the impact of a week-long middle school summer day camp with activities centered around electrical and computer engineering (ECE) topics on students' perceptions of STEM using the contextualized version of the S-STEM survey [16]. In addition, we wanted to know which activities facilitated the change in student perception by using a daily survey developed by the research team. To this end, we ask the following research questions:

1. In what ways does participation in the ECE summer camp influence middle school students' perceptions of and attitudes toward STEM fields?
2. Which specific activities, experiences, or elements of the ECE summer camp program are most impactful in shaping middle school students' perceptions of STEM, and how do these moments facilitate a change in their attitudes and interests?
3. How do the impacts of the ECE summer camp on students' perceptions of STEM vary by gender and age?

Methods

Camp Inception and Planning

At University of Illinois Urbana-Champaign, The Grainger College of Engineering has been offering summer camps for high school students for decades. These offerings have a good mix of residential and day camps in terms of format, board exploratory and disciplinary specific topics in terms of focus. Shortly before the pandemic, some departments started to offer day camps to middle school students. Most summer camps switched to online format during 2020, some were canceled. Most summer camps returned to in-person format in 2021, and some continued to be offered online. With strong support from the ECE department, an ECE faculty who oversaw summer camp activities initiated the planning of a new in-person middle school camp with the college outreach office in 2022. To reduce overhead, the new offering will be day camp only, and the college outreach office will manage the application process.

The ECE faculty consulted with an outreach specialist from another engineering department, who had extensive experience working with middle school students on potential topics and activities. The conclusion was that it would be beneficial to have a variety of hands-on activities to maximize learning and engagement. These hands-on activities included introductions to the following topics: electronics, digital logic, wireless sensing, music synthesis, electromagnetics, optics, and sorting algorithms. In addition, tours and interactive demos cover topics in robotics, solar cars, green energy, measuring vital signs, bioengineering, and semiconductor fabrication (cleanroom). There is a mix of hands-on activities and tours/interactive demos in the morning and afternoon to make these sessions more engaging. Each day will end with campers working within a two to three person team on a group project. Each team was mentored by an undergraduate student in ECE. SparkFun Inventor's kit was used for group projects due to its reasonable cost (~ $100/kit) and an easy-to-follow user manual with curated activities. Social activities, such as bowling and ping pong, were planned after lunch so that campers could get to know each other.

Camp Schedule

The structure of the camp was similar each day, with the goal of ensuring a blend of learning, teamwork, and fun. We began each day by greeting students in front of the building. Specifically, the first thing we did on the first day was an overview of the program and a tour of the building and instructional labs. There were two sessions of different camp activities in the morning, followed by a lunch break. The afternoon had two more sessions of activities, some of which required a short trip on buses to remote labs. At the end of the day, the entire group of students and undergraduate lab assistants gathered for the daily survey and then focused on team projects using SparkFun Inventor's kits. The team project lasted the entire week, and more than half of the teams finished all 16 fun activities using the kit. At the end of the camp, all students and their families were invited to attend a closing ceremony. Every student went on stage and presented their group project as well as their favorite activities. Throughout the week, camp staff observed closely on student participation. At the closing ceremony, every student received a camp completion certificate and an award that recognized their unique talent. After the ceremony, many participants exchanged contact information and inquired about future summer camp opportunities.

Educators from Texas

In addition to the daily routine, our middle school camp hosted a valuable educational exchange with four middle school teachers from Texas. These educators actively participated by shadowing some of the camp activities. They were eager to absorb and integrate the camp activities into their own classrooms. The involvement of the teachers fostered a collaborative atmosphere, as they interacted with both students and camp staff, exchanging insights and ideas. The teachers contributed a unique perspective to the camp, creating a dynamic space where both students and educators could learn from one another.

Participants

Expecting about 15 to 20 campers and more than 10 different activities throughout the week, the ECE faculty recruited a colleague who serves on the department's broadening participation committee as a co-coordinator. Two Ph.D. students in education were also recruited to conduct a research study on the new camp and work with ECE faculty/student presenters to ensure session contents are age-appropriate. In the end, 18 middle school students participated in this new camp. Session presenters included 7 faculty, 1 staff, 7 graduate students, and 5 undergraduate students. 6 undergraduate students served as group project mentors.

The study was approved by the internal review board of the university. There were 15 students who assented along with parent consent to participate in the research study - nine students were female, five were male and one student did not specify gender. Six students were at the age of 12 and nine students were between 13 to 14 (referred to 13+ for the rest of the paper).

All identifiable information was immediately deidentified and pseudo coded. Any physical documentations with identifiable information were stored in envelopes in a secure location on campus. Digital artifacts were contained in a separate folder in a university approved high-level security storage server and were stored separately from the coded data. The data were only handled by the researchers. Faculty, staff, students, and others with permission or authority to see the study information will maintain its confidentiality to the extent permitted and required by laws and university policies.

Data Collection

Data for this study were systematically gathered from middle school (MS) students who provided consent to participate in the research. The primary instrument utilized for this investigation was a modified version of the Student Attitudes toward STEM (Science, Technology, Engineering, and Mathematics) Survey, originally developed by The Friday Institute for Educational Innovation. The modified survey's validity and reliability have previously been established [16], ensuring its appropriateness for assessing students' attitudes and perceptions towards STEM fields.

The survey comprised 37 items, each rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), designed to gauge students' attitudes towards each STEM component. Specifically, the survey included 8 statements related to Mathematics, 9 related to Science, 9 pertaining to Engineering and Technology, and 11 addressing 21st-century skills. The term "21st-century skills" encompasses a broad set of competencies, including knowledge, skills, work habits, and character traits, considered essential for success in contemporary society by educators, reformers, academicians, and employers. In order to gain additional background on the students' current and future STEM education experiences, another section from the STEM survey was added. The last section was broken down into three parts: current class expectations (4 questions), future STEM interests (3 questions), and professional connections (4 questions). The students were given a scale for the expectation parts of one to three (Not Very Well to Very Well) to answer the questions. The professional connections contained a scale of “yes”, “no” and “not sure”. To further investigate collaborative learning aspects within the STEM context, 4 additional questions related to group work skills, derived from the group work skills questionnaire [24], were incorporated into the survey. This inclusion aimed to explore the dynamics of collaborative learning and its impact on students' STEM engagement and perceptions.

In addition to the modified Student Attitudes toward STEM Survey, daily surveys were administered to participants throughout the duration of the five-day summer camp. These daily surveys sought to capture immediate feedback and reflections from the students, focusing on their overall experience each day. Key questions included rating their overall experience, identifying the most enjoyable, challenging, and valuable activities of the day, and pinpointing activities that particularly sparked their interest in engineering or encouraged further exploration. There were seven questions that were asked, listed in Table 1.

Table 1. Questions included in the daily survey

	Questions
1	On a scale of 1 to 5, please rate your overall experience at the engineering camp today.
2	Which specific activity or activities from the engineering camp did you find most enjoyable today? Please select all that apply.
3	Which activity challenged you the most during the camp? Please select one.
4	Which activity from the engineering camp do you think you would like to explore further in the future? Please select one.
5	Did any particular activity or activities spark your interest in engineering? If yes, please specify which one(s) and briefly explain why.
6	What aspect of the engineering camp did you find most valuable or impactful? Please explain briefly.
7	Is there anything else you would like to share about your experience at the engineering camp or your interest in engineering?

Analysis Procedure

The student participants completed a pre-and post-survey comprising a validated and reliable set of 37 items to assess the influence of their summer camp experience on their STEM education. Two researchers organized and conducted statistical analysis in the SPSS software. The pre-and post-survey responses were used to determine the normality of the data and the impact of the camp on the students. Since the data was non-normal, the researchers conducted Wilcoxon

Signed-Rank tests to assess the significant impact from the pre- to post-tests. Additionally, the researchers calculated the effect size (*r*). The variables of gender and age were also collected. During analysis, the researchers separated the students into gender (Male/Female) and age (12/13+) groups. Wilcoxon Signed-Rank test was also utilized to determine if there is an effect on the students' STEM education and careers based on gender or age.

Furthermore, the daily survey responses to questions 1 through 4 were quantitatively analyzed based on frequency, which shed light on the overall experience ratings, the activities enjoyed most, those that presented the greatest challenge, and the ones students wished to explore further. This approach provided quantitative insights into the camp's effectiveness and areas of high engagement or potential improvement. Questions 5 and 6 were analyzed qualitatively, with responses coded for explicit mentions of any activities. This qualitative analysis was instrumental in identifying which specific activities sparked an interest in engineering and what aspects of the camp were considered most valuable or impactful. The aggregation of activities mentioned across these questions highlighted the camp components that were most engaging and influential from the students' perspectives. Additionally, this qualitative exploration offered context to the quantitative findings, enriching our understanding of the camp's impact on students' perceptions and aspirations in STEM.

By integrating these findings with the pre- and post-survey results, we were able to construct a multidimensional analysis of the summer camp's influence on students' STEM education and career aspirations. This comprehensive approach not only quantifies changes in attitudes and interests but also qualitatively assesses the components of the camp experience that were most effective at engaging students and enhancing their interest in STEM fields.

Results

Impact of the summer camp on the students

To measure the impact of the summer camp on STEM education knowledge, a Wilcoxon Signed-Rank Test was conducted on the students’ pre- and post-survey responses. The test results indicate a significant improvement in students’ competencies associated with four domains. The results presented in Table 2 indicate a significant positive impact on the overall domains of the camp related to their 21st-century learning, group work, current class expectations, and future STEM courses.

Table 2. Wilcoxon Signed-Rank Test results (*N* = 15)

Domains	Pre-test Mean (SD)	Post-test Mean (SD)	Wilcoxon Signed-Rank Test		
			Z	***p***	***r***
Mathematics	3.22 (0.25)	3.26 (0.23)	-0.69	0.49	-0.18
Science	3.33 (0.73)	3.49 (0.71)	-1.42	0.16	-0.37
Engineering & Technology	3.93 (0.84)	4.12 (0.77)	-1.46	0.15	-0.38
21st-Century Learning	3.93 (0.65)	4.22 (0.65)	-2.52	0.01*	-0.65
Group Work	4.07 (0.74)	4.43 (0.72)	-2.70	<0.01*	-0.70
Current Class Expectations	2.67 (0.32)	2.92 (0.26)	-2.56	0.01*	-0.66
Future STEM Interests	1.82 (0.60)	2.60 (0.34)	-2.92	<0.01*	-0.75
Professional Connections	1.68 (0.45)	1.60 (0.41)	-0.79	0.43	-0.20

*Significant, $p < 0.05$

A Wilcoxon Signed-Rank Test was conducted on the additional variable of gender portrayed in Table 3. There were five male students and nine female students who consented.

Table 3. Wilcoxon Signed-Rank Test results between male and female ($N_M = 5$; $N_F = 9$)

Domains	Gender	Pre-test Mean (SD)	Post-test Mean (SD)	Wilcoxon Signed-Rank Test		
				Z	***p***	***r***
Mathematics	M	3.25 (0.15)	3.25 (0.00)	0.00	1.00	0.00
	F	3.25 (0.26)	3.28 (0.30)	-0.35	0.73	-0.12
Science	M	3.16 (0.37)	3.49 (0.61)	-0.74	0.46	-0.33
	F	3.56 (0.78)	3.60 (0.74)	-0.34	0.73	-0.11
Engineering & Technology	M	3.87 (0.69)	4.29 (0.76)	-2.02	0.04*	-0.90
	F	4.15 (0.78)	4.11 (0.82)	-0.53	0.60	-0.18
21st-Century Learning	M	3.76 (0.34)	4.16 (0.55)	-1.21	0.23	-0.54
	F	4.06 (0.79)	4.28 (0.76)	-2.32	0.02*	-0.77
Group Work	M	3.80 (0.69)	4.50 (0.71)	-2.03	0.04*	-0.91
	F	4.08 (0.75)	4.33 (0.77)	-1.73	0.08	-0.58
Current Class Expectations	M	2.75 (0.31)	2.90 (0.38)	-1.73	0.08	-0.77
	F	2.64 (0.36)	2.97 (0.15)	-2.03	0.04*	-0.68
Future STEM Interests	M	2.27 (0.60)	2.80 (0.30)	-1.30	0.19	-0.58
	F	1.63 (0.51)	2.48 (0.34)	-2.39	0.02*	-0.80
Professional Connections	M	1.60 (0.63)	1.65 (0.60)	-0.58	0.56	-0.26
	F	1.78 (0.34)	1.56 (0.33)	-1.84	0.07	-0.61

*Significant, $p < 0.05$

The test results for the male group indicated significant positive impacts on the domains of engineering & technology and group work. The female students significantly changed their perception of 21st-century learning, current class expectations, and future STEM interests categories. No other areas significantly impacted the students based on the gender variable.

On the age variable, students were separated into groups of 12 and 13+. Students who are in 12 typically are going into sixth grade. Any students 13+ are in seventh or eighth grade, which has more complex topics. Another Wilcoxon Signed-Rank Test was run to see how the variable age contributes to the students' impact on STEM education. The 12-year-olds gained significant insight in the area of collaborative group work. Meanwhile, a significant impact was observed with the 13+ students on their current class expectations and future STEM interest domains. No other areas showed significant values.

Table 4. Wilcoxon Signed-Rank Test results between 12 and 13+ year old (N_{12} = 6; N_{13+} = 9)

Domains	**Age**	**Pre-test Mean (SD)**	**Post-test Mean (SD)**	**Wilcoxon Signed-Rank Test**		
				Z	***p***	***r***
Mathematics	12	3.31 (0.22)	3.31 (0.31)	-0.11	0.92	-0.04
	13+	3.15 (0.26)	3.22 (0.16)	-1.41	0.16	-0.47
Science	12	3.41 (0.80)	3.59 (0.67)	-1.29	0.20	-0.53
	13+	3.27 (0.72)	3.42 (0.76)	-0.71	0.48	-0.24
Engineering & Technology	12	4.09 (0.75)	4.19 (0.65)	-0.68	0.50	-0.28
	13+	3.83 (0.92)	4.07 (0.88)	-1.27	0.20	-0.42
21st-Century Learning	12	4.20 (0.63)	4.41 (0.52)	-1.63	0.10	-0.66
	13+	3.75 (0.63)	4.10 (0.73)	-1.84	0.07	-0.61
Group Work	12	4.00 (0.81)	4.42 (0.66)	-2.04	0.04*	-0.83
	13+	4.08 (0.74)	4.44 (0.79)	-1.82	0.07	-0.61
Current Class Expectations	12	2.97 (0.34)	2.79 (0.29)	-1.34	0.18	-0.55
	13+	2.67 (0.33)	3.00 (0.22)	-2.23	0.03*	-0.74
Future STEM Interests	12	1.94 (0.80)	2.67 (0.30)	-1.47	0.14	-0.60
	13+	1.74 (0.46)	2.56 (0.37)	-2.56	0.01*	-0.85
Professional Connections	12	1.71 (0.51)	1.58 (0.38)	-0.45	0.66	-0.18
	13+	1.67 (0.43)	1.61 (0.45)	-0.54	0.59	-0.18

*Significant, $p < 0.05$

At the end of each day, students took a daily survey consisting of questions regarding the activities of the day. In Figure 1, the overall rating, in a Likert scale, for each day of the summer camp is displayed. Students seemed to enjoy the camp more as the days progressed.

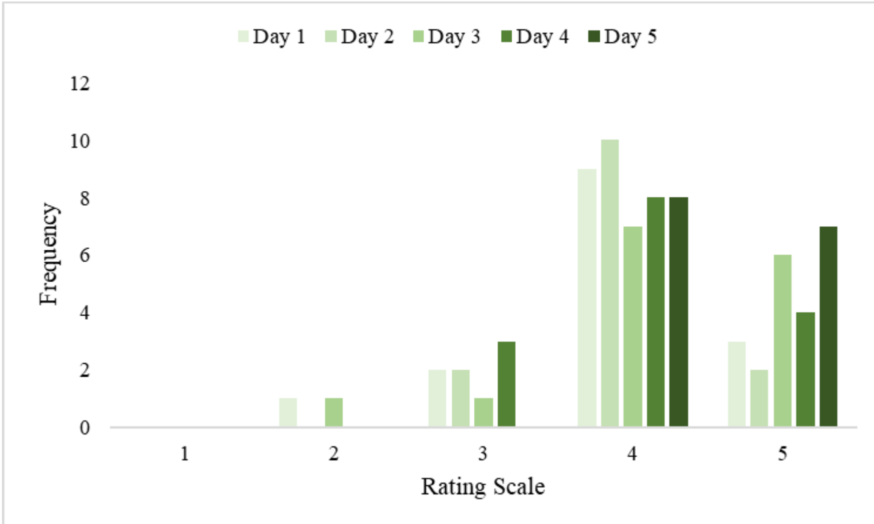
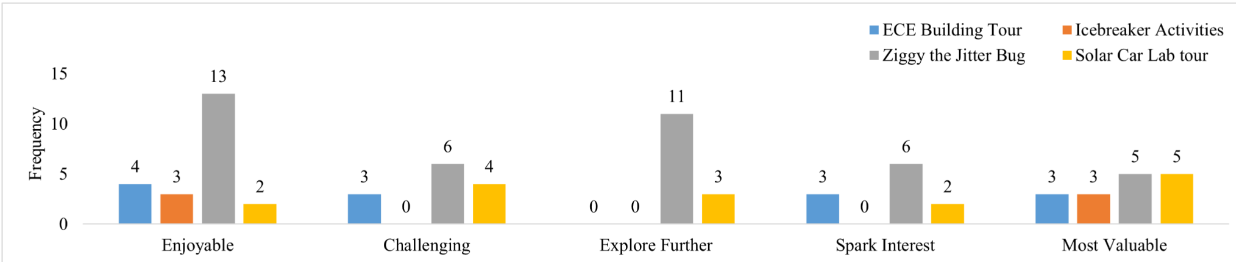
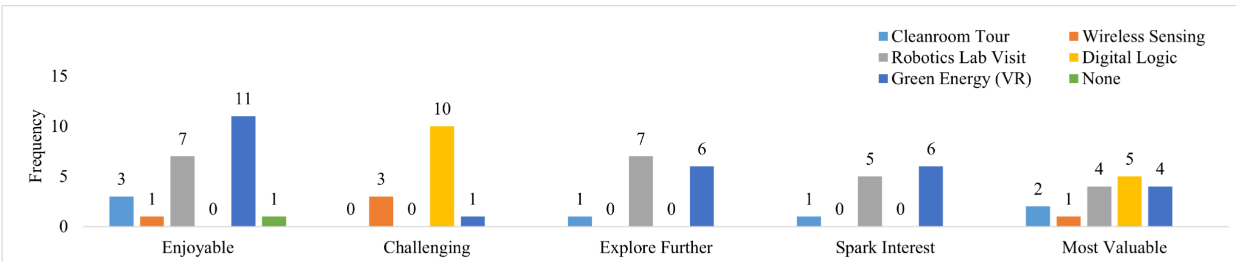


Figure 1: Overall experience of the camp for each day

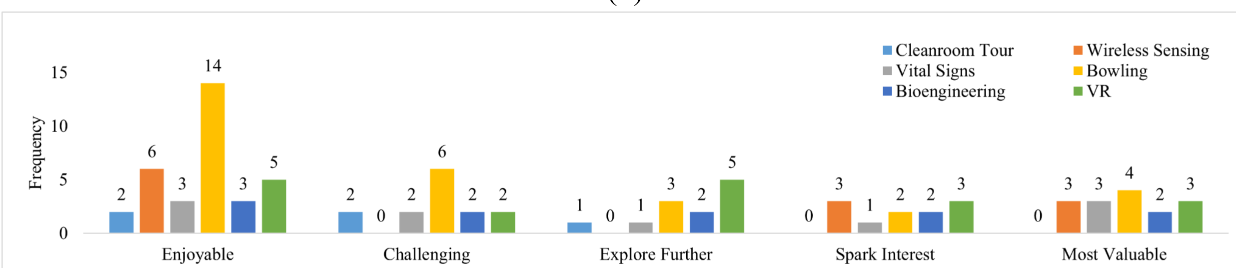
The summer camp unfolded over five days, each marked by distinctive activities and learning experiences tailored to engage and educate the attending students. On the first day, displayed in Figures 2a and 3a, the introduction to electronics session, featuring the Ziggy the Jitter Bug activity, stood out as the most enjoyable, particularly appealing to female participants due to its hands-on nature and the requirement for following instructions carefully. Female and some male students also wanted to explore the electronics lesson further. The second day, represented in Figures 2b and 3b, the camp introduced students to Green Energy through an engaging session on wind turbines, supplemented by virtual reality modules that deepened their understanding and enjoyment. Both male and female students enjoyed the green energy VR experience. A tour of the Robotics lab was also notably well-received, alongside an introduction to Digital Logic, which, despite being challenging, was recognized for its value. More female students found the Digital Logic lesson challenging compared to their male counterparts. The third day, represented in Figures 2c and 3c, saw a shift towards more interactive learning, with bowling and a Wireless Sensing activity that captivated many, especially female students, through practical examples of how wireless and Bluetooth technologies operate. Male students found that the bowling activity was challenging. Day four's highlight, depicted in Figures 2d and 3d, was the construction of an optical projector, an activity that encouraged teamwork and was particularly memorable for the participants. The introduction to Music Synthesis was identified as challenging, yet it sparked significant interest among the students, particularly females, who found it to be the day's most valuable lesson. The camp concluded on the fifth day, portrayed in Figures 2e and 3e, focusing on consolidating learning and group presentation skills. The Oracle Sort game and a STEM-themed movie with a subsequent discussion were the main activities, both of which were enjoyed and found to be intellectually stimulating, with the Oracle Sort game standing out for its challenge and educational value. Both genders found the Oracle Sort game challenging and valuable compared to the movie. These activities culminated in the students presenting their group work at the closing ceremony, marking the end of the summer camp.



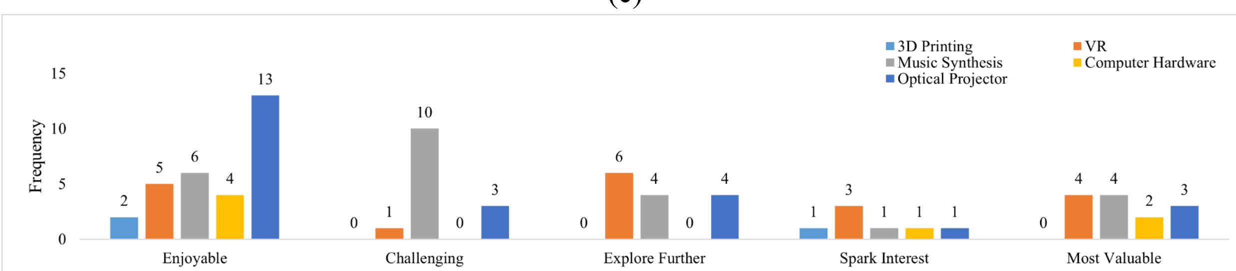
(a)



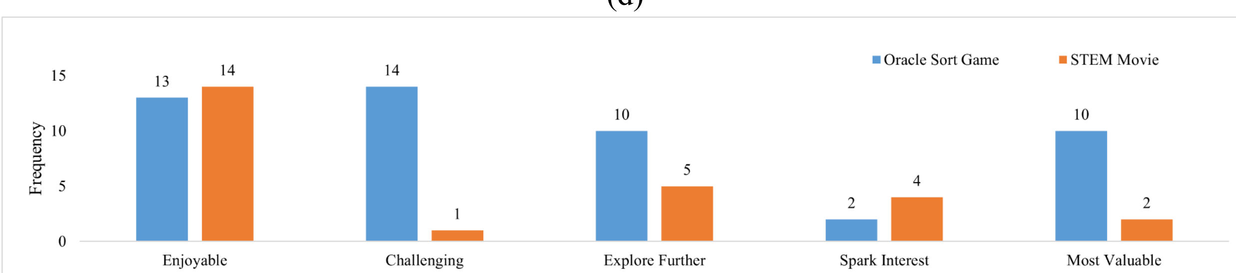
(b)



(c)



(d)



(e)

Figure 2: Survey responses by participants for each day

Figure 3: Survey responses by participants (Male and Female) for each day

Discussion

This study aimed to assess the impact of a week-long middle school summer camp on students' perceptions of STEM fields, focusing on the influence of specific activities and the variation of impacts by gender and age. Our study's significant findings on the impact of a middle school summer camp on students' perceptions of STEM align closely with the imperative of early STEM engagement outlined in the literature [4-6]. Consistent with Lent et al.'s theoretical frameworks [6], our research illustrates the positive influence that targeted interventions during middle school—a pivotal period for shaping interests and career trajectories—can have on students' STEM perceptions and career-relevant interests. Notably, the observed improvements in 21st-century skills and interest in STEM underscore the effectiveness of early, hands-on exposure in cultivating durable aspirations and educational persistence.

Pre and post-surveys indicated a noteworthy improvement in students' interest in 21st-century learning skills, group work, current expectations, and future interest in STEM and related courses. Such changes underscore the camp's role in not only enhancing specific skill sets but also in broadening students' perspectives on STEM. As one student remarked, "The green energy tour taught me a lot about real-life applications of engineering while also being extremely fun," highlighting how immersive experiences can enhance engagement and learning.

Our findings on gender- and age-specific differences in camp impact contribute valuable insights into customizing STEM outreach efforts. Males showed significant interest in engineering technology and group work, echoing a student's feedback, "I enjoyed the Oracle game a lot! It challenged my mind, and I can't wait to play it with my mother," indicating immersive technology and collaborative projects' appeal. Females reported substantial gains in 21st-century skills and STEM interest, likely due to the hands-on nature of activities. A female student's reflection, "I really enjoyed experiencing the VR activity class... I learned about a genius mathematician and how programming can create so many different settings and games for the player," illustrates how exposure to advanced concepts and hands-on activities captivated female students' interests. Males benefited from engineering technology and group work suggesting that collaborative activities with advanced engineering technology topics could benefit male participants. Females benefited with increased perception of current STEM expectations and future STEM interests. Such differentiated responses underscore the need for diverse outreach strategies to engage all students effectively. Age-specific differences were also noted, with 12-year-olds particularly benefiting from group work. This finding suggests that collaborative activities are especially effective for younger students, potentially due to their developmental stage and learning preferences. 13+ year-olds had their perception of the current class expectations and future STEM interests improved. This finding suggests that students in upper middle school are more likely to improve their perceptions of current and future STEM interests.

Daily surveys provided immediate feedback on the camp experience, with students consistently reporting positive experiences. Activities such as the oracle sort game, introduction to digital logic, and wireless sensing were frequently cited as valuable. For example, one student shared, "I found the wireless sensing most impactful, because we learned the purpose of how wireless or Bluetooth items worked," indicating the importance of hands-on and applied learning activities. Moreover, the need for breaks from regular learning activities was highlighted, with students appreciating the balance between educational rigor and socialization opportunities. "I loved playing bowling, because it allowed us the time to socialize with others around us, and a small break from learning or working," a student noted, emphasizing the value of integrating leisure and social activities into educational programs.

This study supports the critical role of informal STEM outreach programs in demystifying engineering and science for middle school students [4], [5]. The camp's success in enhancing students' STEM understanding and appreciation through immersive experiences highlights the potential of such programs to inspire future engineers and STEM professionals. Our research echoes the literature's call for a concerted effort from educational institutions to invest in targeted outreach initiatives, emphasizing the importance of practical, hands-on learning environments.

Limitations

Since this is the first offering of the camp, camp coordinators intentionally kept the group size to no more than 20. There are several considerations, including whether there would be enough interest from families in the local area to enroll their children in a one-week summer camp, instead of a month-long option. It turned out that there was unexpectedly strong interest in this camp and many applicants were placed on the waitlist. 20 were accepted into the camp and 18 eventually completed the week-long experience. Using Yamane's formula, the ideal sample size is 17 for a group of 18 with a 5% error. Since only 15 students consented, the observed results may limit the generalizability of our findings.

The five-day summer camp costs $600 and a small number of scholarships were available through the college to applicants who demonstrated needs. The majority of the campers were paying the full fee, which indicated that they were unlikely to come from families with low socio-economic status.

Another limitation of this study was that our camp activities were designed based on existing resources and infrastructure in our university. Therefore, it is difficult to replicate the exact same camp at another institution. By sharing the survey instrument and the corresponding results, we hope others would benefit from our considerations of camp activity line-up and leverage the instrument to study the impact of their own summer camps.

Conclusion

This study assessed the impact of a week-long middle school summer camp on students' STEM perceptions, revealing enhanced interest in 21st-century skills, group work, and STEM careers, with notable differences by gender and age. The implementation of daily surveys proved crucial, offering immediate insights into which activities most engaged students and highlighting the value of hands-on, immersive experiences. These findings are instrumental for refining future iterations of the camp, ensuring it meets the diverse needs of participants. Despite limitations such as a small sample size and socio-economic bias, our research contributes to a broader understanding of effective strategies in informal STEM education, emphasizing the importance of early, engaging STEM exposure for developing the next generation of STEM professionals.

Future Works

Future work will aim to expand the study's scope by including a larger and more diverse sample of participants, enhancing the generalizability of the findings. Longitudinal studies are recommended to track the enduring impact of STEM summer camps on participants' academic choices and career interests in STEM fields. Additionally, we will explore the effects of socio-economic diversity on STEM engagement outcomes, and investigate which specific camp activities most effectively promote STEM interest across different student demographics. This approach will provide valuable insights for designing more inclusive and impactful STEM education interventions, ultimately contributing to a broader and more diverse STEM pipeline.

References

[1] L.S. Hirsch, J.D. Carpinelli, H. Kimmel, R. Rockland and J. Bloom, "The differential effects of pre-engineering curricula on middle school students' attitudes to and knowledge of engineering careers," in *37th ASEE/IEEE Frontiers in Education Conference Proceedings*, October 10-13, 2007, Milwaukee, WI, pp. S2B-18.

[2] M-I. Carnasciali, A.E. Thompson and T.J. Thomas, "Factors influencing students' choice of engineering major," in *120th ASEE Annual Conference & Exposition Proceedings*, 2013.

[3] B.L. Yoder, "Engineering by the numbers," 2016. [Online]. Available: https://www.asee.org/documents/papers-andpublications/publications/college-profiles/16Profile-Front-Section.pdf.

[4] J. Fairweather, "Linking evidence and promising practices in Science, Technology, Engineering and Mathematics (STEM) undergraduate education," A status report for the National Academies National Research Council Board of Science Education, [Online]. Available: https://nsf.gov/attachments/117803/public/Xc-Linking_Evidence--Fairweather.pdf.

[5] "STEM Perceptions: Student & Parent study," Harris Interactive, [Online]. Available: https://news.microsoft.com/download/archived/presskits/citizenship/docs/STEMPerceptionsReport.pdf.

[6] R.W. Lent, S.D, Brown and G. Hackett, "Toward a unifying social cognitive theory of career and academic interest, choice, and performance," *Journal of Vocational Behavior*, vol. 45, pp. 79-122, 1994.

[7] C. Gewertz, "Teachers Feel Ill-Prepared for Common-Core Despite Training," *Education Week,* vol. 34, no. 1, August 20, 2014, p. 9.

[8] H. B. Lantz, "Science, Technology, Engineering & Math (STEM) Education," National Governors Association, Washington, D.C., 2009. [Online]. Available: http://www.nga.org/cms/stem. Accessed: 10 September 2015.

[9] A. Haugh, O. Lang, A. Polsenberg Thomas, D. Monson, and D. Besser, "Assessing The Effectiveness of an Engineering Summer Day Camp," in *ASEE Annual Conference & Exposition*, June 26-29, 2016, New Orleans, LA.

[10] R. Hammack, T. A. Ivey, J. Utley, and K. A. High, "Effect of an Engineering Camp on Students' Perceptions of Engineering and Technology," *Journal of Pre-College Engineering Education Research (J-PEER)*, vol. 5, no. 2, Nov. 2015, doi: 10.7771/2157-9288.1102.

[11] M. J. Mohr-Schroeder, C. Jackson, M. Miller, B. Walcott, D. L. Little, L. Speler, W. Schooler, and D. C. Schroeder, "Developing Middle School Students' Interests in STEM via Summer Learning Experiences: See Blue STEM Camp," *School Science and Mathematics*, vol. 114, no. 6, pp. 291–301, Oct. 2014, doi: 10.1111/ssm.12079.

[12] T. Roberts, C. Jackson, M. J. Mohr-Schroeder, S. B. Bush, C. Maiorca, M. Cavalcanti, D. C. Schroeder, A. Delaney, L. Putnam, and C. Cremeans, "Students' perceptions of STEM learning after participating in a summer informal learning experience," *International Journal of STEM Education*, vol. 5, no. 1, Sep. 2018, doi: 10.1186/s40594-018-0133-4.

[13] J. M. Faber, L. G. Crzech, M. M. Mahmoud, and K. H. Becker, "The Effect of Summer Engineering Camps on Students' Interest in STEM (Evaluation)," *Virtual ASEE National Conference & Exposition*, June 22-26, 2020.

[14] R. Essig, B. Elahi, J. Hunter, A. Mohammadpour, and K. O'Connor, "Future girls of stem summer camp pilot: teaching girls about engineering and leadership through hands-on activities and mentorship," *The Journal of STEM Outreach*, vol. 3, no. 1, Nov. 2020, doi: 10.15695/jstem/v3i1.09.

[15] A. Martinez Ortiz, L. Rodriguez Amaya, H. Kawaguchi Warshauer, S. Garcia Torres, E. Scanlon, and M. Pruett, "They Choose to Attend Academic Summer Camps? A Mixed Methods Study Exploring the Impact of a NASA Academic Summer Pre-Engineering Camp On Middle School Students in a Latino Community," *Journal of Pre-College Engineering Education Research (J-PEER)*, vol. 8, no. 2, Jul. 2018, doi: 10.7771/2157-9288.1196.

[16] Friday Institute for Educational Innovation, "Student Attitudes toward STEM Survey-Middle and High School Students," Raleigh, NC: Author, 2012.

[17] J. Han, T. Kelley, and J. G. Knowles, "Factors Influencing Student STEM Learning: Self-Efficacy and Outcome Expectancy, 21st Century Skills, and Career Awareness," *Journal for STEM Education Research*, vol. 4, no. 2, pp. 117–137, Sep. 2021, doi: 10.1007/s41979-021-00053-3.

[18] R. Hite, J. Spott, L. Johnson, and L. Sobehrad, "STEM challenge: two years of community-engaged engineering," *Journal of Research in Innovative Teaching & Learning*, vol. 13, no. 1, pp. 57–82, Apr. 2020, doi: 10.1108/jrit-12-2019-0080.

[19] E. Wiebe, A. Unfried, and M. Faber, "The Relationship of STEM Attitudes and Career Interest," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 14, no. 10, pp. 1–17, 2018, doi: 10.29333/ejmste/92286.

[20] N. van Wassenaer, J. Tolboom, and O. van Beekum, "The Effect of Robotics Education on Gender Differences in STEM Attitudes among Dutch 7th and 8th Grade Students," *Education Sciences*, vol. 13, no. 2, pp. 139–139, Jan. 2023, doi: https://doi.org/10.3390/educsci13020139.

[21] A. Unfried, M. Faber, D. S. Stanhope, and E. Wiebe, "The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM)," *Journal of Psychoeducational Assessment*, vol. 33, no. 7, pp. 622–639, 2015.

[22] W. Luo, H.-R. Wei, A. D. Ritzhaupt, A. C. Huggins-Manley, and C. Gardner-McCune, "Using the S-STEM survey to evaluate a middle school robotics learning environment: Validity evidence in a different context," *Journal of Science Education and Technology*, vol. 28, pp. 429–443, 2019.

[23] S. C. Playton, G. M. Childers, and R. L. Hite, "Measuring STEM Career Awareness and Interest in Middle Childhood STEM Learners: Validation of the STEM Future-Career Interest Survey (STEM Future-CIS)," *Research in Science Education*, vol. 54, no. 2, pp. 167–184, Apr. 2024, doi: 10.1007/s11165-023-10131-8.

[24] J. Cumming, C. Woodcock, S. J. Cooley, M. J. G. Holland, and V. E. Burns, "Development and validation of the groupwork skills questionnaire (GSQ) for higher education," *Assessment & Evaluation in Higher Education*, vol. 40, no. 7, pp. 988–1001, Sep. 2014, doi: https://doi.org/10.1080/02602938.2014.957642.

Appendix

Table 5: Summary of the activities in the ECE middle school summer camp

Time	Topic	Activities
Day 1	ECE Building Tour	Students took a building tour of facilities, resources, and research labs.
	Electronics	Students learned about the principles of series/parallel circuits, components, and electronic devices. Each student built their own vibration car which was powered by a cell battery.
	Solar Car Lab Tour	Students observed the design, construction, and testing of solar-powered vehicles. The solar cars are used for competition in the World Solar Challenge.
Day 2	Clean Room Tour	Students took a tour of a clean room facility, where they were shown the manufacturing processes for semiconductor fabrication.
	Robotics Lab Tour	Students observed various types of robotic systems and what the robotics are capable of, including leg system, arm system, robotic dog, etc.
	Digital Logics	Students learned binary numbers, logic gates, and sequential circuits.
	Green Energy	Students learned about renewable energy and sustainable energy technologies and enjoyed a virtual reality tour of wind turbines.

Day 3	Wireless Sensing	Students explored the field of wireless sensing technology, learning the principles of communication protocols and sensor networks.
	Vital Signs	Students explored the concept of vital signs monitoring in healthcare, learning how to measure and interpret parameters such as heart rate, blood pressure, and temperature, etc.
	Bowling	Students enjoyed a fun and social outing to a bowling alley, engaging in friendly competition and team building activity.
	Bioengineering	Students learned about biomedical devices, tissue engineering, and genetic engineering techniques.
Day 4	Virtual Reality	Students explored how virtual reality (VR) games were constructed, and learned about its principles, applications, and potential impact on various industries.
	Music Synthesis	Students discovered the principles of sound synthesis and digital audio processing and built their own music circuits.
	Computer Hardware	Students learned the basic components of desktop and laptops and how to construct them.
	Optical Projector	This hands-on-activity taught students how to build optical projection and display systems.
Day 5	Oracle Sort Game	Students used problem-solving skills to solve challenging puzzles.
	STEM Movie and Discussion	After watching a STEM-related movie, students had a facilitated discussion about the scientific and ethical issues presented in the film.
	Team Presentation	Students formed a team of two to three members and shared their memorable moments and experiences from the camp. Additionally, they presented the SparkFun circuits they built over the week, showing their understanding of electronics through the hands-on project.
	Closing celebration	Students and families celebrate the conclusion of the camp. Awards were given out in the closing ceremony.