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Exploring Female-Identifying Student Participation in Robotics and Post-Secondary Disciplinary Interests

Hilary Lee

Abstract: Science, technology, engineering, and mathematics (STEM), as a whole, has seen an increase in female participation within recent years. The same trend is not apparent within engineering, with female-identifying student enrolment in post-secondary engineering programs remaining proportionally low. Current research shows little understanding between high school experiences and interest in engineering, especially within the female-identifying population. This study aims to explore female-identifying participants in high school robotics and their post-secondary plans. To fill the gap in research, a mixed-method survey with embedded design, employing Likert scales and short-answer questions, was distributed to female-identifying robotics participants in Ontario Independent Schools. The results of the paper suggest that participation in robotics does not necessarily denote an interest in post-secondary engineering but that the skills and support gathered from robotics are applicable to many related post-secondary disciplines of choice.

Keywords: extracurricular activities, engineering, post-secondary enrolment, STEM perception, STEM gender gap

Introduction

Although female student engagement in science, technology, engineering, and mathematics (STEM) (Merriam-Webster, n.d.) has increased in recent years, the same presence is not apparent within engineering disciplines (Ruiz-Bartolomé et. al, 2023). Engineering "has had a gendered history" that caused barriers for women engineers (Bix, 2004, p. 46). According to findings from the University of Toronto (2022), female-identifying students made up only 25.2% of the enrollment within Canadian undergraduate engineering programs during the 2020-2021 academic year. Evidently, there is a problem with engineering interest among female-identifying students, especially in post-secondary education. To remedy this situation, many researchers have highlighted the importance of high school experiences.

Researchers cite extracurricular activities as critical factors in engineering retention of women due to academic enrichment, sense of community, and internal/external motivation (Bahar & Adiguzel, 2016; Blanchard et al, 2023; Gonser, 2021; Ozis et al., 2018). Furthermore, the participation of girls in STEM extracurricular activities was found to be beneficial because it supports STEM career interest and fosters positive relationships (Dabney et al., 2012; Price et al., 2018). In addition, positive factors of STEM extracur-

ricular activities may influence post-secondary interest. According to Sahin (2013), there is a positive relationship between student participation in clubs and their choice of STEM major.

Despite significant research into the study of STEM extracurricular activities and career interest, there is a lack of research on engineering extracurricular activities. In particular, the current findings of lower rates of female-identifying engineers demonstrates a need to research female-identifying student engagement within engineering extracurricular activities. It is also important to explore this form of participation's potential impact towards post-secondary education. The study focuses on female-identifying students in their schools' robotics clubs or programs, all of which are all-girls.

With the decreasing participation of female-identifying individuals in engineering (Martínez et al., 2023), it is critical to examine extracurricular activities due to its potential to reverse the trend. The findings of this study align with Engineers Canada's 30 by 30 initiative to raise the percentage of licensed female engineers to 30 percent by 2030 (Engineers Canada, n.d.a).

Literature Review

In the context of this research paper, post-secondary education or programs refers to studies in "universities, colleges, or institutes" (Government of Canada, n.d., para. 1) and once completed, students are awarded a degree. It is also important to note that undergraduate programs are also categorized as post-secondary education.

To effectively understand the influences that robotics extracurricular activities may have towards post-secondary discipline interests, it is necessary to understand the conversation around women in engineering, as well as the characteristics of engineering/robotics extracurricular activities that lead towards these post-secondary interests.

Women in Engineering

Engagement in Post-Secondary Studies

Randstad (2023) reports that Europe has taken greater strides for women in STEM with women representing 43% of STEM employees as compared with 25% in Canada. Yet, the European Union has also reported that the rate of women engineering graduates is decreasing (Martínez et al., 2023). Although located outside of Canada, women engineers in Europe exemplify the increase of women in STEM studies but decrease in engineering studies.

The environment for women in undergraduate engineering programs has proven to be harsh. It is reported that Canadian female undergraduate engineering students "[feel] like [negative] assumptions were made about their intelligence due to their gender" (Hanson, 2022, p. 19). The situation for Canadian women engineers is urgent. With many engineering positions, especially those at a higher level which require some form of post-secondary education, there is a distinct relationship between pursuing an engineering degree and securing a career in the field.

Public Sentiments

According to Ortiz-Martínez and others (2023, p. 10), "[society] still perpetuate[s] the idea that [women] do not belong to [STEM]." Similarly, Rosenzweig and Chen (2023) found perceived discrimination and cultural cues that can threaten women's sense of belonging. Furthermore, a study conducted by Martínez and colleagues (2023) found that social patterns still cause differentiation of certain activities based on gender. As an example, the study found that primary school students, young boys in particular, thought that professions related to hospitality and the humanities are women's responsibilities while men are more suited towards science-related careers (Martínez et al., 2023). Such public sentiments create barriers to entry for aspiring female-identifying engineers.

The University of Toronto (2020) reported that female enrolment was disproportionately lowest within engineering and physical sciences (29%). These findings align with Martínez and colleagues' findings of primary school student perception of women and men in respective careers. The University of Toronto findings are critical due to the school's proximity to the intended research population.

Calls for Action

Randstad (2023, para. 22), stated in their report on women in STEM that stereotypes "influence

[women]'s interest in pursuing [STEM] careers." Similarly, Ortiz-Martínez and colleagues (2023, p. 12) called for future actions because "differences still exist in women's self-perception and affinity for STEM careers." To increase the participation of women in engineering, researchers highlight the importance of high school activities, such as extracurricular activities.

Engineers Canada, the national organization for engineering professionals (Engineers Canada, n.d.b) created a goal to "[raise] the percentage of newly licensed engineers who are women to 30 per cent by the year 2030" (Engineers Canada, n.d.a). With a pressing need to increase engineering to 30% women by 2030, it is important to examine high school experiences due to their ability to influence post-secondary studies and careers (Ortiz-Martínez et al., 2023).

Extracurricular Activities

The term extracurricular activity has several definitions. For this paper, extracurricular activities are defined by Bartkus and Gardner. They examined the varying definitions of extracurricular activities and proposed that extracurricular activities should a) occur outside of a school's academic curriculum, b) not involve a grade or academic credit, and c) require voluntary participation only (Bartkus & Gardner, 2012). Bartkus and colleagues' work was cited 247 times, creating a general consensus for the definition of extracurricular activities in the field.

Furthermore, Gonser (2021, para. 2) wrote that "[extracurricular activities] often make powerful contributions to students' sense of connection to [community and academics]." Thus, to understand the influences of extracurricular activities towards post-secondary interests, it is important to highlight the characteristics of extracurricular activities that contribute to positive experiences.

Advanced Learning Experiences

There is a unanimous consensus among researchers that extracurricular activities foster learning growth through experience. Ozis and others (2018, p. 1) summarized the current body of knowledge, stating that extracurricular activities "complement STEM skills with creative thinking and open-ended problem solving." Furthermore, Ruiz-Bartolomé and Greca (2023), found that the participation of female-identifying students in a science and technology-based program positively influences conceptual understanding of STEM-related topics. The current body of knowledge, however, only focuses on STEM rather than engineering programming, a gap this study will fill because of its focus on robotics, an activity that practices engineering skills.

Not only do extracurricular activities foster academic enrichment, but they may contribute to an increase in general skills. Blanchard and colleagues (2023) summarized that their sample reported high utility values within extracurricular activities. Utility value, as defined by the researchers, is how useful students found the club to be in terms of skills learned and increased ideas of future goals (Blanchard et al., 2023). As such, extracurricular activities may not only be beneficial for a specific field, but rather for skill enrichment as a whole.

Community and Sense of Belonging

In a study of secondary school composition, Vandelannote and Demanet (2021, p. 19) found that "students who attended secondary-school with high-quality friendships were more likely to attend university programs." The research is not based in STEM or engineering clubs but shows that belonging and community positively influences the decision of high school students to pursue a future education.

Mulvey and colleagues' (2023) literature review effectively summarized that a youth's feeling of belonging in STEM spaces contributes to STEM being centrally important in higher education settings. Further examining community and belonging in STEM, Blanchard and colleagues (2023), studying middle school STEM clubs, found that 40% of the participants emphasized community and common interests as reasons for participation. Several researchers, as summarized by Mulvey and colleagues (2023), outlined that out-of-school STEM activities are especially useful for girls because they support STEM career interests and foster positive relationships.

Motivation

Presently, the research body of knowledge indicates positive influences from both internal and ex-

ternal motivation towards STEM studies and careers. According to Bahar and Adiguzel's (2016) study of high school students, one of the most influential factors for STEM career interest was self-motivation. Other emphasized factors for STEM career interest include one's mother and their subject teacher (Bahar & Adiguzel, 2016). Although both are specific factors, there is a clear motivational factor from external individuals with close relations to the student.

Internal motivation, such as goal setting, has also proven to be important towards post-secondary studies. Blanchard and colleagues (2023, p. 5) stated that extracurricular activities are "non-compulsory experiences that allow students to choose to participate [...] and to consider their future goals." To build on the goal setting perspective, Lichtenberger and George-Jackson (2013) found that those with loftier goals often have earlier plans to pursue STEM studies. The premise of goal-setting and internal motivation towards earlier STEM post-secondary plans shows the importance of non-compulsory experiences that require intentional participation from students.

There is a clear understanding that both self-motivation and external motivation are important for students when choosing their post-secondary program. Since extracurricular activities are non-compulsory, the chosen scope of robotics programs includes levels of internal and external motivations that have been proven to positively influence post-secondary studies. Current research linking forms of motivation to post-secondary education has no distinct focus on female-identifying students or on engineering. As such, the gap in research on internal and external motivation for female-identifying students and engineering is explored in this study.

Summary

There is a distinct gender imbalance within the engineering field that can be attributed to current public perception. The examination of scholarly literature identifies advanced learning, community and belonging, and motivation as positive factors towards picking STEM programs. It is evident, however, that there is little focus on engineering in particular, with most studies focusing on STEM as a whole. Additionally, researchers within similar environments such as Ozis and colleagues' study on STEM-oriented schools found that female students had similar STEM perceptions to their male counterparts (Ozis et al., 2018). Their findings are important to highlight since it contradicts existing literature that shows a lower perception of STEM in girls (Stoeger et al., 2013). Ozis and colleagues call for future work to compare perceptions at different schools (Ozis et al., 2018). It is important, then, to study female-identifying students' participation in robotics in all-female school systems as the population addresses a gap in research.

The lack of studies focused on engineering and in Canada form a knowledge and population gap to be addressed. Additional factors, such as socioeconomic status, were explored in other studies but will not be included within the scope of this research. As a whole, this study attempts to address the determined gaps in research by answering the research question: *How might female-identifying students ages 14-18 in Ontario Independent Schools perceive the influence of robotics extracurricular activities towards their post-secondary discipline interest?*

Method

A mixed-method approach was used to collect the data. Specifically, since "both quantitative and qualitative are collected within the same general time frame…[but] one general approach dominates" (Leedy & Ormrod, p. 260, 2013), embedded data were used. Quantitative data from Likert scales served as the primary data. The secondary focus on qualitative data enables the exploration of prevailing themes, through coding, that contribute to interest in specific post-secondary disciplines and perception of engineering extracurricular activities towards these interests. Overall, using a mixed-methods approach with embedded design allows for "[integration of] conclusions from [the] data into a collective whole" (Leedy & Ormrod, p. 258, 2013).

Sample and Research Instruments

The survey population was female-identifying students on robotics clubs or teams at Ontario all-girls' independent schools. Since high school students will likely have a better understanding of future plans, the

surveys were distributed to Grade 9 to 12 (ages 14-18) robotics teams. To comply with ethical regulations, the survey was kept voluntary and required informed consent from respondents.

To collect data from respondents, a survey was conducted using the online survey administration software, Google Forms. A survey was chosen as the method of data collection due to its ability to collect both quantitative and qualitative data from respondents on the same platform. This resource is also accessible, and could be shared easily to the distributors of the survey and in turn, the respondents.

Procedure

Following approval from an IRB, the survey (Appendix C) was distributed to robotics coaches by email (email addresses were obtained from the school's robotics coach) (Appendix A). Included in the email was the link to a survey, along with instructions to post the link on the school's robotics webpage/conversation platform. Once the survey was open, respondents were asked to give informed consent by checking the checkbox on Google Forms, citing that they have read the informed consent form (Appendix B) and are willing to proceed. The respondents then completed the survey and confirmed the end of participation by checking a box. To ensure ethical data collection, responses were kept anonymous and respondents were reminded that they were free to withdraw at any time. The survey was open for three weeks for robotics participants to complete, although one school only distributed their survey one week before the survey was closed.

Study Design

First, demographic information of the respondents was collected including their age, grade, and gender identity. The respondents were also asked to verify their active participation on a robotics team or club and that they attend an Ontario independent school. This information was important for research into female-identifying high school students. Although the intended recipients attend schools that identify as "all girls," it is important to acknowledge that people may identify as unique gender identities and as such, could not assume that everyone responding identifies as female. Furthermore, collecting the age of respondents is essential for the research to verify their age range. The collection of this demographic data resulted in some quantitative data. Afterwards, qualitative and quantitative data were collected to evaluate the perception of engineering extracurriculars towards post-secondary education. A combination of Likert scale questions and short answer questions were used. Since Likert scale questions allow for "degrees of opinions" (Mcleod, p. 1, 2008), the format was suitable for evaluating potential factors towards post-secondary discipline interest and influences from engineering extracurricular activities. Short answer questions were used to evaluate types of post-secondary disciplinary interests and opinions on engineering extracurricular activities.

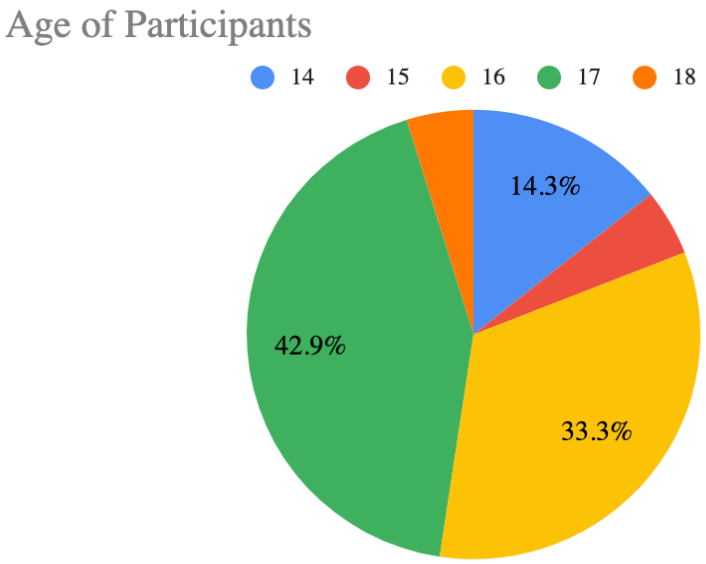
Hypotheses and Assumptions

It was assumed that there is at least some influence, either positive or negative, of engineering extracurriculars towards post-secondary discipline interest and that there was some degree of learning through robotics participation. This assumption stemmed from personal experience within extracurriculars (not limited to engineering) as well as observation of peers within their clubs of choice. Current research further reinforces this assumption. It is also assumed that the intended population of Ontario independent schools will have some offerings of engineering extracurricular activities, specifically robotics within the target sample, and that students have the opportunity to participate in them.

H1: *Students participating in engineering extracurriculars will have a greater interest in engineering post-secondary education.*

Current research has found that extracurricular activities foster a sense of belonging and give more experience outside of the classroom. To illustrate, Blanchard and colleagues' research on student perception of STEM clubs found positive student perception in areas of collaboration, communication, and decision making (Blanchard et al., 2023). Although these findings are within the context of STEM clubs, it is predicted that similar findings will be found within engineering clubs, considering that it is a branch of STEM.

Figure 1
Respondent Age Demographics



H2: *There will be utility values relating to engineering extracurriculars that contribute to an interest in pursuing engineering or related post-secondary programs.*

Students participating in engineering extracurricular activities may have greater interest in engineering post-secondary programs due to values associated with extracurricular activity participation. Blanchard and colleagues (2023) recorded high and increasing utility (degree of usefulness) values in their study of STEM club perception by student grade. Since this research found utility value among their population, there may be utility values relating to engineering extracurricular activities that contribute to a greater interest in pursuing either engineering or related post-secondary programs.

Results and Discussion

In total, 23 participants responded to the survey but only 21 responses were valid. Participant 7 was not an active robotics team participant and Participant 11 did not wish to self-identify as female. The data analysis will be calculated using n = 21. The analysis for every survey question is not included in the results section, rather key findings or combined visualizations are included.

Figure 1 depicts the age demographics of the respondents in percentages. With the exclusion of respondents 7 and 11, all respondents identified as female, attended an independent school, and are active participants in their school's robotics program. There is representation from all intended age groups with a mean age of 16.2.

A pie chart (Figure 2) was created to evaluate Hypothesis 1. Nine respondents stated that they planned to pursue engineering in post-secondary education while six stated that they were not interested in pursuing engineering in post-secondary education. It is important to note, however, that six respondents remained "Unsure." As the survey included students ages 14-18, it is reasonable that some students remain unsure of future education plans.

The distinction of age causes a difference in expectation for Hypothesis 1. Figure 3 is a scatterplot that visualizes the Likert scale averages (LSAs) of respondents' answers to survey questions 13 and 15. By

Figure 2
Respondents plans to pursue engineering

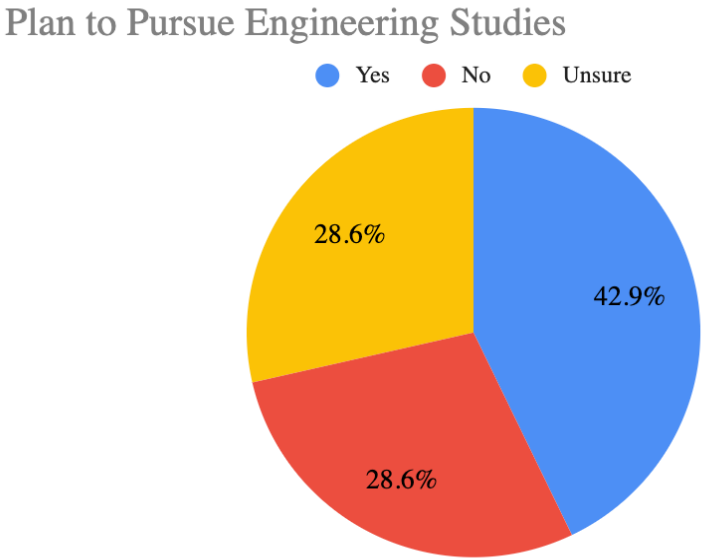
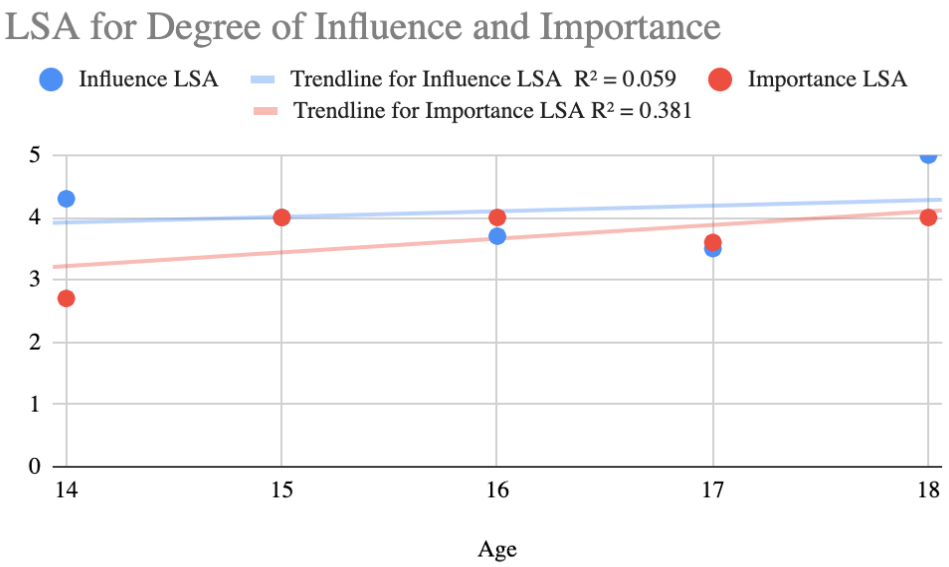


Figure 3
Respondents' perception of robotics participation's influence and importance on post-secondary plans



plotting the LSA of "degree of influence" and "degree of importance," a relationship can be drawn between the value of robotics extracurricular activities to post-secondary interest. The LSAs were plotted against age, since it is critical to note the perception of older students as they are closer to making final decisions in regards to post-secondary plans. A trendline and r^2 value was added to the graph to visualize the overall data trend.

The trendlines for both "influence" and "importance" are both positive, signifying an increasing positive influence from robotics and that robotics plays an important role in their post-secondary plans. The trendline for influence, however, has a weak correlation that can be determined using the Pearson correlation coefficient (r). This statistical measurement was chosen since quantitative values are plotted on both axes and determine the strength of the correlation (Laerd Statistics, n.d.). The r value for the "influence" trendline is 0.242 and since $|r| = 0$ denotes a weak correlation while $|r| = 1$ denotes a strong correlation (Laerd Statistics, n.d.), the overall correlation for "influence" is weak. The trendline for "influence" slopes upwards due to one respondent aged 18 with a high ranking of influence. Overall, the LSA for influence decreased with age from 14-17, which demonstrates that participation in a robotics team does not necessarily have a positive influence towards post-secondary disciplinary interest.

The r value for the "importance" trendline is 0.617. Overall, this denotes a stronger correlation than the "influence" trendline. From visually examining the graph, the LSA for importance increasing overall with age from 14-18, which demonstrates that participa-

Table 1

Respondents' perceived positive and negative robotics participation influences towards post-secondary plans

Survey Question #14: Please explain your response to the previous question. Why do you feel this degree of positive and/or negative influence?			
Influence	Themes	Summary (Some responses may fit into several themes)	Examples
Positive	Exposure to engineering process	Eleven respondents reported that exposure to engineering enables them to develop a better understanding of engineering as a whole. In particular, four respondents noted that robotics enabled them to further consider engineering as a post-secondary education option.	"[Robotics] makes me feel as though I can "take on" a challenging major such as engineering." "Participating… has allowed me to get a feel for different aspects of engineering." "It gives me a small example of what engineering could be like in university."
	Community in engineering	Four respondents reported that they enjoy the community aspect of robotics because they feel supported and part of a team. Moreover, one respondent also noted that they enjoyed the competition aspect of robotics.	"I have the support of my team." "I get a sense of what engineering is when working as a team" "I've enjoyed the competition"

Negative	Stress/ difficulties	Five respondents reported that robotics could be stressful and frustrating. One respondent also notes that the frustration and stress lead to a tense competition environment and unpleasant communities.	"During competitions everyone is stressed and therefore extremely agitated. The environment is really tense as well. Interacting with other robotics kids is an incredibly negative influence." "I really love building and designing but things can get very stressful and frustrating."
	Sexist behavior	Three respondents noted that robotics (especially robotics tournaments) highlighted the difficulties they face as female students in engineering.	"The culture at some robotics competitions has also made me more aware of the fact that I won't always be welcomed in the field as a girl"

tion on a robotics team has a degree of importance towards a post-secondary disciplinary interest.

Survey respondents were given a follow-up qualitative question to explain the degree of positive/negative influence of robotics participation to engineering post-secondary interest. Table 1 details the theme extracted from respondents and their contribution towards a positive/negative influence of robotics participation towards post-secondary discipline interest in engineering. Thematic analysis and coding were conducted to sort the responses.

The quantitative data in Table 1 shows that nearly half (n = 11) of respondents valued the first-hand experience from robotics. Community was noted as another positive influence. The findings align with pre-existing research detailing the academic enrichment and community/belonging as benefits of extracurricular activities.

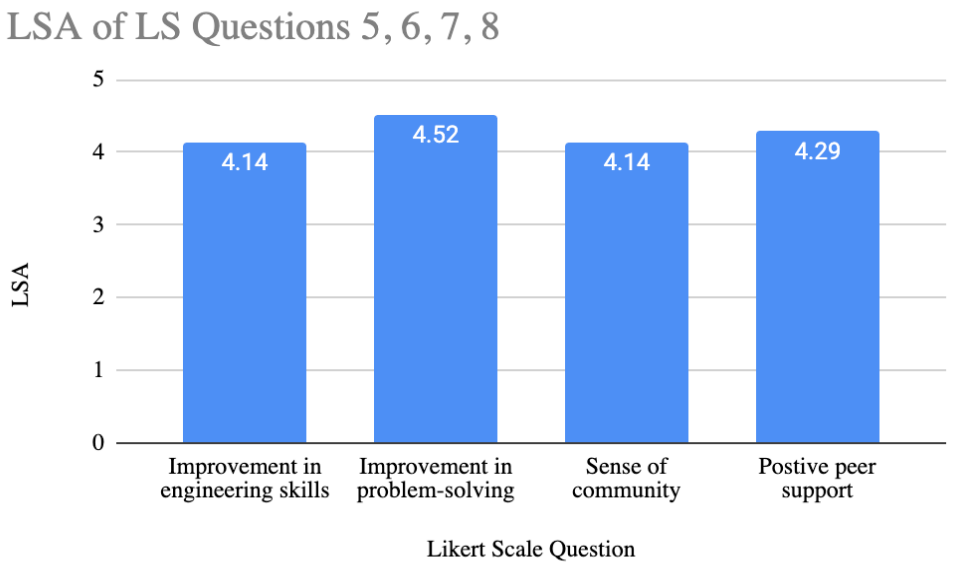
Despite the positive themes, negative themes also emerged. For instance, the stress and difficulties from robotics contributed to a negative attitude towards future engineering plans. Moreover, the competition environment of robotics was noted as stressful and oftentimes challenging for a female-identifying student. The negative findings are important to highlight since they can contribute to the low number of female-identifying students in post-secondary engineering programs. With the high LSA averages for "importance" of robotics towards post-secondary discipline interest, it is important to implement changes in robotics programs to make female-identifying students comfortable in the discipline of robotics and engineering as a whole.

Overall, Hypothesis 1 was disproven through survey analysis. Although 42.9% of respondents plan to study engineering, the remaining 57.1% of respondents are not planning to pursue engineering or are unsure. When analyzing the "positive influence" and "importance" LSA by age, it is clear that robotics participation has little positive influence towards post-secondary yet remains an important factor among older students contemplating future education plans. Lastly, the thematic analysis and coding of quantitative question #14 reveals themes that potentially cause a lack of interest in post-secondary engineering programs.

Mean statistical analysis was conducted to find the LSA of Likert Scale questions #5, 6, 7, and 8. The calculated means are graphed below in Figure 4. The findings from this graph are part of the evaluation of Hypothesis 2.

Overall, the LSAs were high for all questions. The high LSA values align with Hypothesis 2, that utility values will be high. Furthermore, the LSAs indicate that although robotics does not necessarily inspire a specific post-secondary interest in engineering, participants find value in robotics that can be transferred to other disciplines. The high LSA values for all questions also align with findings from the literature review. In particular, they align with Blanchard and

Figure 4
Respondents' self-perceived utility factors



colleagues (2023) findings of an increase in skills and utility.

Respondents were asked to write about their reasons for participating in robotics. The qualitative answers were then thematically coded to align with findings from the literature review. Overall, results (Table 2) aligned with previous research but there were emerging themes from the predetermined themes of internal and external motivation.

The data in question #9 was important to collect to better understand what students value from robotics clubs. Since data analysis in Hypothesis 1 determined that participation in robotics does not necessarily denote future plans to study engineering, the motivation data is critical to understand why students participate in robotics clubs. As seen in Table 2, students value the hands-on enrichment and problem-solving aspect of robotics. Furthermore, students enjoy the community and team aspect of robotics. The findings align with the existing body of research, that community and belonging are highly valued and important within extracurricular activities (Blanchard et al., 2023; Mulvey et al., 2023). This finding is also important, since researchers note that community and belonging were more likely to pursue post-secondary education (Vandelannote & Demanet, 2021).

Respondents presented internal and external motivation differently than in previous research. In particular, several respondents wrote about past experiences (e.g. childhood interests) as motivation factors for participation in robotics. This finding is important because it could help determine who would be interested in robotics/engineering programs and foster greater involvement among younger students. Lastly, university applications were noted as another motivating factor. The emerging theme likely stems from the growing competitive nature of applications to post-secondary institutions. This theme is important to note because it demonstrates how skills and/or utility values from robotics may be useful in various disciplines, not just engineering.

To determine interest in related post-secondary disciplines, survey question #10 asked respondents if they planned to pursue STEM studies. This question was asked because skills from engineering can be transferable to other STEM disciplines (e.g. problem solving, coding). A pie chart was created using this data (Figure 5).

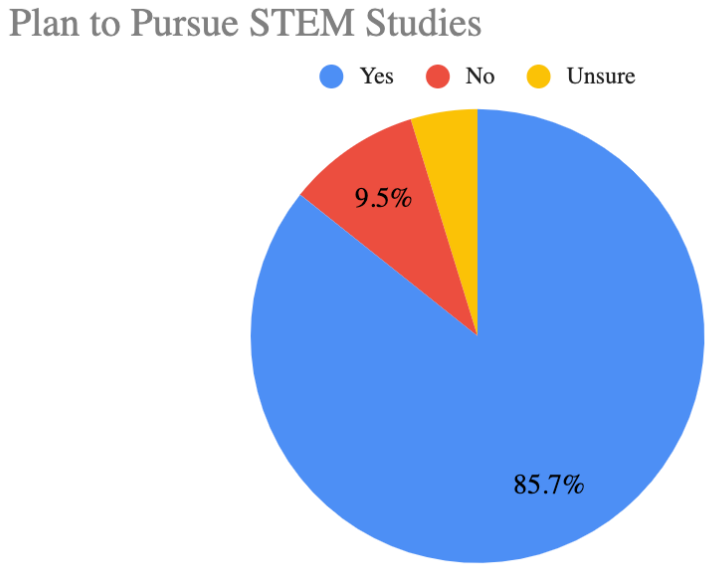
Table 2
Respondents' self-perceived robotics motivation

Survey Question #9: What motivates you to participate in robotics?		
Themes	Summary	Examples
Community	Six respondents noted community as a factor of motivation. In particular, five respondents noted the importance of a team.	"Being able to be part of a strong community that not only learns and grows together as a team." "getting to know others, spending time with my school's robotics team community"
Academic enrichment	Nine respondents noted valuable exposure due to participation in robotics. Three respondents further noted exposure to problem solving.	"Good for improving on problem solving skills" "The problem solving/puzzle aspect"
Internal Motivation	Six respondents wrote about factors that are related to internal motivation. Three respondents felt that accomplishment in robot building and resulting fulfillment were motivation factors. Four respondents (some respondent overlap) noted internal motivation through previous experiences (e.g. childhood memories in robotics and doing well in science/math)	"when i saw the startup for VEX in grade 9 I looked back on some childhood memories that had a positive depiction of robotics." "I really love designing and building and feel a sense of achievement when things work well with my robot."
External Motivation	Six respondents wrote about factors related to external motivation. Three respondents noted future goals (university) as factors for motivation to participate in robotics. Moreover, two respondents noted that their friends were in robotics and one respondent noted enjoying winning in competitions.	"I would like to be an engineer." "putting it on a uni app." "preparing for engineering in university" "Many of my friends are in robotics" "Winning in competitions"

Based on the graph, it is clear that most respondents (n = 18) plan to pursue STEM studies. Thus, although robotics may not necessarily denote an interest in engineering post-secondary programs, it denotes an interest in related STEM programs. This finding aligns with Hypothesis 2, since high utility values/transferable skills cause an interest in related post-secondary interests.

To further examine potential post-secondary discipline interests, survey question #12 asked respondents to write down what they plan to pursue after high school. The quantitative data was then thematically coded and graphed in a bar chart displaying most common interests. Since some respondents gave more than one answer, the total responses in the bar chart do not reflective the sample size n = 21. It is impor-

Figure 5
Respondents' plan to pursue STEM studies



tant, however, to graph all the interests since some respondents remain undecided but have a general idea of what they wish to pursue.

Overall, nearly all categories have direct applications from robotics participation. For example, science/medicine relies on problem solving skills while computer science relies on coding skills. As such, it is clear that, although students do not plan to pursue engineering, they are planning to pursue paths that may benefit from participation in robotics.

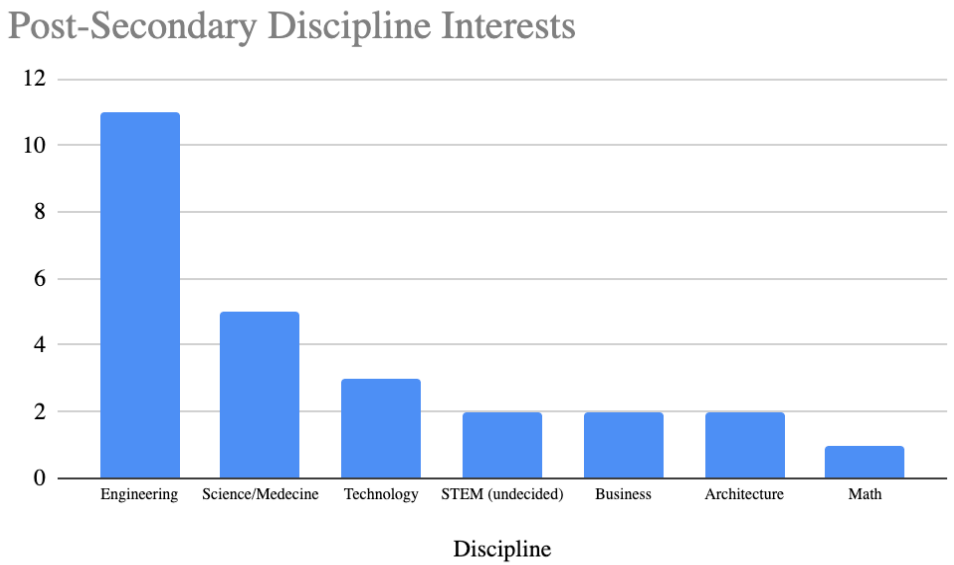
Hypothesis 2 was supported by the data analysis. There are factors of robotics that link to the predetermined benefits of extracurricular activities in the literature review. These high utility values then contribute to an interest in either engineering or a related discipline. Although not all respondents wish to pursue engineering, they are picking fields in which skills are transferable from participation in robotics. Lastly, themes like community and internal motivation remain prominent. This finding is important to note since existing literature determines that individuals must feel comfortable and supported when pursuing their interests.

Limitations and Future Directions

A limitation of this study is the sample. First, the sample size of n = 21 is a small proportion of the overall female-identifying student population on robotics clubs and teams. Furthermore, the sample size was not randomly selected. The distributed survey was voluntary in nature and as such, has potential response bias. Respondents who felt more strongly about their dislike/like for robotics would be more likely to respond rather than robotics participants who felt less strongly on the matter. Lastly, due to the anonymous nature of the survey, it is not possible to determine whether the data was reflective of all schools' robotics teams and their participants. Due to different program structures and environments, there are likely different experiences and sentiments from participants on different robotics teams.

Future studies could connect with more respondents through general communication platforms rather than through distribution by school coaches. Moreover, the time for response could be lengthened in order to give more time for participants to respond

Figure 6
Respondents' post-secondary discipline plans



and reminders could have been sent to remind the participants. The survey could also expand to female-identifying students on teams that are co-ed rather than all-female. Due to findings regarding tense environments at co-ed competitions, there is value in learning whether the same environment can be found on co-ed robotics teams and how these different environments could influence a female-identifying student's plan to pursue engineering. Lastly, future research should explore factors related to socioeconomic status and future plans since previous research noted a potential relationship but such factors were not feasible to cover in this project.

The study's results have critical implications for future conversation around engineering. Educators and school administration, robotics organizers, and post-secondary engineering institutions could benefit from the results of this study. Educators and school administrators would be interested in learning about the motivation factors for robotics extracurricular activities. These factors give insights into potential improvement for programs to increase participation in robotics. Robotics organizers would benefit from learning about the degrees of positive and negative influence from robotics to better structure programming to better support female-identifying students in their programs. Lastly, post-secondary institutions with engineering programs could benefit from these findings to better attract female-identifying students and retain their interest in a typically male-predominant field.

Conclusion

As a whole, the goal of the study was to answer the research question: *How might female-identifying students ages 14-18 in Ontario Independent Schools perceive the influence of robotics extracurricular activities towards their post-secondary discipline interest?*

Through a mixed-method survey with embedded design, with emphasis on quantitative data (Likert scales), statistical analysis was conducted to find mean values while qualitative data further examined prevailing themes. The results of the study found that robotics had little positive influence and some degree of importance towards a student's post-secondary discipline interest. Furthermore, the results found that,

although participation in robotics does not denote interest in post-secondary engineering, it leads to interest in related post-secondary disciplines and interests. Robotics participants reported high utility values and transferable skills that lead to interest in technology, science, and other STEM disciplines.

The study results are important to the engineering discipline because there has been limited research on female-identifying students in STEM extracurricular activities and on engineering extracurricular activities. Moreover, the study fulfills a research gap in location, as little research has been conducted on this topic in Ontario. Overall, it is important to foster environments for female-identifying students in robotics programs in order to further encourage female-identifying students in engineering. The gendered history of engineering must be rewritten, not only for Engineers Canada's 30 by 30 goal, but for improved representation of women in engineering and beyond.

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Appendix A

Survey Distribution Request

In order to distribute the survey to the intended population, two different email templates were drafted, each with two different parts. The first email was to the robotics coach at the researcher's school, requesting for the lower portion of the email to be posted on the school's robotics page.

Table A1
Email Requesting the Distribution of Survey to Researcher's School

Email	Message
FROM researcher TO robotics coach at researcher's school	Hi [robotics coach], Thank you very much for agreeing to help with the distribution of my AP Research survey. As you know, my project is about female-identifying student participation in robotics and its potential influence on post-secondary studies. I would like to survey Grades 9-12 students in robotics clubs/teams, in order to find out about their perceptions of robotics. My survey will only remain open until February 19, so it would be great if you could please post the information below to the [school name's] Robotics Team page as soon as possible. Thanks again for your assistance! [researcher] Please copy and paste the few sentences below as soon as possible to the [school name's] Robotics Team page, because the survey will only remain open until February 19:
FROM robotics coach at researcher's school TO individual respondents of sample	I am a Grade 12 AP Research student here at [school name] and I am conducting a research project. You have been chosen in my survey sample and I would really appreciate you completing my survey on the topic of female-identifying student participation in robotics and its potential influence on post-secondary studies. It should take no more than 10 minutes and should be completed by February 19. Thank you very much! Here is the link to the survey: [url]

The second email was to the robotics coaches at other schools that met the demographic conditions of: a) having participants ages 14-18, b) having all female-identifying student robotics teams, and c) being an independent school in Ontario. The email was sent to the robotics coach requesting that the lower portion of the email be distributed to the robotics participants at the school.

Table A2
Email Requesting the Distribution of Survey at other schools

Email	Message
FROM researcher TO robotics coach at researcher's school	Good morning [robotics coach], My name is [researcher's name] and I am an AP Research Student at [school name]. As part of my research, I am conducting a survey on all-girls' robotics teams and exploring the influence of robotics towards their post-secondary educational choices. I was given your contact by my robotics coach, [coach's name], to ask if you would be willing to distribute my survey to the all-girls robotics teams at [recipient's school name]. In order to conduct my research, I am looking for Grades 9-12 in robotics clubs or teams to answer a short Google Form survey and as such, I was hoping the robotics students at [recipient's school name] would be able to complete my survey. All aspects of my project, including the survey, have been reviewed and approved by my school's Institutional Review Board; therefore, the purpose of this message is not to seek your feedback about or suggestions for changes to the project, but to seek your help in distributing my survey. Please note that my survey should ONLY be filled out by respondents aged 14-18 or in Grades 9-12. Respondents to my survey do not need to fill out and return a completed Informed Consent permission form; however, they will need to check an Acknowledgement Statement in the survey, declaring that their parent or guardian authorizes their participation, or, if they are over the age of 18, to give their own consent. The complete Informed Consent Letter is available via a link at the top of the survey. Should you have any questions or concerns, please contact my AP Research teacher, [teacher name] at [teacher email]. If you are willing to distribute my survey, please share the few sentences (attached below) to any members of the [recipient name]'s Robotics Teams. Thank you very much for your assistance! [researcher] [researcher's school name] If able, please share the few sentences below as soon as possible, because the survey will only remain open until February 19, 2024:
FROM robotics coach at researcher's school TO individual respondents of sample	I am an AP Research student at a local high school, and I am conducting a research project. You have been chosen in my survey sample and I would really appreciate you completing my survey on the topic of female-identifying student participation in robotics and its potential influence on post-secondary studies. It should take no more than 10 minutes and should be completed by February 19, 2024. Thank you very much! Here is the link to the survey: [url]

Appendix B

Informed Consent Letter

AP Capstone Research Informed Consent Form 2023-2024

Please read the following information which is intended to help you decide if you wish to participate in the present research study. No signature on this form is required for consent. You will be asked to consent through a checkbox via the Google Form.

Please be aware that participation in this study is completely voluntary. If you do decide to participate, you may stop participating at any time, without justification or consequence, and you may opt out of answering any question(s) you choose. If you decide not to participate, there will be no negative consequences.

Title of project:

Exploring Female-Identifying Student Participation in Robotics and Post-Secondary Disciplinary Interest Plans

Purpose of project:

To explore how female-identifying student participation in robotics extracurriculars can influence their post-secondary discipline interest.

Method/Procedure:

I will be using a mixed-methods approach. Specifically, since "both quantitative and qualitative are collected within the same general time frame…[but] one general approach dominates" (Leedy & Ormrod, p. 260, 2013), I will be using an embedded design to collect data. Quantitative data from Likert scales serves as the primary data. The secondary focus on qualitative data allows me to look for prevailing themes, through coding, that contribute to interest in specific post-secondary disciplines and perception of engineering extracurriculars towards these interests. Since Likert scale questions allow for "degrees of opinions" (Mcleod, 2008, p. 1), this format will be suitable for evaluating potential factors towards post-secondary discipline interest and influences from engineering extracurriculars. I will also employ short answer questions to evaluate types of post-secondary disciplinary interests and opinions on engineering extracurriculars. Overall, using a mixed-methods approach with embedded design enables me to "[integrate] conclusions from [the] data into a collective whole" (Leedy & Ormrod, p. 258, 2013).

The survey population will be female-identifying students on robotics clubs or teams at Ontario all-girls' independent schools, specifically COSSOT schools. Since high school students will likely have a better understanding of future plans, the surveys will be distributed to Grade 9 to 12 robotics teams. To comply with ethical regulations, the survey will be voluntary and will require informed consent from participants. I plan to distribute my survey to robotics coaches at these schools, with the help of the [my school's] robotics coach.

To collect data from participants, I will conduct a survey using the online survey administration software, Google Forms. A survey was chosen as the method of data collection due to its ability to collect both quantitative and qualitative data from participants in the same space. This resource is also accessible, it can be shared easily to the distributors of the survey and in turn, the participants.

Estimated time required for participation:

The survey will take approximately 5-10 minutes to complete and will be a one-time commitment.

How confidentiality will be maintained:

The data will be anonymous. Names, email addresses, and any other identifying information will not be collected from respondents. Respondents are also asked to not share identifying information (e.g. school or team name) within the short responses to maintain confidentiality. Furthermore, no identifiable information will be shared in reports, articles, or presentations.

Potential risks/discomforts:

There are psychological risks, given that respondents' opinions will be gathered on their future plans. It will be made clear that respondents are free to withdraw and exit the survey at any time without consequence. Survey questions will also be designed so that they are not overly personal.

Benefits:

Administration in high schools and undergraduate engineering programs would benefit from the results of my research study. By having a better understanding of the factors that lead to students either picking or not picking engineering as their post-secondary interest, administration can aim to create better environments for female-identifying students to pursue engineering and foster better engagement among all students.

Furthermore, Engineers Canada have a goal: 30 by 30. They are trying to achieve 30% women engineers in the workforce by 2030 (Engineers Canada, n.d.). Interest in engineering starts in high school so to see an increase in practicing women engineers, it is important to make changes to high school and post-secondary education.

Lastly, mentors of high school engineering extracurriculars, such as older students and teachers will benefit from this study. By understanding the factors that lead to interest in engineering extracurriculars and programs, leaders can cater their programs to better support female-identifying students through their engineering pursuits.

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Please do not hesitate to ask questions about the study. Your responses will be anonymous, and your name will not be associated with the research findings in any way. Please direct any questions you may have to:

AP Capstone Research Teacher: [supervisor name]
E-mail address: [supervisor's email]

Thank you.

Sincerely,

AP Capstone Researcher

[Derived from: Creswell, J. W. Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research (3rd ed.). Upper Saddle River, NJ: Pearson Education, Inc., 2008, p.159; and International Rules: Guidelines for Science and Engineering Fairs 2015-2016 (AP Capstone Research training, Arlington, Texas, June 2017)].

Appendix C

Survey Distributed to Robotics Participants

The survey shown below was created and distributed to respondents on all female-identifying student robotics teams. Each row of the table represents the different sections of my survey, distinguished by header text boxes on the Google Form.

Table C1
Survey Instructions and Questions

Section Heading	Instructions and Questions
Female-identifying students' participation in engineering extracurriculars influences on post-secondary disciplinary interest	Thank you for taking the time to participate in my AP Research survey. The purpose of the survey is to evaluate the perceived influence that robotics participation may have towards post-secondary plans. The survey will contain 4 sections to assess participation in robotics programs and post-secondary plans. Altogether, the survey contains 15 questions and will take approximately 5-10 minutes to complete. The survey is completely anonymous and confidential. As such, your individual responses will NOT be shared and responses will NOT be connected back to you. Names, email addresses, and school names will NOT be collected. To maintain anonymity, please DO NOT include any specific identifying information (e.g. school name, team name). If, at any point, you feel uncomfortable with answering the questions, you can exit the survey at any point with no consequences. This is NOT a test and responses will not be marked for accuracy. A link to the informed consent letter can be found here: [url]. If you have any further questions, please contact my research supervisor [supervisor name] at [supervisor's email] Please note: the survey will remain open until February 19, 2024
Informed Consent	☐ By checking this box, I confirm that I have read and understood the survey outlined above and the Informed Consent Letter (linked above) and freely give my consent to participate in this survey. If I am under the age of 18, I certify that my parent(s) or legal guardian(s) have given their permission to complete this survey.

Demographics	Please note: if you are not currently in an Ontario independent school and participating in a robotics club or team and/or not in the age range outlined below, please exit the survey. Thank you for your interest. How old are you? ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 Do you self-identify as a female? ☐ Yes ☐ No ☐ Prefer not to answer Do you study in an Ontario independent school? ☐ Yes ☐ No Are you a current participant in a robotics extracurricular (club/team) at your school? Please note: extracurricular refers to an activity conducted within the school's administration but outside of usual class time. No academic credits should be received for participation. ☐ Yes ☐ No

Evaluation of Robotics Participation	The following questions will ask you to evaluate different statements on your participation in robotics extracurriculars. Participation in robotics programs has improved my engineering skills (e.g. designing, building, coding) (1 strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, 5 = strongly agree) [Likert Scale] 1 2 3 4 5 Participation in robotics programs has improved my problem-solving skills (1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, 5 = strongly agree) [Likert Scale] 1 2 3 4 5 I feel a sense of community within my robotics program (1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, 5 = strongly agree) [Likert Scale] 1 2 3 4 5 I feel positively supported by my peers in my robotics program (1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, 5 = strongly agree) [Likert Scale] 1 2 3 4 5 What motivates you to participate in robotics? [short answer/free response]

Post-Secondary Plans	The following questions will ask you about post-secondary plans. Please note: post-secondary programs refer to any education after graduation from high school. Do you plan to pursue STEM studies after graduating from high school? Yes No Do you plan to pursue engineering studies after high school? Yes No What do you plan to study after graduating high school? [short answer/free response]
Robotics Program Participation and Post-Secondary Plans	The following questions will ask you to evaluate different statements in regards to both robotics participation and post-secondary plans. My participation in a robotics program positively influences my specified post-secondary interest. (1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, 5 = strongly agree) [Likert Scale] 1 2 3 4 5 Please explain your response to the previous question. Why do you feel this degree of positive and/or negative influence? [short answer/free response] Please rank the importance of robotics participation towards your specified post-secondary interest. (1 = unimportant, 2 = of little importance, 3 = moderately important, 4 = important, 5 = very important) [Likert Scale] 1 2 3 4 5
Concluding Statement	☐ By checking this box, I understand that my role in the survey is complete and no further action will be required after I submit this form. I can request to receive the final research report with a summary of the overall results by contacting [supervisor name] at [supervisor's email]