RESEARCH SHOP

"know what's out there!"

Mathstronauts High School Program Needs Assessment

Prepared for

Mathstronauts

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By

Megan Li
Emma Nicholson
Frank Ong
Sona Rai
Savanah Smith

rshop@mcmaster.ca researchshop.mcmaster.ca

Office of Community Engagement | McMaster University

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Executive Summary

Mathstronauts is a non-profit organization that currently provides experiential science, technology, engineering, and mathematics (STEM) programming and activities to middle school students within the Hamilton area. Mathstronauts is interested in expanding their programming to include a new program for high school students to assist with the transition from high school to post-secondary STEM education. The aim of this project was to gather information about the need for high school level STEM programming within the Hamilton area, the skills high school students require the most support with to be successful in post-secondary STEM education, and preferences for a high school-level STEM program, in order to inform the development of such programming. The research team conducted an environmental scan of existing STEM programs available to high school students in the Hamilton area, surveys with high school students, parents of high school students, and first-year post-secondary students in STEM programs, and interviews with professors who teach first-year STEM courses. Limitations of the study include a small sample size and the possibility of sampling bias.

From the surveys, our results indicated that high school students were most interested in physics/engineering, biology, and mathematics and wanted to learn more about coding. High school students were most comfortable with math, conducting research, and referencing, and least comfortable with statistics and coding. Many first-year students felt that high school prepared them well for university, but indicated that they experienced the most difficulty with math, coding, scientific writing, research, and referencing. They also indicated experiencing difficulty with time management and stress management. In the interviews, professors noted significant difficulties their first-year students were experiencing in relation to soft skills (i.e., adjusting to new expectations, interpersonal skills, study habits) and technical skills such as math and coding. Professors suggested that students should learn how to study effectively and review foundational STEM concepts to better prepare for post-secondary STEM education.

Our environmental scan identified 11 active STEM programs for high school students in Hamilton or available to Hamilton students online. However, many of these programs were not available to Grades 11 and 12 students. The high school survey indicated that high school students were both interested and available to participate in a high school-level STEM program and would be most interested in learning about the topics of health sciences, coding, and biology. In the interviews, professors noted that STEM programs should incorporate logic, mathematics, design thinking, and writing into their curriculum, while taking a flexible, learner-centered inquiry approach to engage students.

The results of this study demonstrate that high school level STEM programming is needed and of interest to both high school students and parents. It is recommended that Mathstronauts (1) focus their programming on the technical skills of coding and math; (2) focus their programming on the soft skills of time management and stress management/resilience; (3) provide education about STEM careers; and (4) provide education about university-level learning and expectations.

Introduction

Careers in science, technology, engineering, and mathematics (STEM) fields, have become the fastest growing occupations, providing exciting opportunities for graduates with an interest and education in STEM. However, the current Ontario elementary and secondary school curriculum does not adequately prepare students for post-secondary level STEM education or careers within the STEM fields. Recently, the Ontario government has acknowledged this gap in STEM learning and has proposed curriculum changes to foster STEM learning opportunities in younger students (e.g., learning coding starting in grade one) (Rushowy & Benzie, 2020; Government of Ontario, 2020).

Mathstronauts is a non-profit organization that currently engages middle school students in STEM education through after-school extracurricular programming, competitions, and workshops. Mathstronauts' programming aims to build STEM competencies and soft-skills necessary for success in STEM fields, such as time management, critical thinking, problem solving, and logical reasoning skills. Mathstronauts is interested in expanding their program offerings to high school students. However, before designing and executing this programming, they want to assess the need for this type of programming for high school students. To help inform the program development and curriculum, they are also interested in determining the most in-demand soft and hard skills for post-secondary STEM education.

Mathstronauts enlisted the help of a team of research volunteers within the McMaster Research Shop to carry out this research. This report provides a summary of the findings.

Methodology and Limitations

Methodology

A team of McMaster Research Shop volunteers conducted research between May and August 2020. The project included three components: (1) an environmental scan of STEM programs; (2) online surveys with high school students, parents of high school students, and first-year post-secondary STEM students (hereafter referred to as "STEM students"); and (3) interviews with university professors who teach in first-year STEM courses. The methods are outlined in detail below.

Environmental Scan

To inform the development of a high school STEM extracurricular program by Mathstronauts, the research team conducted an environmental scan to determine:

1. What extra-curricular STEM programming is currently offered to high school students in the Hamilton area?; and

2. What are the characteristics of these STEM programs for high school students (e.g., status, target demographics, objectives, activities, length, cost, and incentives)?

A description of all competitor STEM programs, workshops, and events available to high school students in the Hamilton area was compiled using: (1) survey data describing the extracurricular STEM programs that high school students/STEM students had previously participated in; (2) programs mentioned by professors during the interviews; and (3) a comprehensive search strategy developed by the research team.

The search strategy consisted of combinations of the following terms using Boolean operators: "STEM program*" or "STEM workshop" or "STEAM program*" or "STEAM workshop" or "science program*" or "science workshop" or "technology program*" or "technology workshop" or "engineering program*" or "engineering workshop" or "math* program*" or "math* workshop" or "coding program*" or "coding workshop" or "STEM summer camp" or "technology summer camp" or "science summer camp" or "coding summer camp" or "robotics summer camp" or "engineering summer camp" or "math* summer camp" or "robotics program*" or "robotics workshop*" or "university prep* course" or "university prep* program" or "university prep* workshop" AND "Hamilton" or "Hamilton-area" AND "high school student*" or "high school student*" or "high schoolers" or "secondary school student*" or "teen*" or "teenager*" or "youth" or "adolescent". Google and the McMaster University Community Engagement and Research Guide databases were searched, as most of the program information was available through program websites, rather than academic journal articles.

The inclusion criteria for the environmental scan included:

- All extracurricular STEM programming in Hamilton and surrounding areas available to high school students (i.e., youth age 14 to 18)
- Any STEM program in the Hamilton area that served high school students with an instruction component

All included programs were reviewed by at least two team members to ensure the inclusion criteria was met.

The environmental scan identified a total of 11 active competitor programs/workshops in the Hamilton area (or online); 9 competitor programs in the surrounding area; 7 STEM competitions open to high school students within Hamilton and surrounding area; and 2 STEM conferences for high school students. The research team compiled information relating to each program's target demographics, purpose, structure, activities, schedule, length, cost, and incentives.

Online Surveys: High School Students, Parents of High School Students, & STEM Students

Mathstronauts and the research team collaborated to create online surveys. The surveys targeted high school students, parents of high school students, and STEM students as

respondents. Participant recruitment started in June 2020 and ended on August 2, 2020. Survey participants were provided with the chance to win one of five $20 dollar Amazon gift cards to promote participation. Mathstronauts and the research team distributed the online surveys by reaching out to community organizations and personal contacts, as well as via recruitment emails and social media advertising. The platform Google Forms hosted the three surveys, which consisted of a mix of open- and closed-ended questions.

To start each survey, participants received a brief description of the survey purpose and gave informed consent. Contact information was stored separate from survey responses and was only used for the purposes of the gift card draw. All other information disclosed in the surveys was kept confidential and used only for the purpose of informing Mathstronauts' program development.

The surveys asked similar questions across all three target groups–high school students, parents and STEM students–to provide different perspectives. The high school student survey consisted of 19 questions and assessed interest in a STEM extracurricular program, interest in STEM learning, and previous experiences with STEM extracurricular programs (*Appendix 1*). The parent survey consisted of 19 questions and assessed their child's interest in a STEM extracurricular program, interest in STEM learning, and previous experiences with STEM extracurricular programs (*Appendix 2*). The first-year STEM student survey consisted of 23 questions and identified challenges first-year students face transitioning from high school into post-secondary STEM education, previous experiences with STEM extracurricular programs, and their experience in post-secondary STEM education (*Appendix 3*).

The high school student, parent, and STEM student surveys received 64, 37 and 28 responses respectively. The research team removed duplicate participant responses (n=5) and participants responses who did not meet the inclusion criteria (i.e., they had not yet completed their first year of post-secondary education, n=2; were not in a STEM program, n=1). Sample sizes used for all analyses for the high school student, parent and STEM student surveys were 62, 34 and 25 respectively.

The research team used multiple methods to analyze the data, incorporating both quantitative and qualitative approaches. Data for closed-ended items (i.e., those with a set list of responses) were converted to percentages, open-ended items were grouped by theme and presented in tables with corresponding percentages, and likert (rating) scale-type item data were converted to weighted averages. The value of calculating a weighted average is that it assigns meaning (i.e., a weight) to the items and allows for easier interpretation. In these surveys, five-point likert (rating) scales were used throughout, meaning that the maximum weighted average that could be achieved for any given item was 5.

STEM Professor Interviews

First-year STEM university professors at McMaster University were interviewed to provide insight into the challenges first-year students face. Recruitment took place via departmental distribution emails, and personal emails sent by a research team member. Each interview was approximately 20-minutes in length and took place over the telephone or Zoom.

At the beginning of the interview, the interviewer obtained verbal informed consent from the participant. The interviewer followed a semi-structured interview guide (*Appendix 4*). The interview consisted of 6 open-ended questions where professors were asked about their experiences teaching first-year STEM students, soft and technical skills important for first-year students in STEM fields, and important topics for an extracurricular STEM program to cover.

The research team interviewed a total of 8 STEM professors. All interviews were recorded, transcribed, and stored on a secure Google Drive folder, before thematic coding. The research team created a coding framework (*Appendix 5*), open coded the transcripts, and finalized codes through group consensus. Findings are presented by theme in the *Results* section.

Analytical Framework

The team created an analytical framework to guide the analysis and reporting (*Table 1*). The analytical framework aligned methods and data collection to the initial research objective.

The research team broke down the research objective into sub-questions (or constructs). The research team then broke down the constructs into indicators that could be measured using our methods (i.e., environmental scan, surveys, and interviews). The constructs, indicators and data sources used in the present study are presented in *Table 1*.

Table 1. Constructs, indicators and data sources used to guide analysis.

Constructs	Indicators	Data Sources
Competitor programs/ Workshops in STEM	·Previous Participation in STEM Extracurriculars ·Competitor programs/workshops in Hamilton ·Competitor programs/workshops outside of Hamilton ·STEM competitions in the Hamilton area ·STEM conferences	·High school student surveys ·Parent surveys ·First-year post-secondary STEM student surveys ·STEM professor interviews ·Environmental scan
Interest in STEM	·STEM areas of interest to high school students ·STEM topics high school students are interested in learning more about ·Parents' perceptions of their child's interest in STEM	·High school student surveys ·Parent surveys ·First-year post-secondary STEM student surveys

	·Interest in getting an education/job in STEM	
Level of preparedness for post-secondary STEM education	·STEM students' perceptions of their level of preparedness ·Professors' perceptions of first-year students' level of preparedness	·First-year post-secondary STEM student surveys ·STEM professor interviews
Student strengths and skill gaps	·Confidence in STEM skills/competencies ·STEM topics parents feel their child would benefit from learning prior to post-secondary education ·Skills students had difficulty with in their first year of post-secondary STEM education ·Hard skill gaps ·Soft skill gaps	·High school student surveys ·Parent surveys ·First-year post-secondary STEM student surveys ·STEM professor interviews
Preparation for post-secondary STEM education	·Suggestions to assist students in preparing for post-secondary STEM	·STEM professor interviews
Preferences for high school-level extracurricular STEM programming	·Interest in a high school-level STEM program ·Scheduling/location ·Willingness to pay to participate ·Program design	·High school student surveys ·Parent surveys ·STEM professor interviews

Limitations

There are limitations to this study that must be taken into consideration when interpreting the data. Survey sampling was limited as privacy restrictions prevented mass distribution to high school systems. High school surveys are required to go through ethics and school board council approval in order to be distributed. Due to time limitations and the scope of this project, the team did not obtain ethics approval on this project. Additionally, this project was started at the end of the school year, during a worldwide pandemic. Therefore it is likely that if the team had sought ethics and school board approval, the project would not have been approved prior to the high school students being released for the summer (as ethics approval is typically a lengthy process). Due to this limitation, survey participants were recruited through connections to organizations/groups that serve high school students and through personal contacts.

With a limited sampling pool, the team obtained small final sample sizes for survey data (e.g., STEM student survey, N=26). As such, analyses are reported on aggregated results, instead of stratifying by demographic classifications (i.e., gender, grade, etc.). Additionally, because many of the participants were recruited as contacts of Mathstronauts, there is potential for sampling bias, as these participants would likely have a pre-existing interest in STEM programming. We

were likely unable to obtain a representative sample of high school students/parents and STEM students. Therefore, these survey results are not generalizable to all high school students, parents of high school students, and STEM students within the Hamilton-area and should be interpreted with caution.

Findings

Demographic Information

High School Students

The majority of respondents to the high school students survey identified as female (71%; 29% male) and half (50%) lived in Hamilton. Other common cities participants were currently residing in included Grimsby (16%), Brantford (10%), and Burlington (5%) (*Table 2*). The high schools most commonly attended by high school participants were Westdale Secondary School (18%), Blessed Trinity Catholic Secondary School (16%), Sir Allan MacNab Secondary School (10%), and St. John's College (10%) (*Table 3*). High school students who participated in the survey were in Grade 12 (47%), Grade 11 (24%), Grade 10 (16%), Grade 9 (11%), and Grade 12 Plus (2%). Most high school students were currently taking University (29%) Academic (24%), or Academic/University (16%) courses (*Table 4*). The majority of high school students (60%) did not have a parent or guardian who worked in a STEM field.

Table 2. Current city high school students' lived in.

City	Percentage (%)
Hamilton	50
Grimsby	16
Brantford	10
Burlington	5
Niagara	3
Caistor centre	3
Other: Vaughan, Toronto, Stoney Creek, St. George, Mississauga, Brampton, Huntsville	11
Preferred not to answer	2

Table 3. Current school high school students attended.

High School	Percentage (%)
Westdale Secondary School	18
Blessed Trinity Catholic Secondary School	16
Sir Allan MacNab Secondary School	10
St John's College	10
Ancaster High School	6
Grimsby Secondary School	6
Glendale Secondary School	5
Bernie Custis Secondary School	3
Other: Homeschooled, Bishop Tonnos Secondary School, Waterdown District High School, St. Marguerite d'Youville Secondary School, Stephen Lewis Secondary School, Assumption College Secondary School, Notre Dame Secondary School, St, Thomas More Catholic Secondary School, St. Mary's Catholic Secondary School, Hamilton District Christian High School, St. Francis of Xavier Catholic Secondary School	26

Table 4. Levels of courses high school students were taking.

Course Level	Percentage (%)
University	29
Academic	24
Academic/University	16
University/Mixed	10
University/College/Mixed	3
Applied/College/Mixed	3
Academic/University/College	3
Applied	2
Applied/Mixed	2

Parents of High School Students

Most respondents to the parent survey had children in Grades 9 (32%) and 10 (32%). The remaining respondents indicated their children were in Grade 11 (29%) or Grade 12 (6%). Half of the parents indicated that their child lived in Hamilton (56%), while others were in the surrounding areas, including Burlington (26%), Brantford (6%), Brampton (6%), Grimsby (3%), and 2.94% generalized their location to the greater Toronto area (GTA). The majority of the parents' children went to Assumption College School (15%), Westdale (12%) and Sir Allan MacNab (9%) (*Table 5*). Of the 34 parents, only 35% noted that they had jobs within STEM. For those who indicated working in STEM (n=12), the most common industries were Science & Health Science (33%), IT & Technology (25%) and Healthcare & Medicine (17%).

Table 5. High schools children of parent participants attended.

High School	**Percentage (%)**
Assumption College School	15
Westdale Secondary School	12
Sir Allan MacNab Secondary School	9
Ancaster High School	6
Orchard Park Secondary School	6
Kings Christian Collegiate	6
Hamilton District Christian High School	6
Other: Homeschooled, St. Marguerite D'Youville Catholic Secondary School, Waterdown District High School, Bishop Tonnos Catholic Secondary School, Bernie Custis Secondary School, Sherwood Secondary School, Notre Dame Secondary School, Saltfleet Secondary School, Nora Henderson Secondary School	40

First-Year Post-Secondary STEM Students

Of the 25 responses to the first-year STEM survey, 68% of the respondents identified as female (32% male). Most participants lived in the GTA (44%) or areas outside of Hamilton or the GTA (32%) prior to entering post-secondary education, rather than within Hamilton (24%). The majority of STEM students who completed the survey currently attended McMaster University (88%). Other institutions the STEM students attended were University of Waterloo (4%), Western University (4%), and Mohawk College (4%). Most students were enrolled in a Mathematics program (68%), compared to Science (12%), Combined (12%) or Engineering programs (8%). The programs were grouped as follows:

- Mathematics: Math and Statistics and Actuarial and Financial Mathematics
- Science: Life Sciences, Medical Sciences, and Integrated Science

- Combined: Math and Computer Science and Integrated Biomedical Engineering and Health Science
- Engineering: Chemical Engineering Technology and Computer Engineering

More students reported that their parents or guardians worked in a STEM field (60%).

STEM Professor Interviews

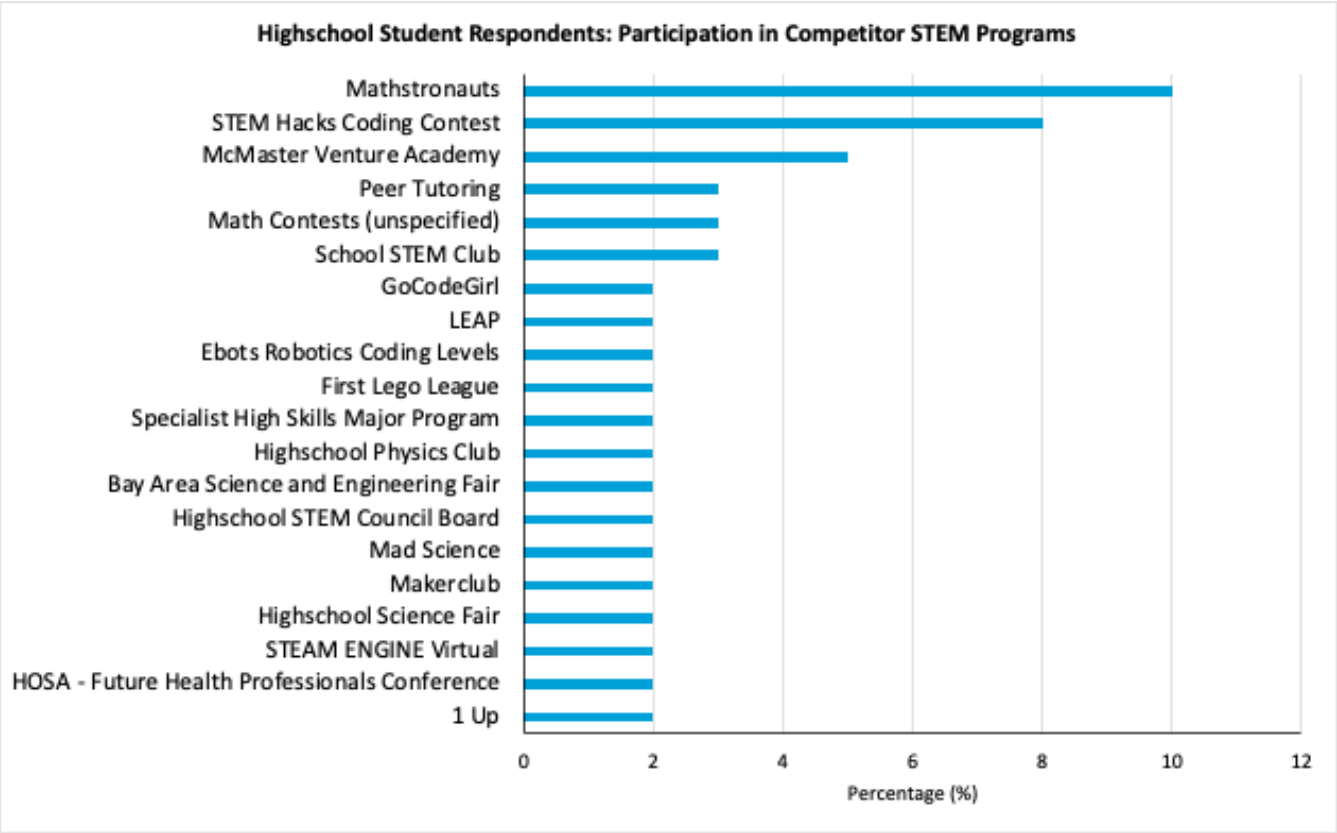
In total, 8 professors were interviewed from McMaster University within STEM programs. All professors had current or past experiences teaching at the first-year level. Most professors represented different departments (i.e., there were only two professors that taught within the same department). The programs represented in the interviews included Kinesiology (n=1), Computer Science (n=2), Software Engineering (n=1), Cross-Listed Courses (n=1), Life / Health Sciences and Medical Sciences (n=1), Engineering and the School of Injury Practice and Technology (n=1), Mathematics (n=1), Chemistry (n=1), and within a Chemical Engineering lab setting (n=1).

Competitor programs/ Workshops in STEM

Previous Participation in STEM Extracurriculars

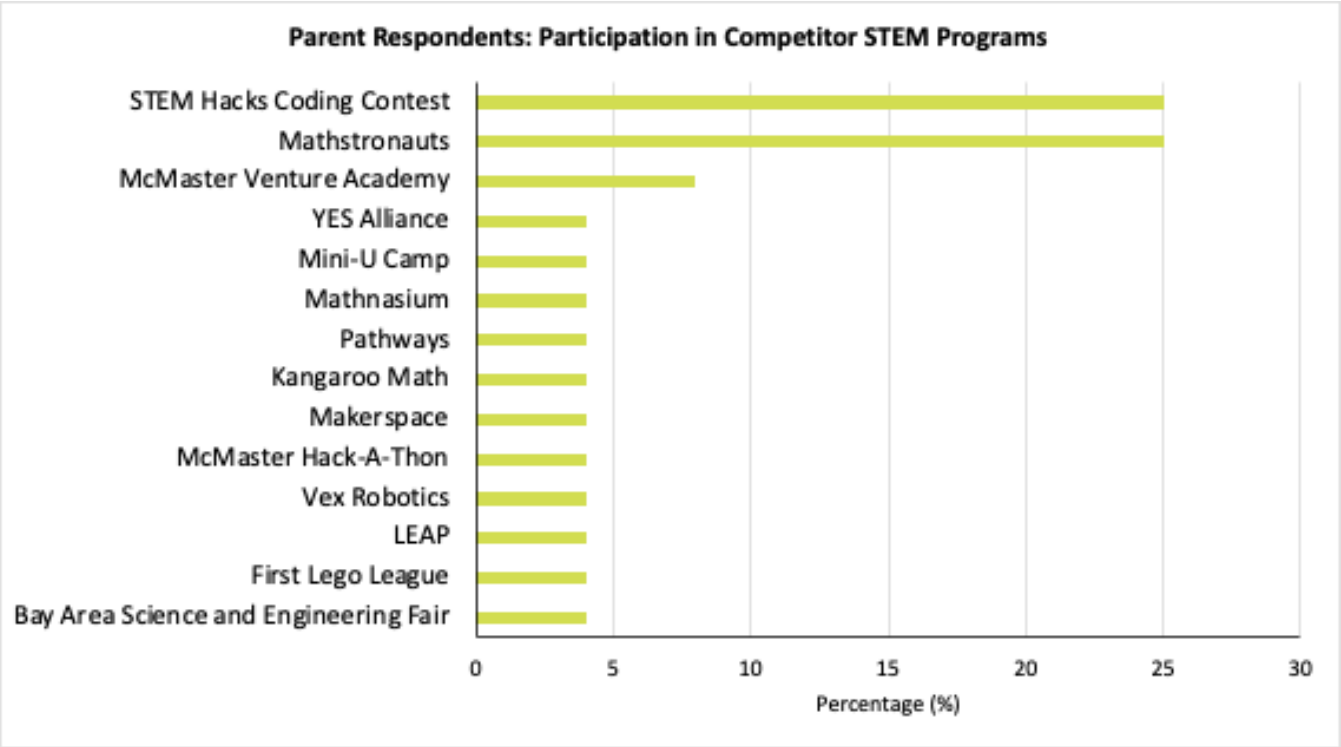
From the high school student survey, approximately half of high school students (45%) had previously participated in STEM extracurriculars. High school students most commonly reported participating in the Mathstronauts program (10%), STEM Hacks Coding Contest (8%) and the McMaster Venture Academy (5%) (*Figure 2*).

Figure 2. STEM extracurriculars high school students described participating in previously.



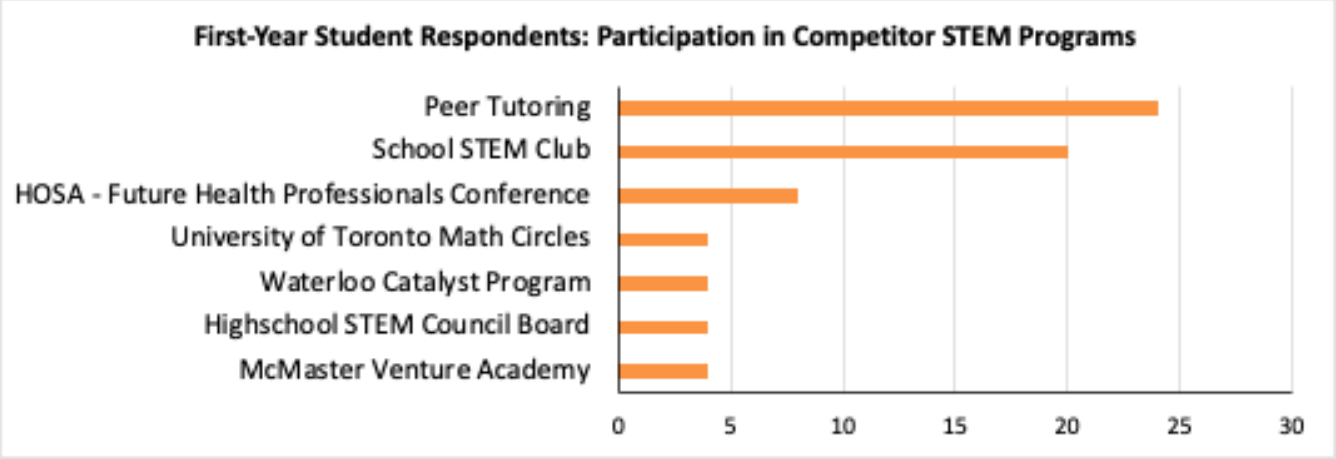
From the parent survey, the majority of parents indicated their children had participated in previous STEM extracurricular programs (71%). Parents most commonly reported that their children had participated in Mathstronauts (25%), STEM Hacks Coding Contest (25%) and the McMaster Venture Academy (8%) (*Figure 3*).

Figure 3. STEM extracurriculars parents described their children participating in previously.



From the STEM student survey, over half of the first-year post-secondary STEM student respondents indicated that, prior to entering postsecondary education, they participated in STEM extracurriculars (64%). They most commonly described participating in peer tutoring (24%), a school STEM Club (20%), and the HOSA - Future Health Professionals Conference (*Figure 4*).

Figure 4. STEM extracurriculars first-year STEM students described participating in previously.



Competitor Programs/Workshops in Hamilton

Through our environmental scan, we identified 12 STEM programs/workshops for youth between the ages of 14 and 18 in the Hamilton area or available to youth in Hamilton online

(*Table 6*). However, one of these programs, the YWCA Girls STEM Club, was no longer active due to lack of funding, leaving a total of 11 programs.

Program Target Demographics

Although a few of the programs/workshops were available to 17 and 18-year olds, many of the programs had a cut off age of 15-16, or grade 10. Many of the programs/workshops were open to any students within the age range described and of all backgrounds and skill levels. However, two of the programs/workshops were specifically for participants who identify as girls, one program served students from underrepresented backgrounds, and one program was specifically for underprivileged youth.

Program Purpose/Activities

Many STEM programs for youth in the Hamilton area provide programming that overviews general STEM education or several STEM areas. However, other programs focus on a specific area of STEM. For instance, one program focused specifically on genetics, whereas other programs focused on coding, engineering, robotics, or digital literacy. Additionally, a few programs aimed to promote interest in post-secondary STEM education careers and help students to prepare for these avenues (GoCodeGirl, Venture Academy, Digitally Lit, Let's Talk Science Outreach).

Program Schedule/Length

In the programs/workshops identified in our searches, the schedule and length were quite variable. For instance, one summer camp program (Venture Academy) ran for eight weeks, Monday to Friday, seven hours each day. Another less structured program (First Lego League Robotics) ran over the course of a year, with the participants communicating with their mentors and team as much or as little needed. We identified STEM workshops that ran for a full day and a half day (GoCodeGirl, GoEngGirl) and a one to two-hour STEAM Museum tour that included a STEM activity (STEM at Steam). There were two virtual STEM programs identified available to Hamilton youth (Codify Zone, Global Engineering Challenge). Codify Zone runs for one hour each week over the course of eight weeks. Global Engineering Challenge runs for six hours each week over a total of four weeks. However, the participant can choose whether to participate in all four weeks, or only certain weeks.

Cost/Incentives

The cost of each program varied, based on the length and number of sessions, materials provided to participants, and sponsors. Some of the programs were free. However, other program prices went up to $340 CAD each week for a 35 hour/week summer camp. Some of the incentives noted included access to McMaster research centers and labs, connecting with graduate level student mentors in STEM, professors and STEM experts, the opportunity to compete in a competition at the end of the program, eligibility to apply for scholarships, and a badge/certificate of completion.

Table 6. Competitor programs/workshops in Hamilton.

Program/Workshop	Location	Purpose	Incentive (Cost)
Venture Academy*	Hamilton (McMaster University)	Provides students with hands-on learning activities to encourage interest in STEM and post-secondary STEM education opportunities.	Students are able to interact with McMaster faculty and graduate students, and have access to McMaster research centres and labs ($320-340 per week)
First Lego League Robotics	Online (international) *Team currently registered in Hamilton.*	Engages students in mentor-based, research and robotics programs to build STEM skills and inspire innovation.	Ability to win an international competition (Various levels: $99-225 US to register a team; $395 US for lego pack, course materials and program guide)
Makerspace	Online (international)	Provides resources for teachers to have their students create their own knowledge through interactive, hands-on activities (e.g., media literacy, coding, robotics, 3D printing, creating inventions with recycled material).	N/A (Free for students; educators pay for programming)
GoCodeGirl	Hamilton	Aims to introduce girls to career possibilities available in the fields of technology, computing, and software engineering.	N/A (Free)
GoEngGirl	Hamilton	Aims to enhance girls' learning about engineering through a series of fun hands-on activities and exhibits.	N/A (Free)
STEM at STEAM	Hamilton	Provides a guided tour of the Hamilton STEAM and Technology Museum and a themed learning/hands-on activity.	"Hamilton Museum of Steam & Technology" badge ($10 for a single visit)
Codify Zone	Hamilton *Currently offering online summer camp.*	Aims to get youth interested in coding and computer science through engaging in animation and games online course-based learning.	Certificate of completion ($250 + HST for an 8-week camp; 1 hour per week)
Global Engineering Challenge*	Online	Provides the opportunity for youth to collaboratively design solutions to a real-world problem related to either engineering, sustainability, or mental health.	Opportunity to interact with experts in engineering ($60 per week or $200 for 4 weeks; 6 hours per week)

Plant Genetics Workshop*	Hamilton	Provides grade 12 students with the opportunity to perform molecular genetic experiments with plant DNA.	Students are able to interact with McMaster faculty and graduate students, and have access to McMaster labs (Free for students; arranged through the high school)
Digitally Lit	Hamilton	Aims to develop digital literacy and coding skills to help youth be prepared for the job market.	N/A
Let's Talk Science Outreach*	Hamilton	Aims to help youth in developing positive attitudes toward STEM, while building critical skills and gaining career awareness through interactive workshops.	N/A (Free)
Start Coding*	Hamilton	Provides STEM workshops/hackathons, focused on coding, to underprivileged pre-university youth.	N/A (Free)

*Program is associated with a university.

Competitor Programs/Workshops Outside Hamilton

Our search of the literature identified 9 STEM programs/workshops for youth from K-12 or specific to high school students, outside the Hamilton area, but focused on other surrounding cities such as Toronto, Mississauga, and Waterloo (*Table 7*).

Program Target Demographics

Many of the programs offered outside Hamilton serve high school students, but the majority also had programming for elementary and middle-school students as well (Mathnasium, Pathways, Brick Works Academy, Competitive Kids STEM). Certain programs did not cater to all high school students, but programming was specific to grades 9-10 (Brick Works Academy, Competitive Kids STEM), or grades 10-12 (Catalyst Summer Program, UTM Math Circles). One program indicated programming was specifically for male high school students only (1-Up), while other programs were open to all genders. Most of the programs were described as additional opportunities for students interested in STEM-learning, but other programs served a tutoring-based program helping struggling students (Mathnasium, Science Senior Scholars).

Program Purpose/Activities

Competitor programs outside of Hamilton covered a wide range of topics including math, coding, environmental science and even developing soft-skills. Some programs were specific to a single area of STEM (Mathnasium, Young Environmental Science Alliance, UTM Math Circles), while others spanned multiple domains within STEM (Pathways, Science Senior Scholars, Competitive Kids STEM, Catalyst Summer Program, Brick Works Academy). One program, in

particular, placed great emphasis on developing student soft skills and was based in Catholic teachings (1-Up).

Program Schedule/Length

The programs/workshops we identified in our search varied considerably in length. A few programs extended the length of a semester (Pathways, 1-Up), while others were only 6-10 weeks (Competitive Kids STEM, UTM Math Circles). Shorter programming ranged from single-day workshops to 2-week camps (Catalyst Summer Program). One program was entirely based on student-need, where students could engage in as many or as few weekly sessions to support their STEM-learning (Mathnasium).

Cost/Incentives

The cost of each program varied based on the level of programming (elementary versus high school students), weekly frequency, and type of programming (weekly sessions versus summer program). Many programs offered their STEM-learning services free of charge (Young Environmental Science Alliance, Pathways, Science Senior Scholars, UTM Math Circles). Programs that offered weekly sessions had prices ranging from $125-350 for approximately one semester of programming. One-off programming such as workshops or two-week long summer camps ranged from $20-620. Many of the programs did not offer additional incentives for students, aside from the engaging learning opportunity. Programs using university resources indicated opportunities to network with faculty (Catalyst Summer Program). One program offered food (UTM Math Circles) and a competition-based program indicated students have the opportunity to win prizes (Competitive Kids STEM).

Table 7. Competitor programs/workshops outside Hamilton.

Program/Workshops	Location	Purpose	Incentive (Cost)
Mathnasium	Ancaster	Provide students with math tutoring and enrichment service.	Improved grades (Unknown)
Young Environmental Science (YES) Alliance	Burlington	Program is a hands-on, active, and immersive program that is geared towards students who are passionate about nature, interested in environmental science, or aspiring to a career spent outdoors.	N/A (Free)
Pathways	Halton Region	Provides students with real-world learning, curriculum integration, and cross-curricular literacy and numeracy. The program includes specialized high school courses and apprenticeship opportunities.	Graduation Recognition (Free)
Science Senior Scholars	Mississauga	The program aims to help students reinforce their scientific foundations and sharpen their skills by providing individual assistance to struggling students.	N/A (Free)

UTM Math Circles *	University of Mississauga (Mathematics)	Students work informally with professors and members of the department to build problem-solving skills, address real-world problems, and explore interesting puzzles.	Food provided (Free)
Competitive Kids STEM	Toronto	Students have the opportunity to enroll in online courses teaching math skills, preparation for math contests, coding in Python, and Engineering concepts. Students also can participate in math competitions, workshops, and activity clubs.	Competition Prizes (Ranges from $250-350 for courses, $20 per workshop)
1-Up	Toronto	Program is founded in Catholicism and teaches students life skills including goal setting, building relationships, career exploration, university preparation, and more.	N/A ($125 per semester, $100 4-day summer camp)
Catalyst Summer Program *	University of Waterloo (Engineering)	Students use STEM technical and entrepreneurial skills to create solutions for community-centered projects.	Experiential opportunities and networking with University faculty ($620)
Brick Works Academy	Waterloo Region	Based on grade-level students enroll in programs aimed at enhancing problem-solving abilities, coding skills, and robotic concepts. Program offerings include app development, music production, online animation, Lego Online, Sketching and Dungeons, and Dragons.	N/A (Ranges from $89-149)

*Program is associated with a university.

STEM Competitions in the Hamilton Area

Our search of the literature identified seven STEM competitions for youth between 14-18, within the Hamilton area or available to youth in Hamilton online (*Table 8*). Many competitions were not limited to the Hamilton area, some were also open to students across Canada or around the world.

Target Demographics

Although all competitions targeted high school (Grades 9-12, ages 14-18 years) students, many were offered to other demographics based on their educational stage in school. Of these identified competitors, three competitions are only offered to only high school students (grades 9-12):

- FIRST Robotics at McMaster
- Annual CIHR Canadian National Brain Bee hosted by McMaster
- Canadian Open Mathematics Challenge

Three competitions are offered to middle-school/high school students (grades 7-12):

- Bay Area Science and Engineering Fair (BASEF)
- Waterloo Math Contests

One competition is offered to elementary/high school students (grades 1-12):

- Kangaroo Math

One competition is offered to elementary/high school/undergraduate students (grades 1-12):

- Vex Competitions

Purpose and Activities

All competitor competitions work to develop students' STEM skills and grow their interest in STEM through exposure to a wide range of activities. Some programs challenge students on a broad range of STEM topics such as science, technology, and math (BASEF, Kangaroo Math, Waterloo Math Contests, Canadian Open Mathematics Challenge), while others have a more niche focus such as robotics, coding, and neuroscience (FIRST Robotics, Vex Competitions, Annual CIHR Canadian National Brain Bee). Math is offered by three different organizations (Kangaroo Math, Waterloo Math Contests, Canadian Open Mathematics Challenge) and is the most popular competition activity for youth in the Hamilton area, closely followed by robotics (FIRST Robotics, Vex Competitions).

Schedule/Length

The length of the competitions generally varied depending on the type of program activity. The science and technology competitions where participants needed time to work collaboratively and build their projects lasted two to three days (FIRST Robotics, BASEF, Vex Competitions). Other STEM contests where participants took an exam lasted 1-3 hours (Kangaroo Math, Waterloo Math Contests, Annual CIHR Canadian National Brain Bee, Canadian Open Mathematics Challenge).

Cost/Incentives

The cost of each program varied, based on the length, materials provided to participants, and sponsors. Two competitions were free of charge (BASEF, Annual CIHR Canadian National Brain Bee). The three math competitions ranged from $2-25 (Kangaroo Math, Waterloo Math Contests, Canadian Open Mathematics Challenge). The two robotics competitions ranged from $100-6000 per team registration (FIRST Robotics, Vex Competitions). All competitions had incentives for participation including scholarships, cash prizes, certificates, trips, trophies, and the opportunity to compete at a national or international level.

Table 8. STEM competitions available to high school students in the Hamilton-area.

Competition	Location	Purpose	Incentive (Cost)
FIRST Robotics Canada at McMaster	Canada-wide	Students work as a team to raise funds, develop a brand, and design and build a robot to	One of ten $15,000 scholarships for

		perform certain tasks judged against competitor teams.	admission into McMaster Faculty of Engineering programs ($5,000 - $6,000 for team registration, a robot kit of parts, and event participation)
Bay Area Science and Engineering Fair (BASEF)	Hamilton, Halton Region, Haldimand County, Norfolk County, County of Brant and Six Nations	Students have the opportunity to showcase their innovations and discoveries at an annual fair for the exhibition and competition of STEM projects.	Over $300,000 in cash, trips, and scholarships are awarded every year (Free)
Vex Competitions	International	Students are tasked with designing and building a robot to play against other teams in a game-based engineering challenge. Classroom STEM concepts are put to the test as students learn lifelong skills in teamwork, leadership, communications, and more.	Competition awards ($100 - $2500 for team registration depending on competition)
Kangaroo Math	Canada-wide	Elementary and high school math competitions designed to introduce youngsters to math challenges in a fun and enjoyable way, thus inspiring their further interest and advancement in mathematics	Competition ribbons, medals, plaques ($17 early bird/ $25 normal)
Waterloo Math Contests	International	High school math competitions designed to help to inspire the next generation of students to develop an interest in and love for mathematics and computer science.	Individual and team awards including certificates, medals, name on Canadian honours roll, plaque and prize of $200 - 500 ($2 - 16 depending on contest)
Annual CIHR Canadian National Brain Bee hosted by McMaster	Hamilton-Halton and surrounding area	Competition modeled on spelling bee format on brain and neuroscience facts.	Competition prizes, name engraved on on a traveling trophy plaque, represent Hamilton at national level brain bee (Free)
Canadian Open Mathematics Challenge	Canada-wide	High school math competition promoting interest in math and problem-solving skills.	Competition prizes, awards, invitations to math camps, represent Canada at international competitions ($25)

*Competition not available to high school students.

STEM Conferences

Survey participants identified two STEM conferences designed for youth currently in high school and university.

Catalyst Grade 11 Girls Conference

The Catalyst Grade 11 Girls Conference is a yearly three-day conference held in the University of Waterloo that aims to engage female students currently in grade 11. The conference aims to provide an opportunity for participants to learn about engineering as a career and gain insight into what university is like. The workshops are facilitated by professional engineers and culminates with a design challenge to apply knowledge gained during the conference about the engineering design cycle. For this conference, participants also have an opportunity to experience residence life as they stay in residence for the duration of the conference. The cost of the program is all-inclusive (e.g. covers accommodation, meals, program, etc.) and is approximately $250.

HOSA - Future Health Professionals Canada Spring Leadership Conference (SLC)

The Spring Leadership Conference (SLC) hosted by HOSA Canada is an annual two-day conference held in Toronto that targets high school and university students. It is Canada's largest health science conference involving technical and soft skills challenges. The conference follows a hands-on and lecture style approach that is delivered by medical students and partner organizations including universities / colleges, corporations and nonprofits. The conference covers a multitude of topics ranging from artificial intelligence to healthcare advocacy to resume critiquing. The cost for the conference varies between high school students ($65) and university students ($85).

Interest in STEM

STEM Areas of Interest to High School Students

In the high school student survey, high school students reported they were mostly interested in the areas of Biology (45%), Engineering (42%) and Mathematics (40%)(*Table 9*).

Table 9. STEM area(s) high school students were interested in.

STEM Area	Percentage (%)
Biology	45
Engineering	42
Mathematics	40
Chemistry	37
Psychology	37

Physics	35
Computer Science	29
Life Science	26
Environmental Science	10
Other: Coding, Medicine, Anthropology, Astrophysics, Mechatronics	10
N/A (Not interested in STEM areas)	5

STEM Topics High School Students were Interested in Learning More About

In the high school student survey, 22 respondents who had previously engaged in STEM extracurriculars provided information about STEM topics they would have liked to learn more about (*Table 10*). The top three topics were coding (32%), engineering (27%), and physics (9%).

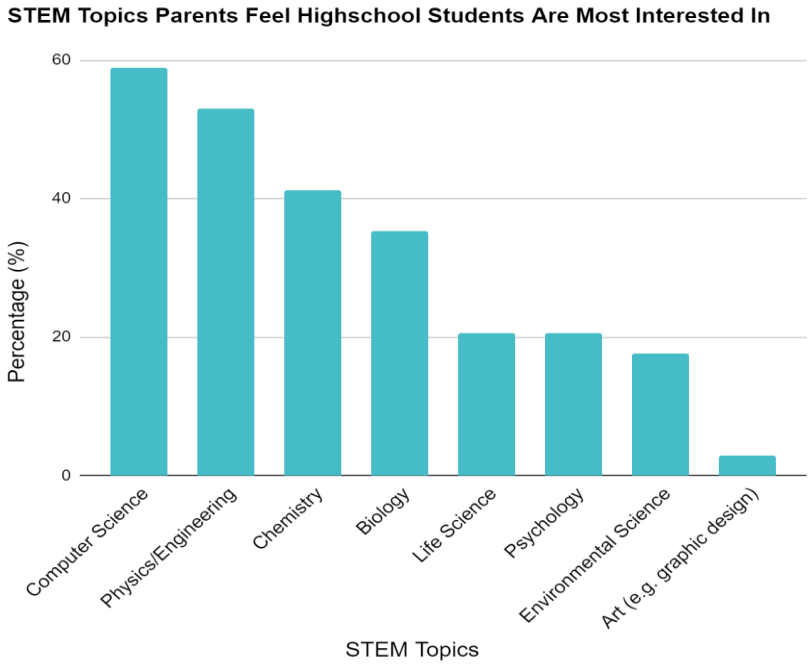
Table 10. STEM topics high school students would have liked to learn more about.

STEM Topics	**Percentage (%)**
Coding (Both generally and across languages)	32
Engineering (Including Biomedical Engineering, Mechanical Engineering, and Environmental Engineering)	27
Physics	9
Medical Biophysics	5
Chemistry	5
Automechanics	5
Software	5
Computer Science (Including 3D models, websites and apps)	5
Computing	5
Psychology	5
Math	5
Human Physiology	5
Business Leadership in STEM	5
More about different STEM areas	5

Parents' Perceptions of their Child's Interest in STEM

From the parent survey, parents reported that their children were most interested in learning about computer science (59%) and physics/engineering (53%) (*Figure 1*).

Figure 1. STEM topics parents feel high school students are most interested in.



Interest in Getting an Education/Job in STEM

Based on the high school student survey, high school students reported being somewhat interested in getting an education and/or job in STEM, with a calculated weighted average of 2.35. However, from the parent survey, parents of high school students thought their children were not interested in getting a job in STEM, with a weighted average of 1.53. Based on the STEM student survey, the majority of first-year post-secondary STEM students planned on pursuing a career in STEM (76%), rather than deciding against this career pathway (12%) or being unsure (12%). Post-secondary STEM students largely responded that they aimed to either enroll in graduate school (40%) or start work (32%) after completing their undergraduate program. Only 16% of first-year STEM students indicated that they hoped to attend professional school (e.g. medical, dental, pharmacy, optometry schools), while 12% of students were unsure of their plans for the future.

Level of Preparedness for Post-Secondary STEM Education

STEM Students' Perceptions of their Level of Preparedness

Based on the first-year STEM student survey, more than half of the STEM students (64%) indicated that they felt high school adequately prepared them for the academic expectations of post-secondary education.

Professors' Perceptions of First-Year Students' Level of Preparedness

From the professor interviews, half of the professors interviewed indicated that first-year students from their respective disciplines were not prepared for university (n=4). One professor specified that students were unprepared with regards to their technical skills (n=1), such as coding and laboratory skills. The remaining participants mentioned there are mixed levels of preparedness among first-year students (n=2), with a subset of students being well-prepared and high-performing, and the remaining being unprepared (n=2). However, it was noted that specific programs might be biased in terms of their students' preparedness, because they only accept students with exceptional high school grades (n=1).

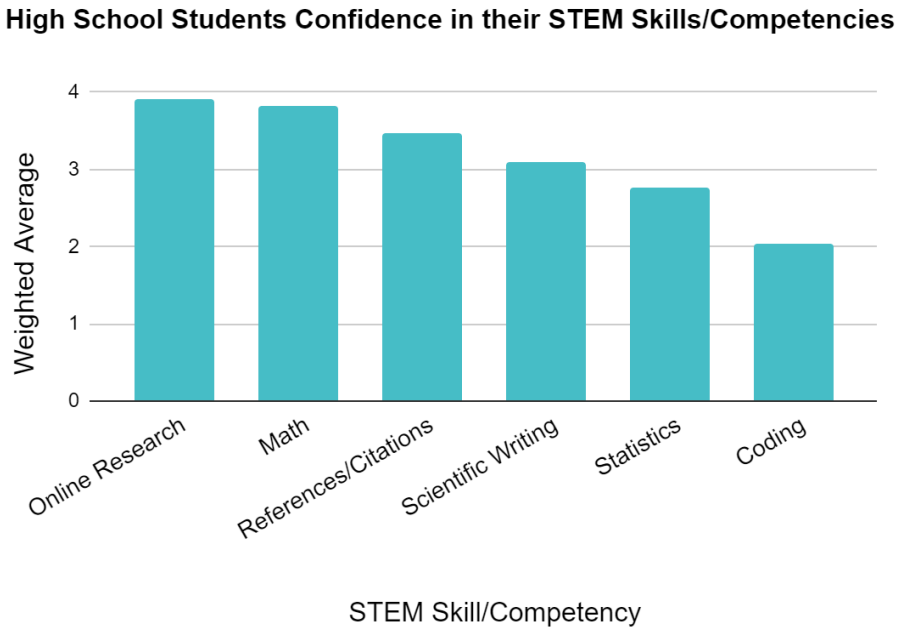
Professors emphasized the new expectations students face while transitioning from high school to university (n=2), and that students likely find this shocking or surprising (n=1). One professor noted that often students may be prepared in terms of their knowledge of the high school-level content, but unprepared to learn new information, content, or ways of thinking (n=1). Another professor indicated that students who have strong math skills tend to do better within their program (n=1). Professors also noted that not only would students benefit from being better prepared for the university, but also having a better understanding of their university program's content (n=1) and increasing their insight into STEM careers (n=1). One professor elaborated further that a better understanding of prospective careers may help to increase female representation in the field (n=1). One professor indicated they would like the students to know more before entering the program in first-year (n=1).

Student Strengths and Skill Gaps

Confidence in STEM Skills/Competencies

From the high school student survey, high school students were comfortable with online research (3.92), math (3.82), and completing references/in-text citations (3.48), and less comfortable with statistics (2.77) and coding (2.03) (*Figure 2*).

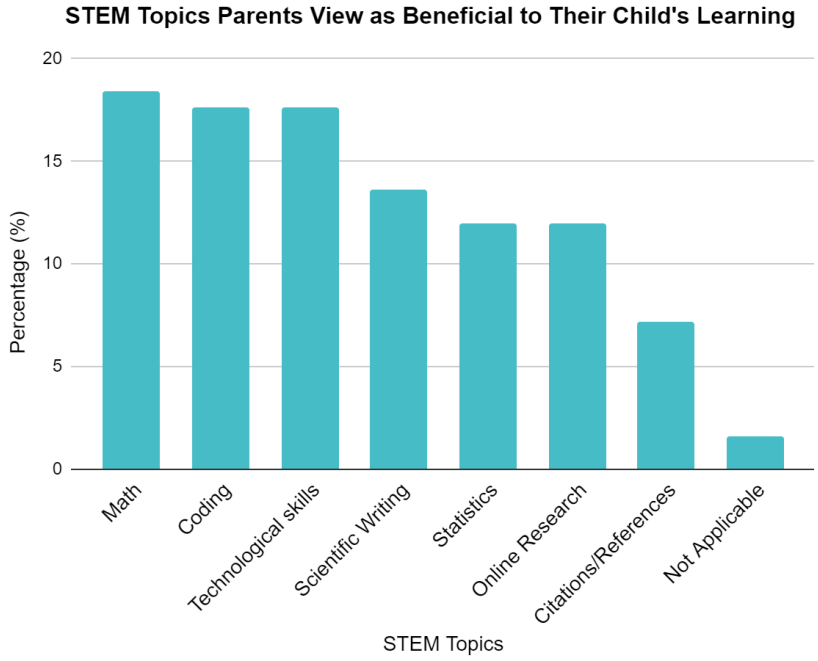
Figure 2. High school students' confidence in STEM skills or competencies.



STEM Topics Parents Feel their Child Would Benefit from Learning Prior to Post-Secondary Education

Based on the parent survey, parents indicated that math (18%), coding (18%), and software use (18%) were the STEM topics their children would benefit most from learning prior to entering post-secondary education (*Figure 3*).

Figure 3. STEM topics parents view as beneficial to their child's learning.



Hard Skill Gaps

The first-year student survey revealed that the majority of first-year STEM students (80%) found certain course-related or technical skills difficult within their first year. Nearly half of the students chose math (48%) and coding (48%) as particularly challenging hard skills, while statistics (16%) and learning how to use software (12%) were not as challenging (*Figure 4*). The top topics that were deemed challenging were all math-related: math (44%), calculus (20%), writing proofs (16%), and calculations (16%)(*Table 11*).

Figure 4. Hard skills first-year STEM students found difficult.

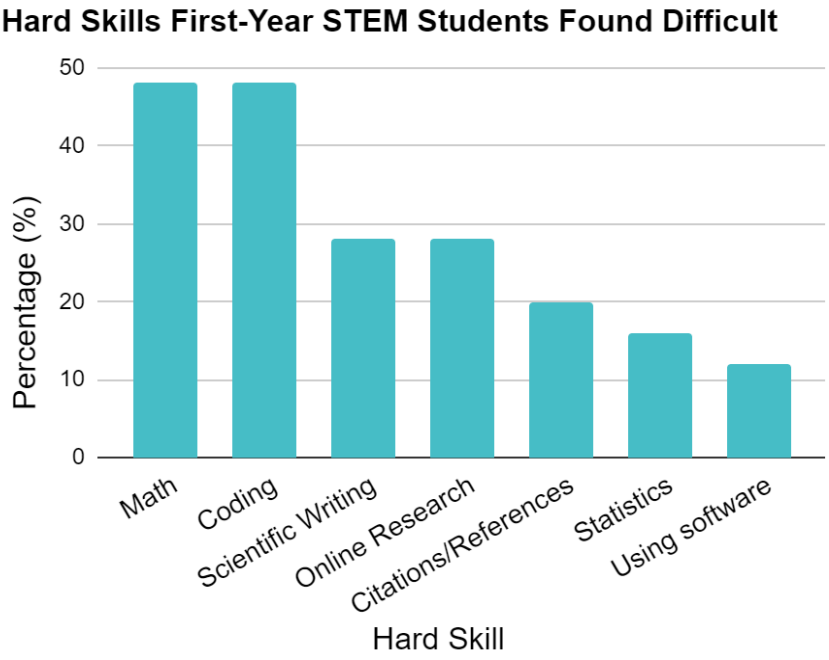
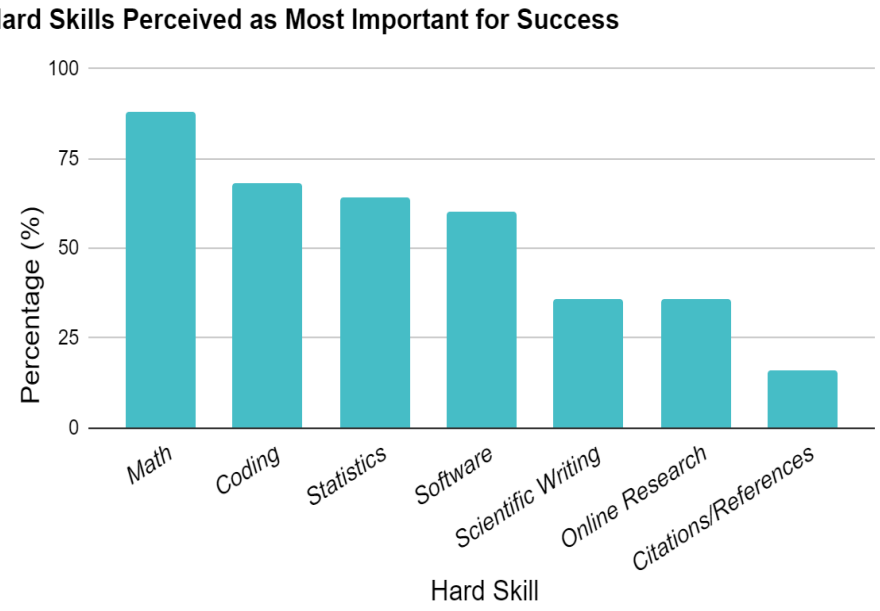


Table 11. STEM topics first-year STEM students reported experiencing difficulty with.

STEM Topics	Percentage (%)
Math	44
Calculus	20
Writing Proofs	16
Calculations	16
Computer Science	8
Chemistry	8
Physics	4
Linear Algebra	4
Trigonometry	4

In the STEM student surveys, a majority of students identified math (88%), coding (68%), and statistics (64%) as hard skills necessary for success in their program (*Figure 5*).

Figure 5. Hard skills first-year STEM students perceived as most important for success.



In the interviews, professors most commonly described first-year students having difficulty with basic mathematics concepts and skills (n=3) and coding (n=2). Other technical skills the professors indicated students were having difficulties with included unit analysis (i.e., dimensional analysis), programming, logic, design thinking, laboratory skills, using 3D printers and computer-aided design software, reading and interpreting primary research articles, and general technical skills. It was also noted that the grade 12 high school chemistry curriculum is quite large and high school classes rarely have an opportunity to finish all of the units, making them less prepared in terms of the chemistry topics that will be covered in first-year university chemistry programs.

Soft Skill Gaps

From the high school student survey, the soft skills that students reported most important to improve on for their personal success were: time management (66%), stress management (55%), focus (42%), and oral presentation skills (42%) (*Table 12*).

Table 12. Soft skills high school students feel they need to improve on for success in post-secondary education/ the future.

Soft Skills	Percentage (%)	Soft Skills (continued)	Percentage (%)
Time management	66	Creativity	19
Stress management	55	Organization	19
Focus	42	Cooperation	18
Oral presentation skills	42	Writing	15

Studying	35	Interpersonal skills	13
Decision-making	32	Punctuality	13
Leadership	31	Accountability	13
Note-taking	31	Self-directed learning	13
Group work	29	Listening	11
Networking	26	Other: Memorization	2
Problem solving	21		

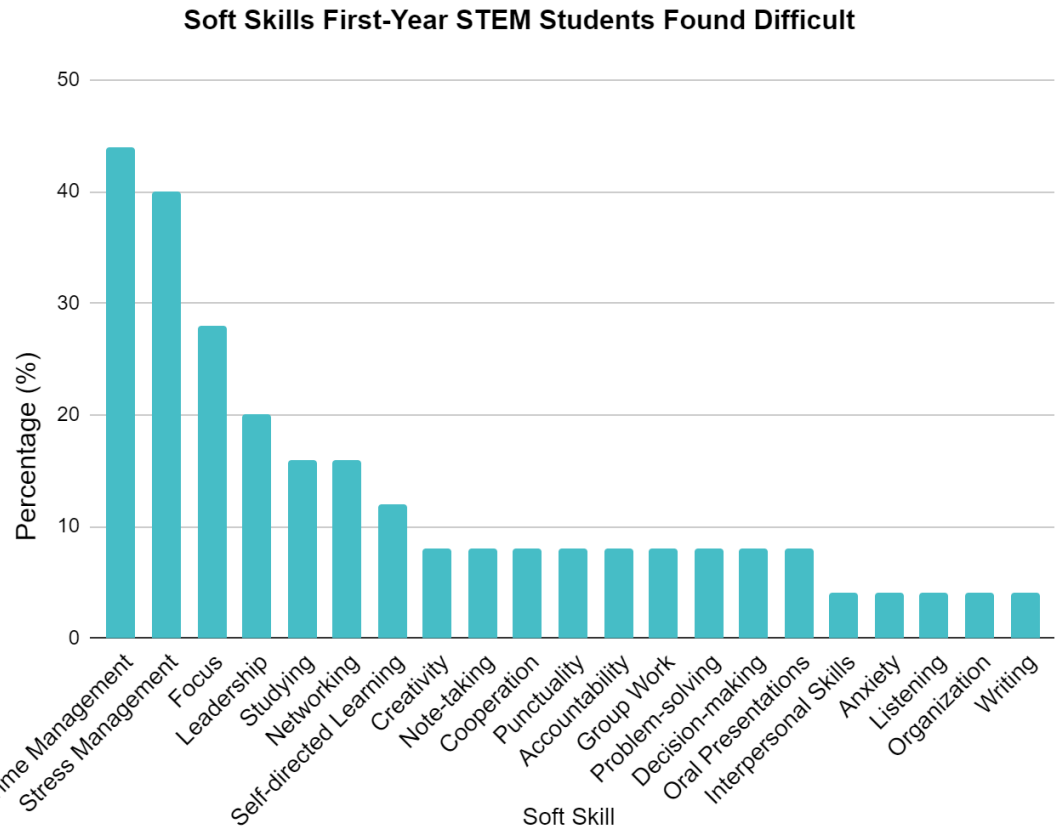
Based on the parent survey, the majority of parent respondents thought time management (71%), oral presentation skills (53%), and organization (53%) were skills that their child could improve upon most to increase their success in post-secondary education (*Table 13*).

Table 13. Soft skills parents of high school students feel their children need to improve on for success in post-secondary education/ the future.

Soft Skill	Percentage (%)	Soft Skill (continued)	Percentage (%)
Time management	71	Problem solving	35
Oral presentation skills	53	Decision-making	35
Organization	53	Punctuality	32
Studying	50	Stress management	29
Note-taking	50	Cooperation	26
Writing	50	Self-directed learning	26
Leadership	44	Listening	26
Focus	44	Creativity	24
Networking	41	Group work	18
Interpersonal skills	38		

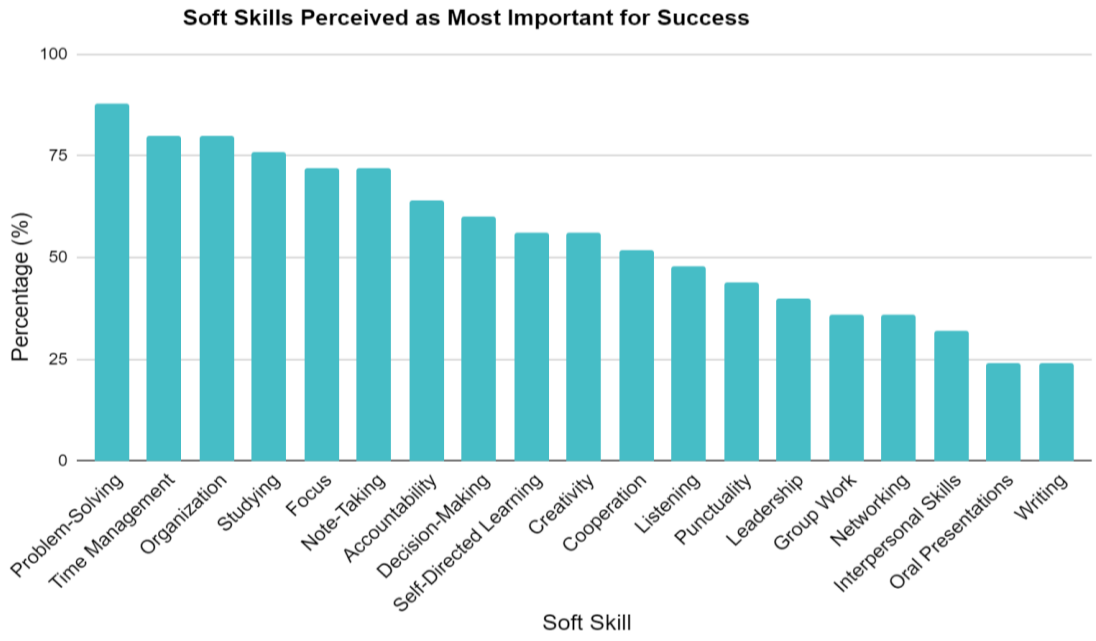
In the first-year student survey, STEM students also indicated that they experienced difficulty with specific soft skills. The top soft skills indicated as challenging for STEM students were time management (44%), stress management (40%), and focus (28%) (*Figure 6*).

Figure 6. Soft skills first-year STEM students found difficult in their first year of post-secondary.



From the STEM student survey, the soft skills perceived as most important for success in post-secondary STEM education were problem-solving (88%), time management (80%), and organization (80%) (*Figure 7*).

Figure 7. Soft skills first-year STEM students perceived as most important for success.



In the professor interviews, six professors (n=6) indicated that many first-year university STEM students experienced difficulties with the necessary soft skills to succeed in university STEM, across programs. Each professor interviewed highlighted the specific soft skills that they have observed students lack, offering insight into how students can better prepare for their first year of university. These skills fall into the three broad categories: adjusting to new expectations, interpersonal skills, and study habits (*Table 14*). In terms of adjusting to new expectations, professors emphasized the need for independence, adaptability, creative problem-solving, initiative, resiliency, and motivation. The main interpersonal skills described by professors as lacking were communication, confidence, teamwork, and empathy. The study habits emphasized by professors were time management and grit.

Table 14. Soft skills lacking in first-year STEM students as indicated by professors.

Skill	***# of Mentions***	***Description***	***Illustrative Quote***
ADJUSTING TO NEW EXPECTATIONS			
Independence	2	Learning to independently manage their personal and academic responsibilities (e.g., chores, studying, assignments, monitoring grades).	"For a lot of students, you know, you move out from home, so you even don't have like the support of your parents to, you know kind of, for lack of a better word, kind of harking on you to make sure you do your homework and everything like that. So that's all left to you to do, but you're also

			left trying to figure out how to live on your own and like discovering who you are as person and everything like that."
Adaptability	2	Adapting to self-directed learning, complex problem-solving, and broader assessment expectations (i.e., moving beyond questions with "right" or "wrong" answers to more abstract assessments).	"I think it can be a bit of an identity crisis for them in some ways, where all of a sudden they're having these experiences that are not matching on to the experiences they had in high school, where they were always succeeding and always told that they were great students... And it's not that they're not great students, but maybe they just haven't figured out how to adapt to a different learning environment of university versus high school."
Creative Problem-solving	2	Assessing problems from multiple perspectives using abstract thinking and designing innovative solutions.	"[Students] don't like uncertainty. And that's a major barrier to creativity and to risk taking and to a whole lot of other sorts of workplace and behaviors and frankly, skills."
Initiative	2	Taking initiative in self-directed learning, understanding tasks and assessments, and monitoring academic performance and integrity.	"With initiative in the classroom, I think students are coming into university, really having been told what to do every step of the way in their education."
Resiliency	2	Learning to effectively cope with the academic and personal challenges of first-year using the tools and resources available. Establishing positive coping strategies.	"There's some resilience issues. I think that often, so if I use my, our program as an example, our kind of cut off average to get into our program is somewhere between 89 and 90%. So you have usually around 200 students coming into our program that have been told that basically they're A+ students their entire education career throughout high school and then they come to university and that, you know, 89 up to 100% is now...some people might fail some courses in their first year and some are still getting 100%."

Motivation	1	Difficulty maintaining engagement with studies without parents or teachers pushing them. Students are less driven by curiosity or desire to learn new things.	"I think a major problem is dramatic decrease in motivation, which evidence itself in basically missing classes. So, what is really hard to do is maintain certain level of motivation."
INTERPERSONAL SKILLS			
Communication	2	Building adequate oral communication skills through group work and explaining concepts to others, condensing information and articulating the main takeaways, and developing in-depth presentations.	"Learning how to present your results is a challenge. Both from the standpoint of feeling confident standing up in front of people… [and] having a clear idea of how to present a scientific story rather than just tell all the data they collected."
Confidence	2	Developing the confidence to participate in class, ask questions, and present ideas in front of peers and professors.	"With every student, learning how to present your results is a challenge. Both from a from the standpoint of feeling confident standing up in front of people. Presenting data, especially when presenting data after having done three or four months worth of research and then standing up in front of all the PhD students and students that are professors can feel daunting. So they need some extra help there."
Teamwork	2	Ability to effectively collaborate with peers on academic assignments and troubleshoot independently if issues arise (i.e., instead of involving the professor).	"In engineering teamwork is very important. I mean, it's kind of set up that they can't really, very few students could make it through without strong support from their teams. And everybody hears stories about how all the work was done by one person and it was done the night before."
Empathy	1	Having a strong sense of empathy in order to design products that work for all types of users rather than focusing on their own personal preferences.	"The goal is not to have a product that is capable of doing something. The goal is to have a product which people can use to do something which people find useful."
STUDY HABITS			

Grit	2	Consistently practicing and building upon foundational skills and basic concepts in order to improve their ability to navigate more complex problems.	"The problem is that at this level math is not interesting. I mean, we just spent half a day working on fractions. And knowing that this is not really the best thing you can do now. But on the other hand, it's understanding that unless you want to do technical things you cannot build."
Time Management	1	Learning to map out due dates and plan to complete tasks ahead of time, rather than procrastinating, studying last minute, asking for accommodations, and/or not meeting deadlines.	"For instance, on the first day of classes, students already know dates for all of their tests. Right? What is a good thing to do? Buy a three-month calendar and put all your tests into a calendar. And then you'll see that for instance, some weeks are easy, no tests, but this in some weeks you might have two or three tests, but you know, a week before or 10 days before. Don't leave things for the last minute."

Preparation for Post-Secondary STEM Education

Suggestions to Assist Students in Preparing for Post-Secondary STEM

Based on the interviews, professors suggested learning and practicing a combination of soft skills and technical skills to help students better prepare for university. They indicated that students should have greater responsibility over their academic behaviour (n=1), engage in real-world problem solving (n=1), increase time management and organization skills (n=1), engage in extracurricular activities (e.g., peer tutoring, protests, mentorship from upper year students), and take the time to review course materials at home (n=1). As one professor stated, "I want students to ask me a conceptual or technical question about the new stuff I'm doing, not about algebra from grade eight. So, in many ways, especially this year when lots of instruction was done more or less through self-discipline, you have to practice at home." Some professors elaborated that students should specifically review their technical knowledge of math (e.g. geometrical proofs) (n=2), organic chemistry (n=1), and software understanding (n=1). One professor noted that it is critical for students to focus on the fundamentals of STEM. Rather than just following a process, they should be taught and understand why they perform each step, so that when they have to solve problems that they have not previously seen, they have the foundational tools to do so (n=1). Another professor mentioned that students' performance may depend on their attitudes towards learning, whether it is driven by grades (n=2) versus a passion/interest towards learning (n=1), so it may be important for students to have an internal motivation to learn. Additionally, one professor suggested that it would be valuable to ask students which course units they did not cover in high school and teach those (as they are often

unable to get through the full high school curriculum, and the university courses build on this; n=1).

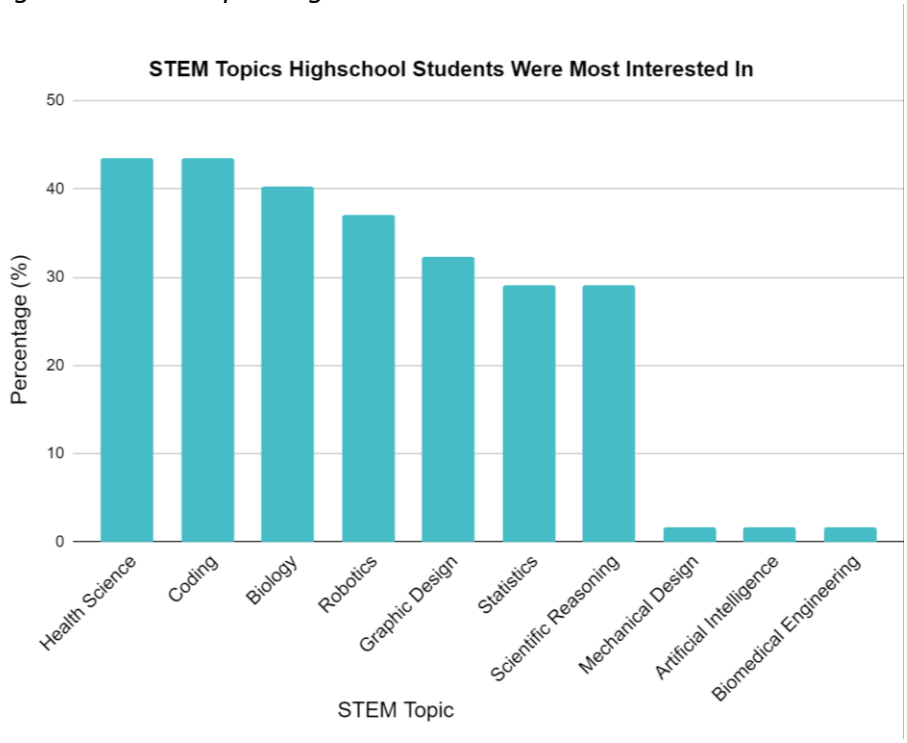
Other professors noted ways that professors and/or the university can assist students. One professor considered that they need to recognize that students come to university with different skill sets and work with those (n=1). Another stated that the university needs to better communicate its programs' vision and attract a diverse group of STEM students to portray the field as more than just 'technology' and create a holistic depiction (n=1): **"**Engineers as leaders and engineers as changemakers and the impact of society are seen to be really motivating factors for women coming into engineering."

Preferences for High School-Level Extracurricular STEM Programming

Interest in a High School-Level STEM Program

In the high school survey, students were moderately interested in an extracurricular program that taught hands-on STEM skills, with a weighted average of 3.05. High school students were slightly more interested in a program that helped them to better prepare for post-secondary education (3.55). High school students were most commonly interested in learning about the following topics in a high school level STEM program: health science (44%), coding (44%), and biology (40%) (*Figure 8*).

Figure 8. STEM Topics High School Students Were Most Interested In.



In the parent survey, parents were interested in an extracurricular program that taught hands-on STEM skills and soft-skills in preparation for university (62%). Parents reported that the

STEM topics their children were interested in learning were robotics (26%), coding (20%), and graphic design (13%) (*Table 15*).

Table 15. STEM topics parents reported their high school children are interested in.

STEM Topic	Percentage (%)
Robotics	26
Coding	20
Graphic Design	13
Health Science	12
Scientific Reasoning	11
Biology	10
Statistics	6
Physics	1
Business/Finance	1

Scheduling/Location

Based on the high school student survey, the majority of high school students (73%) said that their schedules would be able to accommodate a two-hour per week STEM program. Most students preferred that a program take place during the weekdays (i.e., Monday to Friday; 71%), rather than on the weekends. 69% of high school students endorsed that they would be willing to come to McMaster University to participate in a program of this nature. From the parent survey, half of the parents (50%) indicated they thought their child would be willing to go to McMaster University to participate in a STEM extra-curricular program, while 44% were unsure of their child's willingness to travel to McMaster. Only 6% respondents indicated their child would not be willing to participate in programming at McMaster University.

Willingness to Pay to Participate

From the high school student survey, the majority of students indicated that they would be willing to pay for online programming (82%). Based on the parent survey, the majority of parents were willing to pay for a STEM extracurricular for their child (65%). Of the parent respondents willing to pay for their children to participate (n=22), 45% were willing to pay between $150-$200 and 41% were willing to pay less than $150 for their child to participate in a two hour per week, ten-week program. The remaining respondents were willing to pay between $200-$250 (5%) or over $250 (9%).

Preferred Program Format

Based on the high school student survey, in-person programming (61%) or a blended format of online and in-person programming (60%) was preferred for most high school students, whereas others preferred online self-paced courses (47%) and online live training (18%) options. From the parent survey, the majority of parents also indicated that their child would be willing to participate in online programming (74%). With regards to program format, the majority of parents indicated their child would prefer blended learning (53%), while in-person delivery was the second preference (21%). Parents who indicated their child would prefer online learning exclusively, indicated synchronous sessions (live) (18%) were more desirable than self-paced courses (9%).

Program Design

Professors were asked to reflect on the topics/areas they felt would be most important to include in a STEM learning program for high school students. One professor thought that it was critical for students to be exposed to a broad range of STEM topics/areas and have the opportunity to engage with these topics/areas in a hands-on manner. Another professor stressed the need for students to have the opportunity to explore their interests and find what they like before applying to specific university programs. It was thought that a flexible, learner-centered inquiry approach (n=2) with opportunities for experiential learning (n=1) would be the best program design. A learner-centered inquiry approach places an emphasis on students' abilities, interests, and learning styles. This method of teaching acknowledges the student's voice as a key component to learning and has the goal of putting the responsibility for learning in their hands. For example, extracurriculars with a fun, hands-on STEM-based approach provides students with the opportunity to see how intriguing these fields can be outside of the rigid lecture-style learning in primary/ secondary school classrooms. Introducing students to new concepts and establishing a culture where their ideas are explored, tested, and discussed can move students beyond their initial curiosity in STEM and to a path of regular inquiry.

The professors most commonly identified teaching logic (n=4) and mathematics (especially discrete math and math in conjunction with computer science and/or bioinformatics; n=4) as important components of STEM programming for high school students. As one professor noted, "It's less about the language that you learn and more about the logic of coding." Other technical skills professors thought would be most important to include were design thinking (n=2), writing skills (n=2; learning to be concise and precise in their writing), reading skills (n=1), physics (n=1), and coding (n=1). Soft skills professors thought would be most important to focus on included empathy (in terms of making designs for diverse populations of individuals with different needs; n=1), collaboration (n=1), teamwork (n=1), and conflict resolution (n=1). It was also acknowledged that math and STEM programming should be made as fun and exciting for the students as possible to keep them engaged (n=1).

Conclusions

Competitor Programs/Workshops in STEM

- Many high school students (45%) and first-year STEM students (64%) had previously participated in a STEM program.
- The majority of the parents (71%) indicated that their child had participated in STEM programs.
- There are 11 active STEM programs/workshops that serve high school students in Hamilton, but most programs do not accept students in grades 11-12.
- Most of these STEM programs covered general topics in STEM while some focused on more specific topics like coding.
- There are 9 additional STEM programs/workshops in the cities surrounding Hamilton, 7 STEM competitions, and 2 conferences that serve high school students within Hamilton and the surrounding area.

Interest in STEM

- In the high school and parent surveys, participants reported that high school students are most interested in the following STEM disciplines: physics/engineering, biology, engineering, and mathematics. High school students expressed an interest in learning more about coding.
- High school students' interest in getting an education or job within STEM was moderate to low.
- From the first-year STEM student survey, 76% of university students plan on pursuing a career in STEM after graduating.

Level of Preparedness for Post-Secondary STEM Education

- The majority of first-year STEM students (64%) thought that their high school education prepared them well for post-secondary school.
- However, half of the STEM professors interviewed noted that students were unprepared for university.
- Professors interviewed indicated that first-year STEM students had difficulties transitioning to university, facing new expectations, and were unable to adapt to new information or ways of thinking.

Student Strengths and Skill Gaps

- High school students were most comfortable with conducting online research, math, and referencing/citations, but least comfortable with statistics and coding.
- First-year STEM students had difficulties with math, coding, scientific writing, research and referencing/citations.

- Parents thought their child would benefit most from learning math, coding, and technical software skills.
- Professors indicated that first-year STEM students had difficulties with math and coding and a range of soft skills.
- Both high school students and parents agreed that time-management is essential for post-secondary success.

Preparation for Post-Secondary STEM Education

- Professors noted that first-year STEM students should learn how to study effectively in university to be successful (e.g. doing their homework, managing their time and being more organized).
- Professors indicated that first-year STEM students should review concepts learned during high school including math, organic chemistry and relevant software.

Preferences for High School-Level STEM Programming

- Both high school students and parents of high school students were interested in STEM programming for high school students.
- High school students were interested in learning health sciences, coding and biology, while parents thought that their children would be most interested in learning robotics and coding.
- Professors noted that STEM programs should incorporate logic, mathematics, design thinking, and writing into their curriculum.
- The majority of high school students (76%) indicated that their current schedules would accommodate a two-hour per week program and preferred it to be on a weekday (71%) and either in-person or a combination of in-person and online.
- Half of the parents surveyed were willing to pay $150-200 for their child to participate.

Recommendations

#1: Mathstronauts should focus their programming on technical skills that are most needed for success in post-secondary STEM education.
a) Coding
b) Foundational and advanced math skills

We recommend Mathstronauts' new high school program focus on supporting coding and foundational and advanced math skills to ensure student success in post-secondary STEM education. Research findings indicate that there is a high demand and interest in coding and programming among high school students. From survey responses, coding was the most

popular (32%) technical skill students indicated they would like to learn more about and the second most popular (18%) skill parents felt their child would benefit from learning more about. Additionally, more than half of parents felt their child was most interested in computer science. However, student confidence with this skill was relatively low (weighted average of 2.03).

The introduction of an extracurricular program can encourage participation in computer science as well as better prepare students for the technical demands of post-secondary STEM education. Based on surveying first-year university student responses, coding was found to be the second most difficult technical skill and second most important skill for success in university. There is currently no standardized computer science curriculum for all education systems, schools, or classrooms. However, one interviewed professor noted the importance of learning programming logic versus a specific language. Mathstronauts should focus on the structural and conceptual model for many of the most popular programming languages to help students learn computer programming logic while acquiring programming skills. Core competencies students may learn in primary school include abstraction, generalization, decomposition, algorithmic thinking, and debugging (*see Angeli et al., 2016*). Older students may learn logical and abstract thinking, problem-solving by designing and programming algorithms using digital devices, performing calculations and executing programs, collaboration, and ethics such as privacy and data security (*see Syslo et al., 2015*). Mathstronauts can also consider encompassing student interests and diverse abilities by surveying its incoming cohort of students to create a more tailored learning experience.

Math skills should be a second focus in Mathstronauts' learning program. Research findings indicate that there is a high demand and interest in math among high school students. From survey responses, math was the third most popular (40%) technical skill students indicated they would like to learn more about and the most popular (18%) skill parents felt their child would benefit from learning more about. There is evidence math is vital to students' success in a STEM university program. The majority of first-year STEM students (44%) responded that they struggled with math. Almost half of all first-year students' responses (48%) answered math was the most challenging technical skill. However, a majority (88%) of students indicated it as the most necessary hard skill for success in their program. From a teaching perspective, professors most commonly described first-year students having difficulty with basic mathematics concepts and foundational math skills (n=3). Regarding potential areas of instruction for Mathstronauts' new program, among first-year STEM students, calculus (20%), linear algebra (4%), trigonometry (4%), writing proofs (16%), and doing calculations (16%) were the most challenging.

#2: Mathstronauts should focus their programming on soft skills that are most needed for success in post-secondary STEM education.
a) Time management
b) Stress management/resilience

The design and development of this curriculum should consider the importance of soft-skills including time and stress management as factors that are essential to post-secondary success. Results from the qualitative interviews with professors suggest that soft-skills are essential in post-secondary success, but these skills are lacking in first-year STEM students. Each professor interviewed offered important insights on how high school students can practice certain soft-skills in order to better prepare for university.

Based on the survey results, all groups identified time management as one of the most important factors in post-secondary STEM success (66% for high school students, 80% for first-year STEM students, and 71% for parents of high school students). First-year STEM students noted that time management is the most challenging soft-skill to practice, which further highlights the importance of including this soft-skill as a learning objective for Mathstronauts' curriculum.

Although only one professor cited time management directly to be an issue with their students, a number of professors (n=3) indicated problem areas that may be rooted to students' inability to manage their time including procrastination and poor planning/organization. The lack of time management skills may lead to more stress. High school students indicated stress management (55%) as one of the top two skills they need to improve on for post-secondary success. This is reflected in first-year STEM students' responses that stress management is also the second skill they have most difficulty in practicing (40%) next to time management. Surprisingly, parents of high school students were not as concerned about stress management as the students themselves. The difference in viewpoints between parents and students may be explained by the students' reluctance to express to their parents that they are indeed stressed, indicating that students may feel more comfortable accessing external supports to assist them with learning stress management skills.

#3: Mathstronauts should provide education on STEM careers and specific jobs within the various STEM fields.

We recommend that Mathstronauts' program incorporates information about STEM careers to maximize students' interest in the field by highlighting its real-world applications. Several professors (n=2) stated that high school students are uninformed about the various jobs available in STEM and that more insight into these opportunities could help underrepresented students envision a place for themselves within the field (n=1). Further, high school students indicated that they were moderately interested (weighted average: 2.35 out of 5) in STEM as a career while the majority of first-year university STEM students (76%) expressed that their eventual goal was to find employment in STEM. Therefore, students would benefit from learning about careers in STEM because it could motivate them to prioritize their learning by highlighting the connections between their current study and future goals.

Mathstronauts could provide an overview of different careers within each of the subcategories of STEM by pairing academic content with related job profiles. Additionally, Mathstronauts could give students a person-centered look into STEM careers by arranging question and

answer periods with current professionals in the field, offering students insight into how to strategically navigate the transitions from high school to postsecondary education and then from education to employment. With this greater knowledge of the practical aspects of STEM-related jobs, students could better prepare for their academic and professional futures by mapping out a step-by-step plan to reach their specific goals.

#4: Mathstronauts should prepare high school students with education about university-level learning and expectations.

To ensure that high school students are successful in their post-secondary studies, the team recommends Mathstronauts' high school STEM programming include content related to university-level learning and expectations. Specifically, we recommend that Mathstronauts teach some lessons as university-style lectures to give students exposure to this learning environment, and to provide suggestions and support for how to succeed in university.

This recommendation stems from the discrepancy between high school students' and first-year students' perceptions of their preparedness for university, compared to the impressions of first-year STEM professors. Our survey revealed that high school students are more likely to feel prepared for university than not, with a weighted average of 2.9. Similarly, more than half of the first-year STEM students (64%) felt high school adequately prepared them for the academic expectations of postsecondary education. However, these responses differ from first-year STEM professor impressions. Half of the McMaster professors indicated that first-year students were not prepared for university (n=4), while others indicated mixed levels of preparedness (n= 3). Those who did feel that high school students were prepared for university prefaced their answers by noting that they work with exceptional or outstanding high school students and therefore may be biased (n=2). To help align perceptions of preparedness, we recommend Mathstronauts provide an overview of university expectations and review first-year STEM curriculum to ensure high school students have realistic expectations about first-year STEM education.

In addition to implementing lecture-style lessons to increase student familiarity with the teaching style, we recommend Mathstronauts incorporate testimonials from first-year students into their programming. These testimonials can provide information about university expectations, common areas where students are in need of support, and resources to help them prepare for first-year. As evidenced from our professor interviews, Mathstronauts may want to consider developing lessons with the goal of building problem-solving skills so students understand *why* they are performing a given step or task, as opposed to just reciting memorized content. As well, we recommend Mathstronauts encourage students to view university courses as opportunities to learn extensive soft and technical skills and have genuine passion and interest in the topics they study, as opposed to focusing only on grades.

References

Angeli, C., Voogt, J., Fluck, A., Webb, M., Cox, M., Malyn-Smith, J., & Zagami, J. (2016). A K-6 computational thinking curriculum framework: Implications for teacher knowledge. *Journal of Educational Technology & Society*, *19*(3), 47-57. Retrieved from: https://www.jstor.org/stable/pdf/jeductechsoci.19.3.47.pdf?casa_token=Tb0rN4cu-9QAAAAA:GYtKCie-IjyPVw_KMiXj1cKF00QDQYarPz_GbDxOPBfgS8GMnJjyL5GoZ2QPuDllx2ohYIEVzy7J85jzla9jIfnc1e0QlYMb2uqrB4HEmUBLJnpeIZc

Government of Ontario. (2020). *Preparing students for the future - Our plan at a glance.* Retrieved 12 August 2020 from the Government of Ontario: https://www.ontario.ca/page/preparing-students-future

Rushowy, K. & Benzie, R. (2020, June). *New Ontario elementary math curriculum to include coding starting in Grade 1.* Retrieved 12 August 2020 from The Toronto Star: https://www.thestar.com/politics/provincial/2020/06/23/new-ontario-elementary-math-curriculum-to-include-coding-starting-in-grade-1.html

Sysło, M. M., & Kwiatkowska, A. B. (2015, September). Introducing a new computer science curriculum for all school levels in Poland. In *International conference on informatics in Schools: Situation, evolution, and perspectives* (pp. 141-154). Springer, Cham. Doi:10.1007/978-3-319-25396-1_13

Appendices

Appendix 1: High School Survey

Mathstronauts High School Student Survey

High School Students

In this survey we will refer to 'STEM' fields, careers, and education. STEM refers to the broad categories of Science, Technology, Engineering and Mathematics and related fields.

Do you live in the Hamilton area? *Please select one response.*

- Yes
- No
- I prefer not to answer

What gender do you most closely identify with? *Please select one response.*

- Male
- Female
- Gender nonconforming/Genderqueer
- Gender fluid
- Other: _____
- I prefer not to answer

Do either of your parents/guardians work in a STEM field? *Please select one response.*

- Yes
- No

If yes:

What STEM field does/do your parent/parents work in?

Type here…

What high school do you currently attend?

Type here…

What grade are you in? *Please select one response.*

- Grade 9
- Grade 10
- Grade 11
- Grade 12

- Grade 12 Plus

What level of courses are you currently taking? *Please select all that apply.*

- Academic
- Applied
- University
- College
- Mixed

What are your plans after completing high school? *Please select one response.*

- Attend Grade 12 Plus
- Attend University for a STEM related program
- Attend University for a non-STEM program
- Attend College for a STEM related program
- Attend College for non-STEM program
- Other: _____
- Unsure

Do you have any worries about university or college?

- Yes
- No
- Unsure

If yes:

What worries do you have about university or college?

Type here…

What (if anything) do you think you need to improve on for success in your university or college education/future? *Please select all that apply.*

- Time management
- Leadership
- Cooperation
- Problem solving
- Focus
- Creativity
- Decision-making
- Interpersonal skills
- Oral presentation skills

- Listening
- Studying
- Writing
- Note-taking
- Networking
- Stress management
- Punctuality
- Accountability
- Organization
- Group work
- Self-directed learning
- Other: _____
- N/A

How interested are you in getting an education and/or job in STEM? *Please select <u>one</u> response.*

- Not interested
- Somewhat interested
- Very interested
- Unsure

If the participant selects "Somewhat interested" or "Very interested":
What area(s) of STEM are you interested in? *Please select <u>all that apply</u>.*

- Biology
- Chemistry
- Physics
- Engineering
- Computer Science
- Environmental Science
- Mathematics
- N/A

Please rate the extent to which you agree with the following statements:

I feel prepared for university or college. *Please select <u>one</u> response.*

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

My high school has provided opportunities to learn about STEM education and/or careers .
Please select <u>one</u> response.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- Unsure

I feel confident in my knowledge of STEM education and/or careers. *Please select <u>one</u> response.*

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- Unsure

Please rate your confidence level in the following hands-on STEM skills/competencies.

A. Coding. *Please select <u>one</u> response.*
    - Extremely confident
    - Confident
    - Somewhat confident
    - Not very confident
    - Not at all confident
    - Unsure

B. Math. *Please select <u>one</u> response.*
    - Extremely confident
    - Confident
    - Somewhat confident
    - Not very confident
    - Not at all confident
    - Unsure

C. Scientific writing. *Please select <u>one</u> response.*
    - Extremely confident
    - Confident

- Somewhat confident
- Not very confident
- Not at all confident
- Unsure

D. Statistics. *Please select <u>one</u> response.*
   - Extremely confident
   - Confident
   - Somewhat confident
   - Not very confident
   - Not at all confident
   - Unsure

E. Learning how to use software (technological skills). *Please select <u>one</u> response.*
   - Extremely confident
   - Confident
   - Somewhat confident
   - Not very confident
   - Not at all confident
   - Unsure

F. Online research. *Please select <u>one</u> response.*
   - Extremely confident
   - Confident
   - Somewhat confident
   - Not very confident
   - Not at all confident
   - Unsure

G. Citations/references
   - Extremely confident
   - Confident
   - Somewhat confident
   - Not very confident
   - Not at all confident
   - Unsure

Are there any areas in which you feel your STEM experience is lacking? *Please select <u>one</u> response.*

- Yes
- No
- Unsure

If yes:
Which areas would you like to gain more experience in?

Type here…

Have you participated in any STEM learning programs or extracurriculars (clubs, afterschool programs, homework help/tutoring, or academic camps)? *Please select <u>one</u> response.*

- Yes
- No

If yes:
Please describe the programs or extracurriculars you have participated in.

Type here…

If participant answers that they have participated in a STEM program above:
Based on your previous/current STEM program/extracurricular experience(s), were there any topics that you would have liked to learn more about? *Please select <u>one</u> response.*

- Yes
- No

If yes:
What topics would you have liked to learn more about?

Type here…

Have you previously heard of Mathstronauts? *Please select <u>one</u> response.*

- Yes
- No

How interested would you be, if at all, in joining an extracurricular program that takes a hands-on approach to teaching you STEM skills (e.g., coding, scientific reasoning, computer engineering)?

- Very interested
- Somewhat interested

- Neutral
- Not very interested
- Not interested at all

How interested would you be, if at all, in joining an extracurricular program that helps you prepare for success in university or college?

- Very interested
- Somewhat interested
- Neutral
- Not very interested
- Not interested at all

What (if anything) would motivate you to participate in a STEM learning program? *Please select all that apply.*

- Interest in STEM
- Preparation for University/College
- Preparation for a Career in STEM
- Gaining a program certificate
- Gaining STEM knowledge
- Interest in meeting new people (networking)
- Gaining hands-on STEM experience
- Other: _____

What STEM topics are you most interested in? *Please select all that apply.*

- Robotics
- Computer programming
- Statistics
- Scientific reasoning
- Other: _____

Would your current schedule accommodate a co-curricular STEM activity (approximately 2 hours per week)? *Please select <u>one</u> response.*

- Yes
- No

*The following questions are intended to understand your learning preferences in a **<u>non-pandemic period</u>**:*

Would you be willing to go to McMaster University to participate in STEM programming? *Please select <u>one</u> response.*

- Yes
- No

Would you be willing to participate in STEM programming online? *Please select one response.*
- Yes
- No

What type of educational programming do you prefer to take part in? *Please select all that apply.*
- Online (live training)
- Online (self-paced learning)
- In-person programming
- Blended learning format (mix of online and in-person)

This might include any research instruments (survey/interview questions), more comprehensive notes from any primary research, a more detailed list of search terms/search strategy, maps, tables, resource guides, or other information that is helpful for the partner to have, but is distracting if included above in the main text.

For example, our collaboration with the Beasley Neighbourhood Association led to the creation of an online archive.

Appendix 2: Parent Survey

Mathstronauts Parent Survey

Parents of High School Students

In this survey we will refer to 'STEM' fields, careers, and education. STEM refers to the broad categories of Science, Technology, Engineering and Mathematics and related fields.

Do you currently work in a STEM field? *Please select one response*
- Yes
- No

If yes:
What STEM field do you currently work in?

What grade is your child in (or has most recently completed)? *Please select one response*
- Grade 9

- Grade 10
- Grade 11
- Grade 12

What high school does your child attend?

Type here…

What (if any) skills do you think your child needs to improve on for success in post-secondary education? *Please select all that apply.*

- Time management
- Leadership
- Cooperation
- Problem solving
- Focus
- Creativity
- Decision-making
- Interpersonal skills
- Oral presentation skills
- Listening
- Studying
- Writing
- Note-taking
- Networking
- Stress management
- Punctuality
- Accountability
- Organization
- Group work
- Self-directed learning
- Other: _____
- N/A

How interested do you think that your child is in getting an education and/or job in STEM? *Please select <u>one</u> response.*

- Not interested
- Somewhat interested
- Very interested

- Unsure

If the participant selects "Somewhat interested" or "Very interested":
What area(s) of STEM do you think your child is most interested in? *Please select all that apply.*

- Biology
- Chemistry
- Physics/Engineering
- Computer Science
- Environmental Science
- Life Science
- Psychology
- Math
- Other: _____
- N/A

Has your child participated in any STEM learning programs or extracurriculars (clubs, afterschool programs, homework help/tutoring, or academic camps)? *Please select one response.*

- ❑ Yes
- ❑ No

If yes:
Please list the programs or extracurricular your child has participated in.

Type here…

What STEM areas or topics do you think your child would like to learn more about?

Type here…

What (if any) STEM hard skills do you think your child would benefit from developing to improve their chances of success in post-secondary education? *Please select all that apply.*

- Coding
- Math
- Scientific writing
- Statistics
- Learning how to use software (technological skills)
- Online research

- Citations/references
- Other: _____
- N/A

How aware are you, if at all, of the availability of extracurricular programs that use a hands-on approach to teaching students STEM skills (e.g., coding, scientific reasoning, computer engineering)?

- Very aware
- Somewhat aware
- Neutral
- Not very aware
- Not aware at all

How aware are you, if at all, of the availability of extracurricular program that helps students prepare for success in University or College?

- Very aware
- Somewhat aware
- Neutral
- Not very aware
- Not aware at all

Have you previously heard of Mathstronauts? *Please select <u>one</u> response.*

- Yes
- No

Do you think your child would be interested in participating in a STEM extracurricular learning program where they learn STEM hard skills and soft skills relevant for post-secondary success? *Please select <u>one</u> response.*

- Yes
- No
- Unsure

What STEM topics do you think your child is most interested in? *Please select all that apply.*

- Robotics
- Coding
- Statistics
- Scientific reasoning
- Biology
- Health science
- Graphic design

- Other: _____

Would you (or your child) be willing to pay a fee for your child to participate in a STEM learning program? *Please select <u>one</u> response.*

- Yes
- No

If yes:
How much would you (or your child) be willing to pay for your child to participate in a STEM learning program that prepares your child for university (both technical and soft skills)? *Please input a dollar value below.*

- $

*The following questions are intended to scope your learning preferences for your child in a **<u>non-pandemic</u>** period:*

Would your child be willing to come to McMaster University to participate in STEM programming? *Please select <u>one</u> response.*

- Yes
- No
- Unsure

Do you think your child would be willing to participate in STEM programming online? *Please select <u>one</u> response.*

- Yes
- No
- Unsure

What type of educational programming would you prefer your child to take part in? *Please select <u>one</u> response.*

- Online (live training)
- Online (self-paced learning)
- In-person programming
- Blended learning format (mix of online and in-person)

Appendix 3: First-Year STEM Student Survey

Mathstronauts First-Year STEM Student Survey

First-Year Post-Secondary Students (STEM Programs)

In this survey we will refer to 'STEM' fields, careers, and education. STEM refers to the broad categories of Science, Technology, Engineering and Mathematics and related fields.

Are you a first-year undergraduate student in university or first-year college student, or have you recently completed your first year of university or college? *Please select one response.*

- Yes
- No

If participant answers 'no', they will be taken out of the survey.

What post-secondary school do you currently attend? *Please select one response.*

- Mohawk College
- McMaster University
- Other: _____

What program are you currently enrolled in?

Type here…

What faculty is your program in?

Type here…

What gender do you most closely identify with currently? *Please select one response.*

- Male
- Female
- Gender nonconforming/Genderqueer
- Gender fluid
- Other: _____
- I prefer not to answer

Are either of your parents/guardians currently working in a STEM field? *Please select one response.*

- Yes
- No

If yes:
What STEM field does/do your parent/parents work in currently?

Type here…

What high school did you attend prior to entering university/college?

Type here…

Do you feel high school adequately prepared you for the academic expectations of university/college? *Please select <u>one</u> response.*

- Yes
- No

What, if any, academic expectations did you feel unprepared for upon entering university/college?

Type here…

Prior to your first year of university/college, did you participate in any clubs, afterschool programs, homework help/tutoring, or academic camps? *Please select <u>one</u> response.*

- Yes
- No

If yes:
Please list the clubs, afterschool programs, homework help/tutoring, or academic camps.

Type here…

Prior to your first year of university/college, did you participate in any STEM learning programs or extracurriculars (clubs, afterschool programs, homework help/tutoring, or academic camps)? *Please select <u>one</u> response.*

- Yes
- No

If yes:
Please describe the STEM programs or extracurriculars you have participated in.

Type here…

Based on your first year of university/college, were there any areas that you found challenging or difficult (course-related or technical skills)? *Please select <u>one</u> response.*

- Yes
- No

If yes:
What areas (course-related or technical skills) did you find most challenging or difficult?

Type here…

Have you experienced difficulty with any of the following soft skills in your first year of university/college? *Please select <u>all that apply.</u>*

- Time management
- Leadership
- Cooperation
- Problem Solving
- Focus
- Creativity
- Decision-Making
- Interpersonal Skills
- Communication Skills (Oral)
- Listening
- Studying
- Writing
- Note-taking
- Networking
- Stress management
- Punctuality
- Accountability
- Organization
- Group work
- Self-directed learning
- Other: _____
- N/A

Have you experienced difficulty with any of the following hard skills in your first year of university/college? *Please select all that apply.*

- Coding
- Math
- Scientific writing
- Statistics
- Learning how to use software (technological skills)
- Online research
- Citations/references
- Other: _____
- N/A

What soft skills do you think are most important for success in your program? *Please select all that apply.*

- Time management
- Leadership
- Cooperation
- Problem solving
- Focus
- Creativity
- Decision-making
- Interpersonal skills
- Oral presentation skills
- Listening
- Studying
- Writing
- Note-taking
- Networking
- Stress management
- Punctuality
- Accountability
- Organization
- Group work
- Self-directed learning
- Other: _____
- N/A

What hard skills do you think are most important for success in your program? *Please select all that apply.*

- Coding
- Math
- Scientific writing
- Statistics
- Learning how to use software (technological skills)
- Online research
- Citations/references
- Other: _____
- N/A

What are your current plans after graduation from university? *Please select <u>one</u> response.*

- Work
- Graduate School
- Professional School
- Other: _____
- Unsure
- Prefer not to answer

Do you plan to pursue a career in STEM following completion of your schooling/training? *Please select <u>one</u> response.*

- Yes
- No
- Unsure

Appendix 4: STEM Professor Interview Guide

STEM Professor Interview Guide

Introduction and Consent

Hello, my name is [*your name*]. I want to thank you for agreeing to participate in this interview. I'm working on a Research Shop project for Mathstronauts. Mathstronauts is a non-profit organization that provides innovative and creative experiential learning opportunities and programming for youth, focused in the STEM areas. Mathstronauts is looking to develop an extracurricular STEM learning program for high school students. The purpose of this research is to determine whether there is interest in high school-level STEM programming, and better understand the STEM- and soft- skills first-year students struggle within their first year of undergraduate STEM studies.

Do you have questions about the project?

This interview will be approximately 20 minutes in length. I want to spend a few moments going over some information about our discussion today. Firstly, there are no right or wrong answers to the questions I will be asking. Your views and opinions are welcomed. All of your comments –both positive and negative—are important. The information we will collect today will be connected to you as an instructor in a STEM program. Any identifying information (names, places, etc.) mentioned will be removed during the transcription process. The data from the interviews will be synthesized and the themes identified will be summarized in our final report. We strive to protect individual confidentiality. Keep in mind that we are often identifiable through the stories we tell when you are deciding what to share today. Your participation in this interview is voluntary. You are free to stop participating at any time and are not required to answer any questions that you cannot think of an answer to, or do not feel comfortable answering. If you would like to stop participating in the interview, please let me know.

With your permission, this interview will be recorded to increase accuracy and to reduce the chance of misinterpreting what is said. All audio files and transcripts will be securely stored in a Google Drive folder that only the Research Team has access to. I will also be taking notes throughout the discussion, which are only viewed and shared among the Research Team. Only the Research Team will have access to transcripts from this discussion. The tapes and transcripts will only be used for this project and will be destroyed once the report is complete.

Do you give your consent to participate in this interview?

[*Ensure the participant has verbally answered 'yes'*.]

Interview Questions

(1) What program(s) do you currently teach in?

(2) Do you feel that the first-year students are prepared for their first year of university? Is there anything that could be done to help them better prepare?

(3) What soft-skills do you feel that first-year students in your program are having the most difficulty with or lacking?

(4) What technical-skills (hard skills) do you feel that first-year students in your program are having the most difficulty with or lacking?

(5) Imagining that your first-year students had the opportunity to take a high school-level STEM program before coming to university, what do you feel they'd most benefit from learning about?

   (a) **Probe:** Are there specific soft skills (e.g., time management, writing, presentations) that you feel they'd most benefit from? Or are there specific technical skills (e.g. coding, scientific writing)?

(6) Is there anything else that you would like to share about your experience teaching first-year students in the (***program name)*** program?

Closing

Thank you so much for participating in this interview. The information you have provided will be very useful for Mathstronauts to help them better understand the learning needs of high school students looking to pursue STEM education. If you have any other questions please feel free to contact the study lead, Savanah, at smiths73@mcmaster.ca

Appendix 5: Coding Framework

Mathstronauts STEM Professor Interviews Coding Framework	
Node Name	*Node description*
Program	Main parent node for any references to the program the participant teachers first-year students in.
Kinesiology	Main child node for any references to the participant teaching first-year students within the kinesiology program.
Computer Science	Main child node for any references to the participant teaching first-year students within the computer science program.
Software Engineering	Main child node for any references to the participant teaching first-year students within the software engineering program.
Cross-listed Courses	Main child node for any references to the participant teaching first-year students within cross-listed courses (e.g., software engineering, computational science, engineering, etc.)
Chemistry	Main child node for any references to the participant teaching first-year students within the chemistry program.
Life Sciences	Main child node for any references to the participant teaching first-year students within the life science program.
Health Sciences	Main child node for any references to the participant teaching first-year students within the health science program.
Medical Sciences (Graduate)	Main child node for any references to the participant teaching graduate students within the medical science program.
Engineering	Main child node for any references to the participant teaching first-year students within engineering.
School of Injury Practice and Technology	Main child node for any references to the participant teaching first-year students within the School of Injury Practice and Technology.
Mathematics	Main child node for any references to the participant teaching first-year students within mathematics.
Teaches First Year Chemical Engineering Students in Lab Setting	Main child node for any references to the participant teaching first-year students in a Chemical Engineering lab setting.
Students' Preparedness for	Main parent node for any references to the participant's thoughts about first-year students'

University STEM	preparedness for university STEM programs.
Not Prepared for First Year	Main child node for any references to the participant feeling that students are not prepared for their first year of university.
Would Like Them to Know More	Any references to the participants expressing that they would like the participant to know more before entering the program.
Mixed Levels of Preparedness	Any references to the participants expressing that they see both students who are prepared, and other students who are unprepared.
Shocking/Surprising for Students	Any references to the participants expressing that believe students find the social, and academic transition to university shocking or surprising.
New Expectations for Students	Any references to the participants expressing that believe students have new expectations upon entering university.
Accurate Representations of the Field	Main child node for any references to the participant indicating that students should have a good understanding of the program they are getting into (i.e. in high school false or misleading information can be provided, creating a mis-match between the student and their program)
High school students lack preparedness in technical skills to succeed in university	Main child node for references to high school students lacking preparedness in technical skills to succeed in university
Lack of insight into what STEM careers involve	Main child node for any references to the participant indicating students lack insight into what STEM careers involve
A subset of students are well prepared and high-performing	Main child node for any references to the participant indicating certain/some first-year students are high performing and learned very quickly.
Biased - Only Accept Exceptional Averages	Main child node for any references to the participant indicating that their program may be biased in terms of students' levels of preparedness because they only accept students with exceptional averages.
Strategies to Assist Students in Preparing for University	Main parent node for any references to the participant's thoughts about any strategies that could be employed to assist students in preparing for university STEM programs.
Students' Attitudes Toward Learning	Main child node for any references to the participant indicating student's attitudes toward learning (driven by grades versus other motivation)
Passion/Interest in Learning	Main child node for any references to the participant indicating a passion for learning/STEM learning.
Engaging in Extracurricular Activities to Build Soft Skills	Main child node for any references to the participant indicating that having high school students engage in extracurricular activities (e.g., peer tutoring, protests) may help to build their soft skills.

Communicating Program Vision	Main child node for any references to the participant indicating that to attract more women into the program you must portray the field as more than just 'technology' and create a holistic depiction.
Math Review Manual	Main child node for any references to the participant indicating that students can use this university-provided resource to gain confidence and awareness of their math skills prior to entering university.
At-home review	Main child node for any references to the participant indicating that students should review basic math skills on their own time prior to first-year mathematics.
Organize Early	Main child node for any references to the participant indicating that students should organize their deadlines and tests early on in the semester so they have increased awareness.
Accurate Identification of Mental Health Concerns	Main child node for any references to the participant indicating that students should increase time management, to lower stress and therefore reduce chance they will mistake their perceived stress as "really" having a mental health problem.
Taking Control of Academic Behaviour	Main child node for any references to the participant indicating that students take greater control or initiative with regards to their academic behaviour.
Recognizing that students come to university with different skill sets	Main child node for any reference to students entering university with different skill sets
Real-world problem solving	Main child node for any references about a type of problem-solving skills that is based on real-world (e.g. many different solutions to one problem)
Organic Chemistry Knowledge	Main child node for any references to the participant indicating that students would benefit from learning more organic chemistry specifically polymers, organic reactions and the names of organic molecules
Equipment Software Use/Understanding	Main child node for any references to the participant indicating that students are lacking equipment software use and understanding.
Focusing on Fundamentals	Main child node for any references to the participant indicating that students would benefit from focusing on the fundamentals of STEM.
Soft Skills Students Experience Difficulty With	Main parent node for any references to the participant's insights on what soft skills first-year STEM students experience difficulty with or are lacking.
Resiliency	Main child node for any references to the participant indicating student's build resiliency/face challenges head on.
Self-Directed Learning	Main child node for any references to the participant indicating student's using self-motivation for learning behaviour.
Adaptability	Main child node for any references to the participant indicating the student's ability to be flexible to on-going and constantly changing demands.
Independence	Main child node for any references to the participant indicating the student's journey away from home and away from parental/guardian support.

Creative Problem-solving	Main child node for any references to the participant indicating the importance of students having creative problem solving skills.
Poor Soft Skills Generally	Main child node for any references to the participant indicating that students in the program have poor soft skills generally.
Teamwork	Main child node for any references to the participant indicating that students have difficulty with teamwork skills.
Empathy	Main child node for any references to the participant indicating that students have difficulty or lacking empathy.
Confidence	Main child node for any references to the participant indicating that students lack self-confidence (i.e. in their ability to ask questions, or public speak).
Communication	Main child node for any references to the participant indicating that students have poor communication skill and could use work on their oral presentation/communication skills.
Initiative	Main child node for any references to the participant indicating that students lack initiative.
Time Management	Main child node for any references to the participant indicating that students have poor time management skills.
Motivation	Main child node for any references to the participant indicating that student are struggling with staying motivated.
Understanding expectations around academic integrity	Child node for any references to the participant indication students may struggle with understanding expectations around academic integrity and what constitutes academic dishonesty
Grit	Main child node for any reference to the participant indicating that students need to have the grit required to practice the foundational skills that are not necessarily fun.
Technical Skills Students Experience Difficulty With	Main parent node for any references to the participant's insights on what technical skills first-year STEM students experience difficulty with or are lacking.
Programming	Main child node for any references to the participant indicating programming.
Coding	Main child node for any references to the participant indicating coding.
Logic	Main child node for any references to the participant indicating logic.
Design Thinking	Main child node for any references to the participant indicating design thinking.
General Technical Skills	Main child node for any references to the participant indicating general technical skills.
Laboratory Skills	Main child node for any references to the participant indicating laboratory skills.
3D Printer Use	Main child node for any references to the participant indicating capability or experience with 3D printers.

Computer-aided Design Software	Main child node for any references to the participant indicating capability or experience CAD software.
Practice Basic Math Skills	Main child node for any references to the participant indicating practicing basic math skills.
Reading and understanding primary research articles	Main child node for any references to the participant indicating need for better understanding and retaining information from scientific articles.
Unit Analysis	Main child node for any references to the participant indicating a need for students to work on unit (dimensional) analysis.
Important Components of STEM Program for High School Students	Main parent node for any references to the participant's insights on what components would be important for a high school STEM program to help prepare students for post-secondary STEM education.
Mathematics	Main child node for any references to the participant indicating math or numeracy.
Learner-centred inquiry	Main child node for any references to the participant indicating student's motivate their own learning experience based on their interests.
Experiential learning	Main child node for any references to the participant indicating experiential learning opportunities.
Basic reading skills	Main child node for any references to the participant indicating reading skills.
Basic writing skills	Main child node for any references to the participant indicating writing skills.
Exposure to a broad range of STEM topics	Main child node for any references to the participant indicating exposure to a broad range of STEM topics would be beneficial to students
Opportunities to practice writing skills	Main child node for any references to the participant indicating opportunities to practice writing skills would be beneficial to students
Math Skills (in conjunction with Computer Science; Bioinformatics)	Main child node for any references to the participant indicating math skills (especially those in conjunction with computer science, e.g., bioinformatics).
Logic	Main child node for any references to the participant indicating logic.
Empathy/Design Thinking	Main child node for any references to the participant indicating empathy or design thinking.
Physics	Main child node for any references to the participant indicating physics/physical science.
Flexible Learning Structure	Main child node for any references to the participant indicating a change to student's learning environment, moving away from traditional teacher-student interactions and towards more flexible open-ended learning environments.
Groupwork/Teamwork	Main child node for any references to the participant indicating students should be open to working and interacting with others differently than expected.
Collaboration	Main child node for any references to the participant indicating collaboration.
Conflict Resolution	Main child node for any references to the participant indicating conflict resolution.

Making Math/STEM Fun	Main child node for any references to the participant indicating the program should make STEM-learning experiential and fun for students.
Coding	Main child node for any references to the participant indicating the program should include coding.
Ensuring Full Curriculum has been Covered	Main child node for any references to the participant indicating that it would be important for a program to ensure that the students have learned the full high school curriculum, as units are often missed due to time constraints.
Additional Considerations	Main parent node for any references to additional considerations participants may have expressed during the interview.
High School Mathematics Program Not Adequate	Main child node for any reference to the current high school math curriculum not being adequate due to changes that have occurred over the years such as no longer teaching geometrical proofs.
More Women in STEM	Main child node for any references to the participant indicating it is difficult to recruit women into STEM programs (i.e. Engineering specifically).
High school Students More Difficult to Teach	Main child node for any references to the participant feeling that high school students are more difficult to teach than elementary school students (i.e., more resistant to learning new ideas or foundational skills, or doing activities that are not for marks).
Engaging High school Students with 3D Learning	Main child node for any references to the participant trying to engage high school students with 3D learning.
Managing Ambiguity (Accepting Ambiguity)	Main child node for any references to the participant indicating students need a new approach to learning which involves accepting more ambiguity.
Independent Learning (Need for Structure)	Main child node for any references to the participants emphasizing the fact that in the transition to university, first year students are in need of structure.
Resiliency (Understanding that Things will get Better/Recovery)	Main child node for any references to the participant indicating that the students should have an understanding that although the first year is difficult, things will get better and they will recover.
Asking for Accomodations	Main child node for any references to the participant endorsing that many first year students ask for extensions or accommodations due to poor planning or being unprepared rather than an actual crisis or health issue.
Academic Dishonesty Cheating	Main child node for any references to the participant indicating that the online delivery of tests and assignments due to the pandemic has made it easier for students to cheat.
High Engagement in Research and Innovation	Main child node for any references to the participant indicating for students to excel they have high engagement in research and innovation
Willing/Eager to Learn	Main child node for any references to the participant indicating students should bring a willingness/eagerness to learn
Positive Attitude Toward Learning	Main child node for any references to the participant indicating students should have positive attitudes towards learning

Self-esteem (Confidence in Themselves)	Main child node for any references to the participant indicating that students should be confident in themselves.