Bridges to Success: How Access programs create pathways to STEM education

by

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Abstract

The Transitional Year Programme (TYP) is an 8-month University of Toronto access program for mature students who have faced barriers to higher education related to race, class, Indigenous issues, family issues, etc. For fifty years, the programme has served as a pathway to an undergraduate degree at U of T with an initial focus on Black status, legal and Indigenous students. The majority of TYP graduates transfer to humanities-based academic programs, far fewer to science, technology, engineering, and mathematics fields (STEM). The current study therefore focuses on current TYP students who aim to transfer to an undergraduate STEM program at U of T. Current TYP students completed a 21-question survey containing questions about their perception of barriers to entering STEM programs at U of T, their preferred learning styles, as well as their confidence in pursuing STEM fields. Descriptive analyses of the results revealed several barriers, personal and systemic, to pursuing STEM programs of study. Within the program, we found that participants felt prepared for future studies in English and humanities courses however only 25% felt prepared for taking courses in the sciences and 0% for first year mathematics. We investigate how the current TYP STEM curriculum could be modified to improve pathways to STEM undergraduate programs.

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Chapter 1 Introduction

Bridging or access programs are designed for mature students lacking formal qualifications for admission to enter post-secondary education. There are various types of bridging programs, some offer ‘access through admissions’ for students that have a high school degree, but their grades were considered too low for admission (Doran et al., 2015). Entrance into most Ontario universities requires students to have completed their Ontario Secondary School Diploma (OSSD). In addition, most require six university preparation courses or equivalent from their final year of secondary school (Rainsberger, 2011). In STEM streams, four of those credits must be from university level English, Advanced Functions or Calculus & Vectors, and two credits from university level Biology, Chemistry or Physics. Other programs, such as The Transitional Year Programme, do not have this requirement and will be the focus of this paper.

The Transitional Year Programme (TYP) is an 8-month University of Toronto access program for mature students who have faced barriers to higher education related to race, class, Indigenous status, legal issues, family issues, amongst other issues. For fifty years, the programme has served as a pathway to an undergraduate degree at the University of Toronto (UofT) with an initial focus on Black and Indigenous students. TYP is unique in that it is open to anyone regardless of race, and that upon successful completion of the program, students are admitted into the Faculty of Arts & Science (FAS) even without having a high school degree. The majority of TYP graduates transfer to humanities-based academic programs, far fewer to science, technology, engineering, or mathematics fields (STEM). One reason for this could be that even after admission, TYP students wishing to take first year courses in science or mathematics are expected to have the appropriate math or science high school pre-requisite which TYP does not provide.

According to the Access Strategy & Partnerships Office recently established at the University of Toronto, the institution has demonstrated a longstanding commitment to promoting access and outreach, as evidenced by the presence of over 100 diverse access and outreach programs throughout the institution. While many of these initiatives focus on promoting STEM education among underrepresented youth to support and inspire them in their secondary education pursuits, TYP is uniquely tailored to meet the needs of a distinct community. Specifically, TYP caters to adults who were unable to complete their secondary education for various reasons or lack the necessary background to qualify for admission into the university. Many TYP students come from marginalized communities and have complex life situations, making most of the university's access and outreach programs unsuitable for them. Notably, TYP's unique feature is its inclusivity, as it welcomes all individuals, unlike most access programs that cater to a specific group. While targeting specific disadvantaged communities is crucial, it also means that individuals who do not conform to the conventional definition of "disadvantaged" are denied access to these programs.

Author's Anecdote: Many alumni of the programme express that TYP was one of the hardest years of their academic careers. As an alumnus myself, I share this view. As I celebrated my 2018 TYP graduation I knew the upcoming months would take on a less celebratory note. Throughout the summer I would need to be working full time, figuring out accommodations near school and preparing myself to enter the unfamiliar setting of the wider FAS program at the UofT.

I had been hoping to enter FAS and study Cell and Molecular Biology. However, despite having been awarded the provost math and science award, I still did not qualify for entry to the program because I had not earned grade 12 math or sciences. With only one summer before the program began, I knew I would not be able to earn those credits, and therefore decided to settle for entry into the Cognitive Science and Bioethics arts program. This scenario is common to so many TYP graduates. This year I celebrate graduating with an Honours Bachelor of Science having majored in Bioethics & Cell and Molecular Biology. Getting to this point came with its hurdles. Going from one department to another to be granted permission to take first year courses, struggling through chemistry, biology, and calculus all the while feeling like I didn’t belong here.

TYP has done an excellent job at preparing students for the rigours of academic writing. Indeed, this is what the program has aimed and cultivated over the last 50 years. The focus of the program has never been on science, technology, engineering, or math (STEM) related subjects, leaving their curriculum underdeveloped. The program provides students with the sufficient knowledge to count as the equivalent of grade 12 English which many first-year courses in the humanities and social sciences require. However, it does not offer adequate preparation for entry into first year science or mathematics. While historically this may have been a less pressing issue, more students, like me, are coming to the program. If we really want to celebrate TYPs accomplishments, we must continue to expand the program to include pathways to STEM. Otherwise, we risk creating new group of disadvantaged learners who are left to struggle on their own, and possibly not get the chance to pursue their dreams in a science-based discipline.

During each term, students take a full course load designed to prepare them for the rigors of university along with one FAS course. Research on TYP between 1980-1985 has shown that the TYP curriculum contained a Social Science Methodology course (Ferris, 1992). By 1999-2000 the program has expanded its course offerings in science and mathematics to include a general science (Reasoning in Sciences or RIS) and two math courses (Quantitative Reasoning (QR) and optional Advanced Quantitative Reasoning (AQR)) (Brathwaite, 2003). The FAS courses which were available to TYP students expanded to include courses with the department of ecology & evolutionary biology (EEB). In recent years the RIS curriculum was revised and most recently TYP students were granted a limited number of spots in two first year biology courses, Adaption & Biodiversity and Molecular & Cell Biology. Unlike the course that was offered through EEB, both these courses are required courses for most life-science based programs. However, they normally require students to have grade 12 biology and chemistry.

Over the last 2 years, I've seen our students show incredible drive and determination to successfully pass both first-year biology courses even without the high school pre-requisites. I've also witnessed many leave the programme without completing their studies. In conversations with these students over the years feeling overwhelmed by the full courseload and trying to catch up on biological concepts is just too much. While increasing the number of FAS courses available to TYP students is a fantastic step forward, we risk setting our students up for failure in these areas if we don't update and restructure how we teach STEM. We cannot simply offer courses and extend the same TYP supports we would for other FAS courses. They must be STEM specific. The first step to do this would be to identify barriers that TYP students have faced in accessing and pursuing STEM fields, both before and during their TYP year. Then, we need to assess their preferred learning styles and preparedness for entering the FAS. To do this, we conducted an exploratory study to identify barriers in program components and supports available to students as well as how prepared they felt to enter post-secondary studies after completing TYP.

In this paper, we identify what barriers students have faced and their level of preparation for STEM courses upon their departure from TYP. In addition to questionnaire data, a literature and curriculum review of the science and mathematics courses at TYP against their UofT first year counterparts in biology, chemistry, and calculus was conducted. Given our findings, we provide recommendations for specific curriculum changes in TYP courses. Two recommendations are to revise our math and science courses to provide sufficient pre-requisites and to pilot a 3 to 4 semester STEM stream.

Chapter 2 Methodology

This chapter outlines the qualitative research used to identify barriers in program components and supports available to students intending to pursue STEM. A detailed account of the methodology and procedures employed used to develop the questionnaire, as well as a systematic outline of the analytical process used to evaluate and assess the data collected. Although the questionnaire was anonymous, this chapter offers essential insights into the 2022-2023 TYP cohort of students to contextualize the analysis. Moreover, this chapter expounds on my role as an inside researcher and elucidates the steps taken to minimize any potential research bias, thereby ensuring an objective and impartial evaluation of the research findings.

The methodology and methods of this study conform to the ethical guidelines and standards for research with human participants. This study was approved by the University of Toronto Research Ethics Board in January of 2023. The approval letter can be found in Appendix G.

2.1 Questionnaire design

We used an exploratory study approach to identify barriers in program components and supports available to students intending to pursue STEM. We took a convenience sampling approach to recruiting participants. The link to the online questionnaire was circulated through TYP weekly flyers as well as during the “Reasoning in the Sciences” class. We promoted the study by informing students that participants would have the opportunity to critically engage with their learning perceptions within the sciences during their TYP year and reflect on how previous educational experiences may have influenced their performance, confidence, and pursuit within STEM fields. Further, by identifying barriers students have faced in accessing and pursuing STEM fields, we can work towards mitigating or eliminating those barriers for future students. This will be of benefit for the stem workshop that we hold in the winter semester at TYP and future STEM related courses.

The questionnaire was completely anonymous and consisted of 21 questions along with an open space for students to write about any other thoughts they wanted to express. It was made clear in both the announcements and information packets that participants must read before continuing to the questionnaire that their responses are anonymous, and this in no way affects their standing in the course or with TYP faculty. The questionnaire can be broken into six main sections:

1. Participants interest in math.
2. Interest in science.
3. Barriers in STEM.
4. Their experience of STEM before and after TYP.
5. Methods of learning they found effective.
6. Models of learning they found effective.

Questions were developed using the authors personal experience as a TYP student and being a teaching assistant for Reasoning in Sciences students throughout their undergraduate degree. Sections 1 and 2 used a modified version of the STEM Semantics survey (Tyler-Wood et al., 2010). Continual comparison of the data against survey results and observations was done using the Corbin and Strauss methodology (2008). This assisted in providing direction for research of the existing literature.

2.2 Positionality and ethical considerations

As an alumnus of the Transitional Year Programme and having worked with the programme throughout my undergraduate degree, the primary author is an inside researcher. Insider research involves a member of a group or organization conducting research within their group while also continuing their day-to day role within that community. Individuals in the TYP community come from diverse backgrounds with their core commonality being that they are adult learners who have been barred or excluded from post-secondary education due to circumstances outside of their control. Being a TYP alumni and teaching assistant has provided the author with pre-existing knowledge of the programmes design, institutional procedures and a deep understanding and respect for the diversity of TYP students. Considering this, we created an optional, anonymous online questionnaire to avoid conflicts of interest while still being able to thoughtfully design the questions to elucidate meaningful data.

Chapter 3 Findings

3.1 Findings from literature: Learning gaps between TYP and FAS course expectations

Using Dyjur et al. (2019) process for curriculum review, we analyzed TYPs science and mathematics courses against the University of Torontos Faculty of Arts and Science (FAS) Calculus I (MAT135), Chemistry I (CHM135) and Biology (BIO120/130) courses. For Calculus I, the department of Mathematics provides a clear outline of topics they expect students to know before entering the course which we have highlighted in Tables 3 and 4. For chemistry and biology, FAS only list grade 12 university preparation Chemistry and Biology as pre-requisites. To narrow down applicable topics, we looked at Grade 12 Ontario Science and mathematics curriculum for these subjects, highlighting specific concepts that each course builds upon.

Each of the Tables below use the same system for course comparison and the course learning outcomes (CLOs) for both a particular FAS course and its TYP counterpart. Each CLO is summarized from the syllabi from each course which can be found in appendices A through F. Each of the letters, “I”, “D” and “A” correspond to whether the TYP course is introducing (I) the FAS topic, developing concepts (D) or advancing complex knowledge of a given topic (A) (Dyjur et al., 2019).

3.1.1 Biology

At the University of Toronto, there are two distinct first year biology courses, BIO120 and BIO130 which cover adaption and evolution and cell and molecular biology respectively. Currently TYP students take both courses as their FAS electives. While TYP has seminars each week to provide extra support for students in their FAS course, the purpose of the seminar is to reinforce concepts taught, not to build foundational concepts required for the course itself. We have separated biological and chemical topics taught in RIS between Tables 1 and 2. Table 1 shows that most of the fundamental topics required for BIO130 are introduced or are beginning to be developed. Topics related to BIO120 which deals primarily with population dynamics and concepts related to evolution are not covered in RIS.

Table 1

Course learning outcomes (CLOs) for TYPs Reasoning in the Sciences (RIS) course mapped to FAS first year Biology expected CLOs from grade 12 University preparation biology (bolded). If a topic relevant to the CLO for grade 12 biology was covered in RIS, it is marked with either an "I", "D" or "A" depending on depth and level of engagement with the topic.

Expected CLOs for entry to BIO120/130 → CLOs for Reasoning in Sciences ↓	**Role of biological molecules and compounds in cells**	**Roles of organelles in cellular processes**	**Structure of cell membranes and movement of particles**	**DNA and RNA replication, repair, and protein synthesis**	**Use appropriate numeric, symbolic, and graphic modes of representation**	**Four main types of biochemical reactions**	**Population dynamics**
Understand the scientific method					I		
Eukaryotic vs prokaryotic cells	D	I	I				
Protein synthesis and folding				D			
GMOs and industry trends				D			
Transcription and Translation				D			
Biochemical reactions						I	
Understand the chemical and molecular basis of biomolecules such as carbohydrates, lipids, DNA, and proteins		D					

I	I = Introduced: Key ideas, concepts or skills related to the learning outcome are introduced and demonstrated at an introductory level. Instruction and learning activities focus on basic knowledge, skills and/or competencies and entry-level complexity
D	D = Developing: Learning outcome is reinforced with feedback; students demonstrate the outcome at an increasing level of proficiency. Instruction and learning activities concentrate on enhancing and strengthening existing knowledge and skills, as well as expanding complexity
A	A = Advanced: Students demonstrate the learning outcome with a high level of independence, expertise and sophistication expected upon graduation. Instructional and learning activities focus on and integrate the use of content or skills in multiple levels of complexity.

3.1.2 Chemistry

All science topics are only covered during the one semester RIS course. Due to this, only basic chemistry topics are introduced which as can be seen in Table 2 is insufficient for the expected student to know to take CHM135.

Table 2

Course learning outcomes (CLOs) for TYPs Reasoning in the Sciences (RIS) course mapped to FAS first year chemistry expected CLOs from grade 12 University preparation chemistry (bolded). If a topic relevant to the CLO for grade 12 chemistry was covered in RIS, it is marked with either an "I", "D" or "A" depending on depth and level of engagement with the topic.

CLOs for Grade 12 Chemistry → / CLOs for Reasoning in Sciences ↑	**Understand the structure of matter**	**Phase equilibria and diagrams**	**Colligative properties**	**Chemical equilibria**	**Electrolyte solutions**	**Reaction kinetics**	**Have an introductory knowledge of thermodynamics**
Understand the scientific method							
States and physical properties of matter. How temperature and pressure effect them	D		I				
Brownian motion and diffusion	I						
Interpret the standard notation of atoms and identify/draw atomic structure							
Understand patterns and groupings seen on periodic table							
Chemical bonding and interactions and molecules						I	

I	I = Introduced: Key ideas, concepts or skills related to the learning outcome are introduced and demonstrated at an introductory level. Instruction and learning activities focus on basic knowledge, skills and/or competencies and entry-level complexity
D	D = Developing: Learning outcome is reinforced with feedback; students demonstrate the outcome at an increasing level of proficiency. Instruction and learning activities concentrate on enhancing and strengthening existing knowledge and skills, as well as expanding complexity
A	A = Advanced: Students demonstrate the learning outcome with a high level of independence, expertise and sophistication expected upon graduation. Instructional and learning activities focus on and integrate the use of content or skills in multiple levels of complexity.

3.1.3 Calculus

Both Quantitative and Advanced Quantitative Reasoning introduce students to most of the concepts required for entry to MAT135. The bolded topics shown in both Tables 3 and 4 are concepts from grade 12 Calculus and Vectors and Advanced Functions that the University of Torontos mathematics department expects incoming student to know (*Entry Level Math Preparation*, n.d.) Some of the topics covered in the TYP math courses are outside the scope of both high school courses. These concepts include number systems, arithmetic in base other than base ten, areas of statistics, and matrices. These concepts are not covered in calculus I (MAT135) as can be seen by the syllabus in appendix D.

Table 3

Course learning outcomes (CLOs) for TYPs Quantitative Reasoning course mapped to FAS first year calculus expected CLOs from grade 12 University preparation math (bolded). If a topic relevant to the CLO for grade 12 math was covered in Quantitative Reasoning, it is marked with either an "I", "D" or "A" depending on depth and level of engagement with the topic.

Expected CLOs for entry to MAT135 → / CLOs for Quantitative Reasoning ↑	**Algebra**	**Inequalities /Absolute values**	**Mathematical logic**	**Functions, inverses, exponentials, and logarithms**	**Polynomials /factoring**	**Geometry**
Learn number systems from other civilization						
Arithmetic in base other than base ten						
Exponents, laws of arithmetic, real numbers, algebraic expressions, and formulae	D					
Sets, logic operations and applications of sets in logic problems			D			
Linear polynomial functions and equations, ratios, rates, and proportions		I		I		
Properties of quadratic/polynomial functions of degree 2				I	I	
Reading/plotting points on rectangular coordinate plan.					I	
Description of graph from its function or vice versa					I	
Types of statistical data. Data organization, averages						
Statistical graphs and measures of dispersion						

I	I = Introduced: Key ideas, concepts or skills related to the learning outcome are introduced and demonstrated at an introductory level. Instruction and learning activities focus on basic knowledge, skills and/or competencies and entry-level complexity
D	D = Developing: Learning outcome is reinforced with feedback; students demonstrate the outcome at an increasing level of proficiency. Instruction and learning activities concentrate on enhancing and strengthening existing knowledge and skills, as well as expanding complexity
A	A = Advanced: Students demonstrate the learning outcome with a high level of independence, expertise and sophistication expected upon graduation. Instructional and learning activities focus on and integrate the use of content or skills in multiple levels of complexity.

Table 4.

Course learning outcomes (CLOs) for TYPs Advanced Quantitative Reasoning course mapped to FAS first year calculus expected CLOs from grade 12 University preparation math (bolded). If a topic relevant to the CLO for grade 12 math was covered in Advanced Quantitative Reasoning, it is marked with either an "I", "D" or "A" depending on depth and level of engagement with the topic.

Expected CLOs for entry to MAT135	**Functions, inverses, exponentials, and logarithms**	**Polynomials/factoring**	**Geometry**	**Graphing**	**Trigonometry**	**Sequences/series**
Polynomial, rational, algebraic, logarithmic, transcendental, and trigonometric functions	I	I			I	
Properties of functions, graphing functions	D	I		D	I	
Application of functions, direct and inverse proportions	D					
Arithmetic and geometric sequences and their applications						I
Arithmetic and geometric series and their applications						I
Systems of linear equations with two-three variables			I			
Matrix row reduction method and its applications						
Pythagoras Theorem and proof					D	
Trigonometric ratios, Sine and Cosine rules and application to any triangle					I	
Conceptual understanding of types of statistical data, its collection, and inferential statistics						

CLOs for Advanced Quantitative Reasoning

I	I = Introduced: Key ideas, concepts or skills related to the learning outcome are introduced and demonstrated at an introductory level. Instruction and learning activities focus on basic knowledge, skills and/or competencies and entry-level complexity
D	D = Developing: Learning outcome is reinforced with feedback; students demonstrate the outcome at an increasing level of proficiency. Instruction and learning activities concentrate on enhancing and strengthening existing knowledge and skills, as well as expanding complexity
A	A = Advanced: Students demonstrate the learning outcome with a high level of independence, expertise and sophistication expected upon graduation. Instructional and learning activities focus on and integrate the use of content or skills in multiple levels of complexity.

3.2 Minority and TYP representation in STEM

50% of participants stated that a barrier to pursuing STEM was lack of role models. Role models or individuals we consider like ourselves provide us with one indicator of self-efficacy. When an individual observes their role models engaging in a task and whether they are successful or not, the individual makes judgements as to their ability to do the same or similar task (Bandura, 1977; Gladstone & Cimpian, 2021). Two respondents provided these comments:

> *I feel the representation of visible minority faculty and students in STEM, specifically African, Caribbean, Black folks, affects my confidence in being successful in a STEM program at U of T.*

And:

> *If I wasn't so self conscious in my learning disabilities and had more confidence in being able to succeed in STEM, I might've considered pursuing a degree.*

Looking more broadly at the University of Toronto undergraduate community, we can see the saliency of such comments. The University of Toronto's 2020 National Survey of Student Engagement found that among 10,000 respondents, only 6% identified as "Black" and 1% as "Indigenous"(*RESULTS OF THE NATIONAL SURVEY OF STUDENT ENGAGEMENT 2020 - University of Toronto*, 2020). This survey did not include any mention of disabilities. As both students pointed out, there is also a lack of representation in minority faculty. The 2021 Report on Employment Equity from the university supports this. Analyzing faculty from all three campuses, 7.9% self-identified as a persons with disabilities, 3.8% identified as Black, and only 1.5% identified as Indigenous or Aboriginal People of North America (*2021 Report on Employment Equity*, 2021.).

Chapter 4 Findings from questionnaire

4.1 Background on participants

From the 2022-2023 TYP cohort of students, four participated in our questionnaire. They would have been students who were either in Reasoning in the Sciences or Quantitative Reasoning. Notably, two of the participants self-identified as members of commonly marginalized groups, as previously highlighted in the previous section. Form analytics showed that responses occurred between December 1st-5th, 2022 which was after the end of first semester classes. Participants exhibited varied academic backgrounds with 50% of participants having solely taken science courses, 25% having taken both math and science courses, and 25% having taken neither at the secondary level. When asked whether they planned to enter a STEM related field, 50% said no, 25% said they were planning on entering a STEM field and 25% was still undecided. Of the three respondents who expressed disinterest or indecisiveness towards STEM, reasons for their stance were solicited, with one attributing their lack of interest to the subject matter, while the remaining two believed that they would not succeed in a STEM programme at a post-secondary level.

4.1.1 Barriers to STEM

The descriptive analysis conducted in this study revealed an array of personal and systemic barriers that impede students' pursuit of STEM fields. These obstacles included:

- Lack of support to continue in STEM.
- Negative experiences with teachers.
- Math was a barrier to science.
- Not having access to STEM resources or courses.
- Unique challenges from being apart of a minority.
- The way course content was taught.

4.1.2 Interest in math and interest in science

Participants were given four questions from the STEM Semantics Survey, which probed their attitudes towards mathematics and science using pairs of descriptive adjectives (Tyler-Wood et al., 2010). Respondents held a significantly lower interest in mathematics in comparison to science. Specifically, only one participant found mathematics to be interesting, fascinating, very exciting, and appealing. In contrast, the responses towards science were more favorable, with 50% of participants finding it to be very interesting and exciting, 75% considering it to be very fascinating, and all respondents finding it very appealing. It is evident that the majority of respondents held unfavorable perceptions towards mathematics in contrast to the STEM disciplines, with many identifying mathematics as a barrier rather than a bridge to further STEM study.

4.1.3 Preferred learning methods and styles

To better comprehend effective adult learning strategies and whether the TYP curriculum utilizes any of these approaches, respondents were asked to identify the methods of learning that were most helpful to them throughout their educational journey. The findings indicated that lectures, small tutorials or groups, and hands-on learning were the three methods that students found most beneficial. In contrast, self-learning modules were found to be only somewhat helpful to all respondents, while half of the participants found homework and projects to be very helpful, and the other half considered them helpful. Additionally, the majority of respondents found having access to practice tests helpful.

It is crucial to understand how students learn to structure the TYP curriculum effectively, and this includes comprehending their preferred learning methods. This understanding allows instructors to tailor homework, projects, and activities to meet the needs of adult learners. The most effective strategies included the opportunity to discuss concepts with others or apply them to real-world situations, as well as making or coloring diagrams. Taking notes and doing practice problems were found to be effective by half of respondents, somewhat effective by one, and very effective by another. Memorization was considered to be the least effective learning tool.

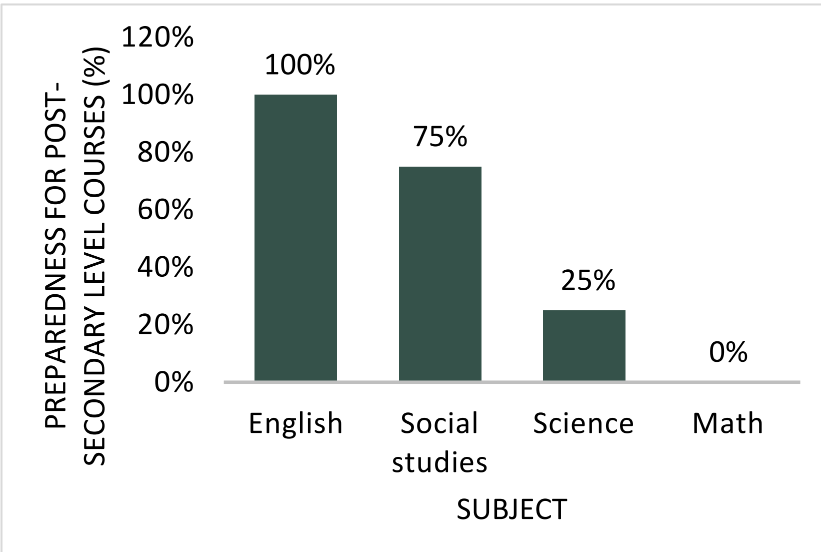
4.1.4 Preparedness for STEM after TYP

To gain insight into how the TYP program was preparing students for future academic pursuits at the University of Toronto, we asked respondents to rate their preparedness for various courses at UofT. The results, shown in Figure 1, indicated that all respondents felt ready to take English or writing-based courses, which suggests that the TYP program had effectively prepared them in this area. When it came to courses in the humanities and social sciences, the majority of respondents felt prepared, likely due to the number of humanities courses they had taken during their TYP year. However, the picture was different for science and math courses, with only 25% of respondents feeling prepared for science and none feeling prepared for math.

These findings suggest that TYP may need to reassess its approach to teaching science and math courses, as these are important areas of study for many STEM-related fields. The findings also highlight the need for continued support and resources for students who may struggle in these subjects, to ensure that they are adequately prepared for future academic pursuits at UofT.

Figure 1

How Prepared Participants Felt for First Year Courses at the Post-Secondary Level After TYP Based on Subject



Chapter 5 Discussion

5.1 Self-Efficacy

TYP plays a crucial role in developing students' self-efficacy in science and math. Self-efficacy, which refers to an individual's belief in their ability to succeed in a specific task, is influenced by past performance and role models. Research has shown that self-efficacy is a better predictor of academic outcomes than prior performance alone (Bandura, 1977; Capa-Aydin et al., 2018). In our study, only one respondent had prior experience with both science and math courses before enrolling at TYP. This is not uncommon, as many students have limited prior exposure to these subjects. Two determinants of self efficacy include mastery experiences and vicarious experiences which we will use to analyze data from sections 1-4.

The most influential factor that determines an individual's level of self-efficacy is their previous performance in a particular task, especially whether they have "failed" or "succeeded" (Bandura, 1977). Such experiences provide authentic evidence of one's ability to succeed and offer valuable insights into one's potential to complete similar tasks. Students who have failed a task may become discouraged from continuing or attempting similar tasks, which can affect their self-efficacy. Our questionnaire was completed at the end of the fall semester, after students had completed Reasoning in Science or Quantitative Reasoning. It is essential to note that, as previously mentioned, 66% of students who were uncertain about or did not wish to pursue a STEM field cited a lack of confidence in their ability to succeed in such fields. This indicates the need for improvement in TYP's STEM courses to help cultivate self-efficacy. Future research may consider how students interpret their grades, as half of our respondents reported reduced enthusiasm and engagement following a poor grade.

The second determinant of self efficacy is a person's vicarious experiences which refers to the individual observing others they consider role models or similar to themselves succeeding in a given task. Lack of role models, particularly among visible minorities in STEM fields, was cited as a barrier to pursuing STEM fields by half of the participants. Research suggests that teachers who serve as role models and demonstrate success in STEM fields can significantly increase student self-efficacy (Gladstone & Cimpian, 2021). Therefore, it is crucial to have a diverse pool of teachers who can act as role models for students from different backgrounds. As such, teachers are a key resource in increasing self-efficacy using mastery and vicarious experiences. They not only have the ability to modify curriculum and grading schemes but also deliver social persuasion, which has been shown to be a common source of student self-efficacy in research (Won et al., 2017). The current professor of mathematics at TYP wrote on their observations of African Canadian students and engagement with math:

> “Unfortunately, there are very few teachers of African descent to instruct them in school or to act as role models. This is detrimental to the students’ development, and especially to their development of mathematics ability, because mathematics is ultimately an exercise in asserting the product of ones thinking and reasoning. Mathematics requires all the self-confidence one can muster” (Ahia, 2003).

Teachers can also utilize peer mentoring and tutoring programs to provide students with vicarious experiences of success in STEM fields. Moreover, highlighting the achievements of successful individuals from diverse backgrounds in STEM fields through guest lectures or other initiatives can help inspire and motivate students to pursue STEM fields.

5.2 Math as a barrier to science

The impact of self-confidence and self-efficacy on students' cognitive and emotional dispositions towards mathematics has been extensively researched (Di Martino & Zan, 2011). Our study found that mathematics was cited as a barrier by our participants in accessing science courses, which could have contributed to the negative sentiments expressed in sections one and two of the questionnaire. This suggests that negative perceptions of mathematics could prevent students from pursuing science courses, even though they find the subject matter interesting.

Given the integral role of mathematics in most STEM-related professions, it is crucial to shift students' perception of their ability in mathematics, boost their self-efficacy, and integrate mathematics into other courses offered by TYP. Many adult learners return to school with the aim of improving job performance or expanding career prospects (*Adult Learning and Foundational Skills: Findings from the First Cycle of the Programme for the International Assessment of Adult Competencies (PIAAC)*, 2021).

25% of participants indicated their intent to enter a STEM related field. The other 75% did not plan on entering this field, with 66% stating they would not enter STEM field because they "don't feel like they would succeed in STEM education". Indicating that motivation and interest in STEM as a vocation is present but lack of self efficacy both before and during TYP may contribute to students not pursuing a STEM related degree.

5.3 Support and experiences with teachers prior to and during TYP

In sections 3 and 4 of the questionnaire, participants were asked to evaluate the support they received from their teachers, peers, and learning institutions. While some participants indicated a lack of support before TYP, all participants reported feeling supported during their time at TYP. The program's history has been characterized by a strong sense of community despite being part of a large university. Approximately 60 students are accepted into the program each year and are connected with an in-house academic advisor, accessibility service advisor, as well as a dedicated administration team of seven and ten faculty members who demonstrate a genuine commitment to each student's success (*The Alumna-Founded Transitional Year Programme*, 2022).

We also inquired whether participants' perception of STEM had changed over the course of the semester. 75% of participants reported a positive change in their perception of STEM. The Reasoning in the Sciences course is designed to introduce students to scientific thinking rather than prepare them for first-year sciences. As such, the current curriculum aligns with the program's goal of fostering a positive perception of science among students of all academic levels.

5.4 Integrating math and science

Within the context of TYP, it is important to investigate how both the mathematics and science curricula can collaborate to engage students with both subjects and to eliminate the perception of mathematics as a barrier to science. The alignment of our current mathematics curriculum with first-year calculus expectation which we examined in Tables 3 and 4 can be used to examine how mathematics and science can be integrated to create a positive learning experience for TYP students.

Similar to our findings using the STEM semantics survey, Butcher et al (2019) interviewed adult learners who had participated in a STEM access module prior to entrance to a STEM undergraduate degree program through the Open University of England. They found that during interviews with students, “no student suggested that they were nervous about studying science, yet maths was an area of uncertainty for many students coming into the Access module” (Butcher et al., 2019). Showcasing that math being a barrier to science is a common narrative amongst access program learners. However, the study also found that by emphasizing the integration of mathematics and science, rather than treating them as separate subjects, students gained a higher level of self-confidence in both subjects. By introducing mathematics as a means to support the learning of science, students were able to enjoy the challenge of mathematics and leave the course with a more positive perception of both subjects. This highlights the potential benefits of integrating mathematics into science curricula within access programs such as TYP.

In Reasoning in the Sciences, students are introduced to independent and dependent variables, equations for density and units of volume and mass. However, we do not delve into the mathematical logic behind these concepts, such as explaining why the mass of an electron which is 5.45×10^{-4} amu is considered zero. When we introduce independent and dependent variables, it is in the context of the hypothetico-deductive method and does not include their application to graphs. This is an area where collaboration between both the math and science courses could exist. Since students currently must choose between taking either math or science in the fall semester, RIS could benefit from integrating more mathematics concepts to familiarize students with how math can be applied within the sciences. There has been noticeable success in integrating biology and mathematics in first year biology courses without leading to shallower skill development or increasing math anxiety (Madlung et al., 2011). Since

TYP students have the option to take first year biology and sociology, there could be ways of integrating components of either into TYP math.

5.5 Lack of access to STEM resources or courses

Professors from TYP both stressed that many students who come to the program were streamed in non-academic mathematics and science (Ahia, 2003; Gitari, 2003). Our data aligns with this, as only one student had taken both math and science courses prior to entering TYP. This underscores the importance of providing sufficient support and resources to help these students succeed in STEM fields. The same respondent cited that lack of support and resources were one of the main barriers they had faced to continue in a STEM field. With students having to choose between taking math or science, their ability to access the STEM courses currently offered is limited. Excluding FAS courses, TYP students take 4-5 humanities-based courses over the entirety of the program. In comparison, there is only the ability to take 2 STEM courses which can be further limited if students decide to take RIS in the fall instead of QR, leaving them unprepared to take AQR in the winter semester.

While TYP provides bi-weekly STEM preparation sessions in the winter semester for students interested in pursuing STEM-related fields, the program could benefit from additional resources to support STEM learning. For example, TYP could establish a centre that provides one-on-one instruction and workshops focused on STEM-related skills, similar to the Writing and Academic Skills Centre (WASC) that runs throughout both semesters and has been popular among students. Alternatively, TYP could consider offering a math aid centre akin to those offered by FAS. Such initiatives would enhance the STEM resources available to TYP students and support their success in STEM fields.

5.6 Preparedness for future courses

With the primary objective of TYP being to equip its students with the essential skills necessary for success within the academic environment of the University of Toronto, we conducted an inquiry into the extent of their readiness for future coursework. As depicted in Figure 1, while students indicated a sense of readiness for writing courses and humanities-based classes, only one participant felt that TYP had adequately prepared them for first-year science courses, and none of our respondents felt prepared for mathematics. In an effort to gauge the level of preparedness of our participants for STEM courses at any level, we asked them to rate their preparedness on a scale of 1-5 after completion of the program. The average score was 2.75, which is indicative of the fact that the current STEM curriculum at TYP is not designed to equip students with the requisite knowledge and skills for STEM-related courses. This aligns with previous literature on TYP, where it has been noted that “Quantitative skills are not a focus. These skills are more directly cumulative, and the eight-month TYP does not provide sufficient time to upgrade students to university level mathematics or science” (Ferris, 1992).

5.7 Current TYP curriculum vs students preferred methods and models of learning

The respondents in our study identified lectures, tutorials, and hands-on learning as the most helpful models of learning for their STEM courses. Unfortunately, at TYP, there are only lectures offered for both math and science courses, with no tutorials or labs available. Respondents also emphasized the importance of being able to apply classroom knowledge to real-world problems and engaging in discussions about concepts, which are both effective learning methods. However, due to the limited time of the two-hour weekly lecture, there is little opportunity for additional activities or discussions. This lack of interactive experiences is a concern, as research has shown that physical and interactive experiences can significantly improve student performance and understanding, especially during early stages of learning new concepts (Kontra et al., 2015; Zacharia et al., 2012).

Chapter 6 Recommendations and final remarks

While we have explored various modifications to current STEM courses, such as incorporating tutorials and labs, integrating more math into science, and providing additional STEM resources, we suggest two major recommendations that could have a significant impact on promoting equitable access to STEM education in TYP. Firstly, we propose expanding the current TYP course offerings by adding more STEM courses. Secondly, we suggest extending the duration of the TYP program from the existing two semesters to a 3-4 semester program tailored specifically for students interested in pursuing STEM studies. These recommendations would provide TYP students with more opportunities to explore and excel in STEM fields, thus better preparing them for future academic pursuits in STEM.

6.1 Course additions

To provide students with sufficient knowledge for first-year chemistry and biology, we recommend introducing courses specifically tailored to each topic. This approach would enable students to gain a deeper understanding of the concepts required for entry into chemistry and biology, as highlighted in Tables 1 and 2.

6.2 Lengthening TYP to a 3 to 4 semester program

One potential objection to adding more STEM courses to TYP is that it may come at the expense of writing and humanities courses, leaving students ill-prepared for those subjects. To address this concern, we propose extending the TYP program for students who express interest in pursuing STEM studies. This would allow us to offer additional science and math courses without compromising on the foundational TYP courses. Research has shown that longer engagement with a bridging program leads to increased levels of self-efficacy (Johnson & O'Keeffe, 2016), which is essential for success in academia.

Moreover, extending the TYP program would provide additional benefits, such as allowing students to prepare for their FAS courses in advance. Currently, TYP students start their FAS course in the fall semester, but for those taking courses like BIO120 that require grade 12 prerequisites, it can be challenging to balance a full course load. By beginning the TYP program in the summer, students can take a biology course at TYP before starting their FAS course, ensuring they are better prepared and more successful in these courses. This would ultimately increase their chances of success in STEM fields and promote greater equity in STEM education.

6.3 Conclusion

In conclusion, our examination of TYP's effectiveness in preparing students for STEM courses at the University of Toronto has revealed several areas for improvement. While students reported feeling prepared for writing and humanities courses, they lacked preparedness for science and math courses, and a need for additional resources, such as tutorials and labs, to facilitate interactive learning. We suggest two major recommendations to address this issue: expanding the current TYP course offerings by adding more STEM courses and extending the program from a two-semester program to a 3-4 semester program specific for students interested in studying STEM. By extending the program, we can offer additional science and math courses without compromising on other fundamental TYP courses. Additionally, we argue that an extended program can increase self-efficacy levels and allow for better preparation for FAS courses, ensuring students are successful in their future academic pursuits in STEM.

Equitable access to STEM education is crucial for ensuring that all students have the same opportunities to pursue academic success in these fields. The lack of preparedness reported by students in science and math courses highlights the need to address this issue and provide additional resources to facilitate interactive learning. Expanding the TYP course offerings to include more STEM courses and extending the program specifically for students interested in studying STEM can help to improve access to STEM education. An extended program can also help to increase self-efficacy levels and better prepare students for FAS courses, ultimately ensuring their success in future academic pursuits in STEM. By prioritizing equitable access to STEM education, we can pave the way for a future where a diverse and inclusive STEM workforce thrives, leading to groundbreaking innovations and progress that benefit us all.

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Appendices

Appendix A Syllabus for BIO120

BIO120H1F – Adaptation & Biodiversity
Department of Ecology and Evolutionary Biology, University of Toronto

Course Syllabus – Fall 2022

The BIO120H Team

Lecturers: **Prof. Asher Cutter** (Lectures 1-12) **Prof. Megan Frederickson** (Lectures 13-24)	**Jill Wheeler**, Course and Laboratory Coordinator **Laura Heslin Piper**, Course Administrator **Veronica Chong**, Course Administrator **Bianca Sacchi and Jessica Leivesley**, Lecture TAs + many **Laboratory TAs** **Dom Fenech, Dongling Zhao, Anna Li, Fariha Memon**, Laboratory Technicians

BIO120H office – bio120@utoronto.ca

- Please direct all course enquiries to the BIO120 office; the office will re-direct enquiries as appropriate.
- Email: **bio120@utoronto.ca.** Phone: 416-978-7588
- Please include your full name and student number when emailing the BIO120 Office
- Location: RW 105 Office suite (Ramsay Wright Building, 25 Harbord St., see Quercus for details)
- **Office hours:** Monday to Thursday, 11:00 am – 1:00 pm; they will be offered online or in-person depending on the day – please check Quercus for more details

Course description

Principles and concepts of evolution and ecology related to origins of adaptation and biodiversity. Mechanisms and processes driving biological diversification illustrated from various perspectives using empirical and theoretical approaches. Topics include: genetic diversity; natural selection; speciation; physiological, population and community ecology; maintenance of species diversity; global environmental change; conservation, species extinction, and invasion biology. Prerequisite: Grade 12 Biology or equivalent. Exclusion: BIO150Y1Y.

Course objectives

1. A goal of this course is to provide you with a solid foundation in evolutionary and ecological principles and concepts—as related to the origins of adaptation and biodiversity—so that you can make informed decisions on pressing societal issues, such as population growth, global environmental change, and the conservation of biodiversity, and be prepared for advanced study in the biological sciences.
2. Darwinian evolution is the unifying concept in biology and explains biodiversity on earth and why species differ. You will learn that the traits of organisms are the product of a complex interplay between natural selection, genetic variation, and evolutionary history.
3. You will learn that adaptive evolution is a process that results from selection pressures imposed by the physical and biotic environment on individuals within populations. The ecological challenges of capturing resources for growth, successful reproduction, and avoiding enemies largely determine the ways organisms function.
4. Required readings will extend and reinforce lecture material on how natural systems work and how diverse organisms respond to the challenges of the natural world. From reading *Evolution: a very short introduction* for Prof. Cutter's lectures, you will learn how various independent lines of evidence demonstrate the fact of evolution and give insight into its mechanisms, particularly adaptation by natural selection.
   Required readings for Prof. Frederickson's lectures will extend and reinforce lecture material on how natural systems work and how diverse organisms respond to the challenges of the natural world.
5. In the laboratories you will learn to make observations, devise hypotheses, and conduct experiments in ecology and evolutionary biology, including critically evaluating and communicating (both orally and in writing) hypotheses and experimental designs.

Appendix B Syllabus for BIO130

BIO130H1S 2023

Course Syllabus

Course Address

University of Toronto
Department of Cell and Systems Biology, University of Toronto
Ramsay Wright Labs, 25 Harbord Street
Toronto, Ontario
M5S 3G5

Course Requirements

Pre-requisites:
SBI4U and SCH4U (Grade 12 University Preparation Biology and Chemistry) or permission of the course coordinator. Please e-mail bio130@utoronto.ca for more information.
Exclusion: BIO240H1, BIO241H1, BIO255Y1 and BIO250Y1

Lecture Location & Hours

Day Section: Mondays 10:00am -11:00am and Thursdays 10:00am – 12:00pm, Convocation Hall.
Evening Section: Thursdays 6:00pm - 9:00pm, MacLeod Auditorium (MS 2158)

Required Course Material

1. Textbook: Essential Cell Biology. 5th Edition. 2019. Alberts B, Hopkin K, Johnson A, Morgan D, Raff M, Roberts K, and Walter P. WW Norton and Company.
2. COURSE ANNOUNCEMENTS posted on this website. These are updated regularly. It is the responsibility of all students to read course announcements.
3. Lab coat, Safety Glasses/ goggles are Required by Health and Safety regulations for ALL WET LABS. Students will be denied access and forfeit credit for the lab if they are not wearing a lab coat and safety glasses/goggles.

climate, as it relates to learning. The goal of this research is to make courses more equitable for all students. The student experience in first year science classrooms will be studied at the start, middle and end of the term through online surveys as part of this research project.

For completing all three CCSES surveys, you will earn a bonus 1% towards your final course grade (i.e., if you complete all 3 surveys, we will add 1% to your course grade, but your course grade will not be affected if you choose not to complete all 3 surveys).

Lecture Syllabus

Section 1 The Building Blocks of Life
Prof. M. Neumann (Team Leader), Department of Cell and Systems Biology

Lectures 1-4
- Introduction to Cell and Molecular Biology
- Cellular Diversity
- Prokaryotes and Eukaryotes
- The Molecules of Life and Their Chemistry
- DNA, RNA, and Proteins
- Introduction to Genomes

Lectures 5 - 8
- Nuclear and Organellar Genomes
- Chromosomes and chromatin
- DNA replication and repair
- Introduction to transcription

Lectures 9 & 10
- Transcription
- RNA processing

Lectures 11 & 12
- Translation
- Protein Folding
- Antibiotics

Section 2 Cellular Form and Function
Prof. D. Goring, Department of Cell and Systems Biology

Lectures 1-4
- Cellular membranes
- Membrane proteins
- Transport across membranes

Lectures 5&6

- Intracellular compartments
- Protein sorting

Lectures 7&8
- The cytoskeleton
- Filament assembly and dynamics
- Motor proteins

Lectures 9&10
- Interactions between cells and their environment
- Cell junctions and adhesion
- Extracellular matrix

Lectures 11&12
- The cell cycle
- Interphase and M phase
- The role of the cytoskeleton in M phase

Lab Syllabus

- Intro lab
- Lab 1: Learning to Work like a Molecular Biologist I
- Lab 2: Learning to Work like a Molecular Biologist II
- Lab 3: Learning to Work like a Molecular Biologist III
- Lab 4: Learning to Work like a Cell Biologist

Lab Policy

Labs are held on alternate weeks. In-person labs are held in the Department of Cell and Systems Biology, Ramsay Wright Building (RW), 25 Harbord Street.

Group Assignments
You can check your assigned lab group on Quercus under the Group section on the left-hand side.
Cycle 1 labs (labs with code Pxx**01**) start the week of **January 16th**.
Cycle 2 labs (labs with code Pxx**02)** start the week of **January 23rd**.
Labs are every other week.

Arrive on time for your lab
Labs start promptly at 10 minutes past the hour (9:10, 1:10, 5:10, 6:10). If you arrive late, you will still be expected to finish the lab within the assigned time, with no compensation

Appendix C Syllabus for Reasoning in the Sciences

COURSE DESCRIPTION:

This course explores aspects of scientific knowledge that are applicable in everyday life and in academic settings. These include: key discoveries in the history of science, the processes of scientific inquiry, fundamental scientific concepts, and examples of the use of science in agriculture and industry. This takes us from the point of understanding the processes involved in using science to establish facts, through to its use in innovation and understanding disease processes. Course delivery includes lectures, class exercises and discussions. Course evaluation consists of attendance, take-home assignments, and tests.

COURSE OBJECTIVES:

1. Gaining an appreciation of the evolution of science by looking at key discoveries in the history of science
2. Understand the processes involved in moving from a casual observation to an established scientific fact
3. Learning basic and fundamental scientific concepts that can be used to explain the functioning of more complex systems that exist
4. Gain an insight into the application of science in agriculture and industry
5. Use science to gain an understanding of a genetic disease process

IN-PERSON LEARNING:

This course will take place in-person unless circumstances change based on public health guidance and U of T's COVID-19 policies. The University of Toronto continues to monitor Toronto, Peel, and provincial public health guidance. Despite the current pause in our mandatory mask requirement, the use of a medical mask is highly recommended especially in high-density indoor spaces when physical distancing is not possible. The university also requests everyone to respect each other's decisions, comfort levels, and health needs.

COURSE MATERIAL ACCESS:

All materials for this course will be posted on Quercus. You will be required to log in using your UTORid (and password).

The Quercus webpage is as follows: https://q.utoronto.ca/courses/284898

SUBMITTING COURSEWORK:

Coursework can be submitted via Quercus or to the email addresses shown above.

COURSE CONTENT AND SCHEDULE OF CLASSES:

Session #, Date & Venue	**Topic & Materials**	**Activities**
#1 Thursday, September 8	Introduction *Course schedule/syllabus*	Introduction to the course
#2 Thursday, September 15 Venue: VC-215	The Scientific Method: I *Induction and Deduction* *The Hypothetico-Deductive Approach*	Lecture In-class questions
#3 Thursday, September 22 Venue: VC-215	The Scientific Method: II *Scientific Fact and Changing Paradigms* *Observation and Experimentation*	Lecture In-class questions **Homework 1** **Due date: Wednesday, September 28 @11:59PM EST** **Value: 10%**
#4 Thursday, September 29 Venue: VC-215	Scientific perspectives on matter I *Chemistry: The science of matter* *Atomic structure*	Lecture

Session #, Date & Venue	Topic & Materials	Activities
#5 Thursday, October 6 Venue: VC-215	Scientific perspectives on matter II *The periodic table* *Chemical Bonding/interactions and molecules*	Lecture In-class exercise **Homework 2** **Due date: Wed., October 12 @11:59PM EST** **Value: 10%**
Monday, October 10	Thanksgiving Day	
#6 Thursday, October 13 Venue: VC-215	Scientific perspective on living things: I *Biological Molecules I*	Lecture Q&A
#7 Thursday, October 20 Venue: VC-215	Scientific perspective on living things: II *Biological Molecules II*	Lecture Q&A
#8 Thursday, October 27 Venue: VC-215	**TEST 1**	**Details of the test will be announced in class (session #7)** **Value 35%**

Session #, Date & Venue	Topic & Materials	Activities
#9 Thursday, November 3 Venue: VC-215	Scientific perspective on living things: III *Cells & Cell Functions:* *Animal Cells* *Plant cells*	Lecture In-class exercise
FALL READING WEEK, November 7-11	***No classes during this week***	
#10 Thursday, November 17 Venue: VC-215	Scientific perspective on living things: IV *Genetic basis of sickle cell anemia*	Lecture **Homework 3** **Due date: Wed., November 23 @11:59PM EST** **Value: 10%**
#11 Thursday, November 24 Venue: VC-215	Biotechnology & Society: I *Genetically Modified Organisms (GMOs)*	Lecture
#12 Thursday, December 1 Venue: VC-215	Biotechnology & Society: II *Industry*	Lecture
Date: TBD Venue: TBD	**TEST 2**	**Value 25%**

Appendix D Syllabus for MAT135

MAT135H1 S: Calculus I

Summer 2021
University of Toronto

LEC5101, Tuesday 18:00-21:00 and Thursday 18:00-21:00 via Zoom.

1 Contact information

Instructor: Jamal Kawach
Email: `jamal.kawach@mail.utoronto.ca`
Instructor office hours: Tuesday 9:30-11:30, and by appointment
TA: Leonard Afeke
TA office hours: Wednesday 9:00-10:00 and 18:00-19:00

2 Course overview

2.1 Course description

In this first introduction to Calculus, students will be introduced to the tools of differential calculus, the branch of calculus that is motivated by the problem of measuring how quantities change. Students will use these tools to solve other problems, including simplifying functions with straight lines, describing how different types of change are related, and computing maximum and minimum quantities. This course will focus on developing a deep understanding of why the tools of calculus make sense and how to apply them to the social, biological, and physical sciences. It will also emphasize translating between algebraic, graphical, numerical and verbal descriptions of each concept studied.

2.2 Prerequisites

Prerequisite: High school level calculus
Exclusion: MAT133Y1, MAT136H1, MAT137Y1, MAT157Y1, MATA30H3, MATA31H3, MATA32H3, MATA33H3, MATA35H3, MATA36H3, MATA37H3, MAT133Y5, MAT134Y5, MAT135Y5, MAT137Y5, MAT138Y5, MAT186H, MAT187H, MAT196H, MAT197H, ESC194H, ESC195H

2.3 Course objectives

By the end of the course, you should be able to:

- understand, use, and translate between multiple representations of functions, limits, and derivatives;
- solve complex and novel problems using tools from calculus;
- build a mental framework of calculus that serves as a foundation for future learning;
- see yourself as a confident and capable user and communicator of mathematics; and
- possess skills and habits for effectively learning math.

Keeping the above learning goals in mind, in this course we will address the following questions:

- Why should we represent a single relationship in different ways?
- What is infinity? What is an infinitesimal?
- How do we model the real world with mathematics?
- What is speed, and how do you measure it? What are rates, and how do you measure them?
- How can you solve novel problems that are unlike any you've encountered before?
- What do good readers and writers of math do?

2.4 Course topics

We will work through the following topics in MAT135. The corresponding sections of the textbook are indicated below; we will cover two or three sections per lecture. A precise schedule is included on the last page of the syllabus.

(1) **Modeling with functions**: How do we use mathematics to describe related quantities? §1.1-1.6

(2) **Limits**: How do we work with the infinitely small and the infinitely large? §2.1, §1.7-1.9

(3) **The derivative**: In what different ways can rates of change be represented? How are rates of change described and used? §2.2-2.6

(4) **Computing derivatives**: How are derivatives efficiently computed? §3.1-3.7

(5) **Using the derivative**: How can we use the derivative to solve complex problems from the sciences? §3.9, §4.1-4.4, §4.6

(6) **The area problem**: How is the rate of change problem related to the area problem? §5.1-5.3

2.5 Textbook and course materials

The textbook for the course is **Calculus: Single Variable, 7th edition** by Hughes-Hallett et al. It will come packaged with the homework system that we are using for the course, called WileyPlus. WileyPlus, along with the textbook, will be available from the bookstore. Do not purchase the textbook or a WileyPlus subscription from another source; you need to make sure that they link properly with the course. Please note that the bookstore offers both one- and two-semester options for WileyPlus; for this course, **you only need to purchase the one-term option**.

2.6 Course website, Zoom, and communication

All course materials, announcements, and grades will be available on Quercus at `q.utoronto.ca`. All lectures, tutorials and office hours will be held synchronously via Zoom. The Zoom links will be posted on the course website. In order to attend, you should download Zoom and create an account using your UofT email address prior to the first class. For security reasons, **you will need to use your UofT email** in order to join each Zoom session. This will also ensure that your participation grades can be assigned accurately.

The University has a policy requiring that students have a UofT email address and that you check it regularly. Please use your UofT email address when contacting the instructor. Furthermore, please include "MAT135" in the subject line in order to ensure that your email is not missed. Please do not write to your TA; our TA hours are limited and reading/responding to emails is not part of the TA duties. You may email the instructor with math questions, but (given the difficulty in effectively communicating math over email) is it preferred that you attend office hours. Alternatively, you can post and ask/answer questions on Piazza (a link will be available on Quercus).

2.7 Lectures, tutorials, office hours

This course will consist of **two weekly three-hour lectures** and **one weekly tutorial session**. The schedule is as follows:

- LEC5101: Tuesday 6-9pm and Thursday 6-9pm.
- TUT0101: Monday 9-10am.
- TUT5101: Monday 6-7pm.

All times in this course are stated in EDT (Toronto time). All components of the course will be delivered online synchronously on Zoom. The first lecture for this course will take place on **July 6**. Lectures will be recorded and posted on the course website at the end of each week. While not strictly required, you are **strongly encouraged** to read through the relevant sections of the textbook before each lecture, as it will help maximize your understanding and increase engagement during lecture.

Tutorials will start on **July 12** and will be held synchronously via Zoom. Students are required to attend the tutorial at the scheduled times of their registered section. Tutorials will primarily consist of problem sessions and/or review of the previous week's written quiz. Please note that we will **not make use of the Wednesday tutorial hour**; instead, TA office hours will take place at these times (Wednesdays 9-10am and 6-7pm).

In addition to lectures and tutorials, there will be weekly office hours held by the instructor and the TA. This is an opportunity for you to ask questions about the material outside of lectures and tutorials. No appointment is necessary; you are welcome to drop in any time during an office hour. All office hours will take place via Zoom.

The course lectures, including your participation, will be recorded on video and will be available to students in the course for viewing remotely and after each session. The unauthorized use of any materials provided by a MAT135

Appendix E Syllabus for Quantitative Reasoning

Week 1 *Thursday September 8, 2022* **Outline**

Review Questions: To be done in class to help structure how material would be presented.

About Numbers

Readings:

1. http://home.ubalt.edu/ntsbarsh/zero/ZERO.HTM

Scroll to Menu, and read #28 – From Finger Numbers to Computers: The Most Fascinating Journey. Read the Introduction also.

2. https://mathshistory.st-andrews.ac.uk/HistTopics/

Read Arabic, Indian (Hindu), Babylonian, Egyptian, Greek, Roman, Inca, Mayan and other civilizations Number Systems

Homework 1: From Readings 2 (Exclude Arabic and Indian civilizations) Write about the Number system of a civilization of your choice. Compare the Number System you chose to the Number System of the Indian-Arabic number system (used universally). (Your paper must be at least a page and at most two pages). Supplement what is in the readings above with other sources.

Due: 5 p.m. Wednesday September 14, 2022. To be submitted through platform, Quercus or at TYP 203

Week 2 *Thursday September 15*

Arithmetic in base other than base ten. Count, Add, Subtract, Multiply, and Divide. Exponents, Order of Operations. (Example base two, base sixteen, base seven)

http://www.cimt.org.uk/projects/mepres/book9/book9int.htm Click Unit 1

Week 3 *Thursday September 22*

Continue from Week 2 – Exponents (or Indices), Order of Operations, Laws of Arithmetic. Real numbers. Algebraic expressions. Formulae. Evaluation of formulae.

Reference:

Interactive Tutorials at;

http://www.cimt.org.uk/projects/mep Scroll to Year 7 | 8 | 9 Interactive material. Click on year 8 and 9 exploring each for topics covered and of interest to you.

Week 4. *Thursday September 29*

Concept of a Set, Special Sets –Universal, and Empty set; Subset, Superset, etc.; Operation on Sets – Intersection, Union, Complement etc. Application of sets in 'logic' problems.

Cardinality of Sets. Finite sets, Infinite sets or sets with finite, infinite cardinality respectively.

Homework 2: On topics covered from Week 2 to Week 4 inclusive

Due on or before Wednesday October 5, 2022, 5:00 p.m. at on-line platform, Quercus

Week 5 *Thursday October 6*

Continue from Week 4

Week 6 *Thursday October 13*

Functions from set of numbers to another set of numbers. Linear polynomial functions and equations; Solution of linear equations; Application to everyday events; Construction and solution of equations – 'Word' Problems. Ratios, Rates, Proportion and Percent: Definition and Properties, Application including Word Problems from Newspapers and encounters in daily transactions, etc.

Readings: Relevant Topics at:

http://www.cimt.org.uk/projects/mepres/book8/bk8_7.pdf

http://www.cimt.org.uk/projects/mepres/book9/bk9_4.pdf

Interactive Tutorials at;

http://www.cimt.org.uk/projects/mep Scroll to Year 7 | 8 | 9 Interactive material. Click on year 8 and 9 exploring each for topics covered and of interest to you.

http://www.cimt.org.uk/projects/mepres/book8/bk8_12.pdf

http://www.cimt.org.uk/projects/mepres/book9/book9int.htm Click Unit 5

http://www.cimt.org.uk/projects/mepres/allgcse/allgcse.htm Click on 'appropriate' topic'

Read: https://www.sciencenews.org/article/emmy-noether-theorem-legacy-physics-math

https://en.wikipedia.org/wiki/Muhammad_ibn_Musa_al-Khwarizmi

Week 7 *Thursday October 20*

Continue from Week 6. Quadratic or Polynomial Function, and Equation of degree 2. Solution of Quadratic equations, Derivation of the Quadratic formula and its application. Properties of Quadratic function.

Week 8 *Thursday October 27*

Continue from Week 7. Rectangular co-ordinate Plane; Reading and Plotting points on a rectangular co-ordinate plane. Applications: Plotting graphs for a table of values for two variables, or items. Construction of Table of Values; Use of Graph to solve algebraic equations; as a 'conversion' table. Description of graph from its function (or equation); description of function (or equation) given a graph.

Readings, Relevant topics at:

https://www.cimt.org.uk/projects/mepres/allgcse/bkc13.pdf

Homework 3: On topics covered from Week 5 to Week 8 inclusive

Due on Wednesday November 2, on or before 5:00 p.m. at online platform Quercus

Week 9 *Thursday November 3*

Continue from Week 8

Week 10 *Thursday November 10*

Reading Week so no classes

Week 11 *Thursday November 17*

What is Statistics?; Why is Statistics Studied?; How important is Statistics? What is Data? Types of Statistical Data; Data Organization – Tallying, Stem and Leaves, 'Ungroup' and Group Tables, etc

Descriptive Statistics: Measures of Central Tendency or Averages – Mode, Median, Mean

Readings, Relevant topics at:

https://www.cimt.org.uk/projects/mepres/allgcse/allgcse.htm Scroll to Pupil Text Units 7 – 12, Units 13 – 19, and Unit 20. Click on relevant topics.

Week 12 *Thursday November 24*

Statistical Graphs – Pie Chart, Bar Chart, Histogram, and use of Histogram, etc

Measures of Dispersion: Range, Variance, Standard Deviation

Readings: Use the readings from Week 11

Week 13 *******Thursday December 1, (Last Day of This Class)***

Continue from Week 12

Take Home Test: On topics covered in week 9, and 11 to 13 inclusive.

To be submitted not later than 5:00 p.m. on December 22, 2022 at on-line portal, Quercus

NOTE: *The course outline may be modified to follow the evolution of the work we do. The major expectation is development of skills to tackle problems and that depends crucially on subject matter knowledge.*

Appendix F Syllabus for Advanced Quantitative Reasoning

Topics and Schedule:

Week 1 – Wednesday January 11, 2023

Polynomial, Polynomial functions, Rational functions, Algebraic functions, Exponential functions, and Logarithmic functions. Transcendental functions – Trigonometric functions (Degrees, and Radian unit of measurement of Angles)

Week 2 – Wednesday January 18, 2023

Continue from **Week 1**; Some properties of functions – Maximum / Minimum of a function. 'Sketching' Graph of a function, Asymptote(s) of graph of a function

Week 3 – Wednesday January 25, 2023

Continue from **Week 2**; Some Application of functions; Proportional Relation – Direct proportion (linear function with constant term zero) and Inverse proportion (rational function with non-zero numerator and denominator linear function with constant term zero)

Week 4 – Wednesday February 1, 2023

Continue from **Week 3**; Sequences - Function with Domain a subset of the set of Natural Numbers – Sequence; Arithmetic Sequence – linear function with domain a subset of the set of Natural Numbers; Geometric Sequence – Exponential function with domain a subset of the set of Natural Numbers

Series – Arithmetic Series (Sum of Arithmetic Sequence), Geometric Series (Sum of Geometric Sequence), Derivation of formulae for Arithmetic Series, and Geometric Series. Applications of Series and Sequences

References

http://cimt.org.uk/projects/mepres/alevel/pure_ch13.pdf

http://cimt.org.uk/projects/mepres/alevel/fpure_ch6.pdf

Or google Sequences and Series.

* **Homework 1: Covering Weeks 1 to 4;** To be submitted by **Tuesday February 7, 2023**

Week 5 – Wednesday February 8, 2023

Continue from **Week 4;** Systems of Linear Equations in Two and Three Variables (or Unknowns): 'General' Method of Solution based on Matrix (Matrice) Row Reduction Method. Applications

Week 6 – Wednesday February 15, 2023

Continue from **Week 5;** Trigonometry: Right (angle) triangle – Definition. 'Pythagoras' Theorem and a proof; Trigonometric Ratios – Sine, Cosine, Tangent defined in relation to two sides, and an angle of a Right Triangle. The Sine, and Cosine Rules applied to any triangle (not necessarily a Right Triangle). Proof of the Cosine, and Sine Rule. Applications – Angle of Elevation, and Depression, etc.

References:

http://www.cimt.org.uk/projects/mepres/allgcse/bka4.pdf

Pythagoras Theorem, Sine Rule, Cosine Rule

http://www.ca.ixl.com

Perimeter of Polygon, Area of Rectangles, Area of Trapezoids. Challenge Exercises

http://www.cimt.org.uk/projects/mepres/alevel/pure_ch10.pdf

http://www.cimt.org.uk/projects/mepres/alevel/pure_ch15.pdf

http://www.cimt.org.uk/projects/mepres/alevel/fpure_ch1.pdf

http://www.thiel.edu/mathproject/CNAT/chapt1/section2/default.htm

A Proof of 'Pythagoras' Theorem.

Frank J. Swetz and T. I. Kao *Was Pythagoras Chinese?*

Week 7 – February 22, 2021 – Reading Week (No Classes)

Week 8 – Wednesday March 1, 2023

Continue from **Week 6**

** **Homework 2:** Covering Weeks 5, 6, 8; **To be submitted by Tuesday March 7, 2023**

Week 9 – Wednesday March 8, 2023

Continue from **Week 8**

Week 10 – Wednesday March 15, 2023

Continue from Week 9

*** **Homework 3:** Covering Weeks 9, and 10; **To be submitted by Tuesday March 21, 2023**

Week 11 March 22 to Week 13 April 5, 2023: Statistics

STATISTICS: Deals with Data. So our focus will be on the following: Types of Data: Data Collection – Random Sampling, Preparing Questionnaire: Data Presentation - Table and Graphical; Data Description by statistical measures - averages and dispersion; Analysis and if time permits some decision theory and inferential statistics. Emphasis is not on calculation or procedure but on conceptual understanding of the topics. There are statistical packages example SPSS, to do the 'manual' work and it will be for you to interpret the results.

OBJECTIVE: 1. To be an informed reader whenever statistics is either directly or indirectly implied in a report. 2. Basis for further statistics study. 3. Appreciation of statistical research. 4. Familiarity with SPSS

Types of Data and Data Collection and Presentation

http://www.cimt.org.uk/projects/mepres/book7/book7.htm

Types of Data, Data Collection and Presentation. There is interactive tutorial at:

http://www.cimt.org.uk/projects/mepres/book7/book7int.htm Units 11.1 and 11.2

Further topics on Data Collection at:

http://www.cimt.org.uk/projects/mepres/book9/book9.htm

Unit 18 sampling at:

http://www.cimt.org.uk/projects/mepres/book7/book7.htm

Quantitative Data Presentation and Description

'Complete' Statistics Text:

http://www.cimt.org.uk/projects/mepres/allgcse/pbtxt.pdf

(May work on some computers)

Step Up to A-level Math at:

http://www.cimt.org.uk/projects/mepres/step-up/index.htm

* **Test**: Schedule would be announced

NOTE: Course outline may be modified to reflect the class response to the topics.

Appendix G Ethics approval letter

UNIVERSITY OF TORONTO

OFFICE OF THE VICE-PRESIDENT, RESEARCH AND INNOVATION

RIS Protocol Number: 43503

Approval Date: 31-Jan-23

PI Name: Ms Jessica Stockdale

Division Name:

Dear Ms Jessica Stockdale:

Re: Your research protocol application entitled, "Understanding Transitional Year Students Perspectives on STEM Focused Fields of Study"

The Social Sciences, Humanities & Education REB has conducted a Delegated review of your application and has granted approval to the attached protocol for the period 2023-01-31 to 2024-01-30.

This approval covers the ethical acceptability of the human research activity; please ensure that all other approvals required to conduct your research are obtained prior to commencing the activity.

Please be reminded of the following points:

- An **Amendment** must be submitted to the REB for any proposed changes to the approved protocol. The amended protocol must be reviewed and approved by the REB prior to implementation of the changes.
- An annual **Renewal** must be submitted for ongoing research. Renewals should be submitted between 15 and 30 days prior to the current expiry date.
- A **Protocol Deviation Report** (PDR) should be submitted when there is any departure from the REB-approved ethics review application form that has occurred without prior approval from the REB (e.g., changes to the study procedures, consent process, data protection measures). The submission of this form does not necessarily indicate wrong-doing; however follow-up procedures may be required.
- An **Adverse Events Report (AER)** must be submitted when adverse or unanticipated events occur to participants in the course of the research process.
- A **Protocol Completion Report** (PCR) is required when research using the protocol has been completed.
- If your research is funded by a third party, please contact the assigned Research Funding Officer in Research Services to ensure that your funds are released.

Best wishes for the successful completion of your research.

OFFICE OF RESEARCH ETHICS
McMurrich Building, 12 Queen's Park Crescent West, 2nd Floor, Toronto, ON M5S 1S8 Canada
Tel: +1 416 946-3273 ● Fax: +1 416 946-5763 ● ethics.review@utoronto.ca ● http://www.research.utoronto.ca/for-researchers-administrators/ethics

Appendix H Copy of questionnaire

Transitional Year Programme
UNIVERSITY OF TORONTO

Questionnaire Consent Form

Date

Month Day Year

Have you taken courses in science or mathematics prior to TYP?

☐ Yes, only science courses
☐ Yes, only math courses
☐ Yes, both math and science courses
☐ Neither
☐

To me, SCIENCE is:

1 2 3 4 5
Ordinary Fascinating

To me, SCIENCE is:

1 2 3 4 5
Unappealing Appealing

To me, SCIENCE is:

1 2 3 4 5
Unexciting Exciting

To me, SCIENCE is:

1 2 3 4 5
Boring Interesting

To me, MATH is:

1 2 3 4 5
Ordinary Fascinating

To me, MATH is:

1 2 3 4 5

Unappealing Appealing

To me, MATH is:

1 2 3 4 5

Unexciting Exciting

To me, MATH is:

1 2 3 4 5

Boring Interesting

Do you plan to enter a STEM related field?

Yes
No
Undecided

Do any of the following sentiments apply to why you are not entering a STEM related field?

I'm not interested in the subject
I have always wanted to go into a non-stem related field
I do have an interest in STEM but not enough to pursue it as a line of work or study
I don't feel like I would succeed in STEM
STEM is too hard
I used to enjoy STEM but I would need to do too much catching up in order to study it

Has a bad grade in a STEM course made you less enthusiastic or engaged with the course material or subject as a whole?

☐ Yes
☐ Partially
☐ No
☐

Throughout your academic career, do you feel that the grades you have received in STEM courses (either at TYP or prior) accurately reflect your knowledge of the subject?

☐ Yes
☐ Partially
☐ No

What barriers have you faced during your educational journey in STEM fields? (check all that you feel apply to you)

- ☐ Mathematics (for example, you enjoyed chemistry, but the math component was confusing)
- ☐ Teachers (for example, you may have had a negative experience with a teacher in STEM)
- ☐ The course content (for example, you found the course was not engaging)
- ☐ The way the course content was taught (for example, you may have enjoyed the content more but the way it was being taught made it boring or difficult to pay attention to)
- ☐ I did not have access to STEM courses (for example, school did not offer STEM based courses)
- ☐ Lack of support or resources for me to continue in a STEM field (for example, your peers or family made you feel that you wouldn't succeed in STEM)
- ☐ Very few people in my community or social circle have pursued STEM fields. (for example, women are underrepresented in the STEM field you are interested in, which has affected your confidence in pursuing that field)
- ☐ As a member of a visible minority, I have faced unique barriers in accessing STEM education.
- ☐ ______

Do you feel you have had adequate support (either from learning institutions, peers, teachers, family etc) while learning a STEM focused course BEFORE TYP?

Yes
No
Somewhat
______

Do you feel you have had adequate support (either from learning institutions, peers, teachers, family etc) while learning a STEM focused course DURING TYP?

Yes
No
Somewhat
______

Throughout your educational journey, which methods of learning have you found the most helpful?

	Not at all helpful	Somewhat helpful	Helpful	Very helpful
Having access to lots of practice tests				
Hands on learning				
Lectures				
Tutorials or small group settings				

Self-learning modules
Homework
Projects

What learning strategies do you use and how effective are they?

	Not at all effective	Somewhat effective	Effective	Very effective, this is one of my main learning strategies
Memorization				
Drawing or making diagrams				
Talking to others about the material				
Attempting to apply what you've learned to your day-to-day life				
Taking notes/highlighting				
Doing practice problems				

On a scale of 1-5, do you feel prepared to take STEM courses in the future? (either within the University of Toronto or from other educational institutes).

	1	2	3	4	5	
Not at all prepared						Fully prepared

With the semester almost over, do you feel that your perspective of the sciences has changed at all?

Yes, but not in a good way
Yes, it's changed for the better!
No, I still feel the same way as I did before I came to TYP

Which areas do you feel TYP has helped to prepare you for university studies? (check all that apply)

- ☐ Math
- ☐ Science
- ☐ English
- ☐ Social studies
- ☐ Biology
- ☐

This space is open for you to write about anything you feel our questions missed, or if there was anything extra you wanted to add. If you're happy with your answers, click Submit. Once you press

Submit, you will be unable to change the answers you have provided.

Submit