ESC472: Electrical and Computer Engineering Capstone in Engineering Science

Winter 2021

Course Instructional Team Information

Before we dive into some information on the course, we think it is important to introduce ourselves.

Officially, the instructor is Philip Asare (email: philip.asare@utoronto.ca).

I am an Assistant Professor in the Institute for Studies in Transdisciplinary Engineering Education & Practice (ISTEP) and the Division of Engineering Science (EngSci). Prior to UofT, I was an Assistant Professor of Electrical & Computer Engineering and Swanson Fellow in the Sciences and Engineering at Bucknell University. I have a PhD in Computer Engineering from the University of Virginia, and a Bachelors and Masters in Electrical Engineering, both from the University of Pennsylvania.

Officially, the teaching assistant is Amr Mohamed (email: amr.mohamed@mail.utoronto.ca).

I am an Engineering Science alumnus (1T6+PEY). I am currently a PhD graduate student in the Department of Electrical and Computer Engineering researching data-driven control for cyber-physical systems. I have previously worked as an EIT at the Independent Electricity System Operator (IESO) and the engineering consultancy firm, Hatch.

We will both be working closely together on this course more like co-instructors.

Quick Useful Course Information

We will post all relevant course materials to the course Quercus site:
https://q.utoronto.ca/courses/206573

We will send announcements and emails through the Quercus.

We also a have a Piazza site for asynchronous group discussions:
https://piazza.com/class/kjvlcmpa3sb22u

Background and Motivation

Welcome to the Engineering Science Electrical and Computer Engineering Capstone (ESC472). Capstone courses typically serve as the culminating design course in a curriculum, providing students with an experience of integrating their knowledge in the context of an authentic engineering project; this one will be no different in that regard. This course is an opportunity for you to prepare for your transition out of university into the next chapter in your life by practicing your design skills working on an authentic engineering project.

One motivation for this course is that the Canadian Engineering Accreditation Board (CEAB) mandates that all engineering degrees must have a capstone course. According to the CEAB,

> *The engineering curriculum must culminate in a significant design experience ... based on the knowledge and skills acquired in earlier work and it preferably gives students an involvement in teamwork and project management.*

We agree that this is a good idea.

The CEAB is the accreditation body for engineering degree granting programs such as Engineering Science. An accredited engineering degree is one of the requirements for attaining the professional engineering (P.Eng) designation if that is a path you choose. Regardless of whether you want to become a P.Eng or not, the CEAB's requirements shapes undergraduate engineering education so they are worth paying attention to. Later in this document we will address Graduate Attributes, another CEAB perspective, and how they relate to the course outcomes.

Our specific motivation as educators in this course is to provide you with an environment where you can go through an authentic engineering experience, with lower stakes than working in industry (this is an educational environment after all). We want this experience to help you develop personally and professionally as you transition out of university into the rest of your adult life. In particular, the course focuses on the following general outcomes:

1. Leveraging previous knowledge and experience in design of an artifact that addresses a real-world opportunity in a way that demonstrates how well you have 'mastered' the various graduate attributes.
2. Experience working through an engineering design process from initial framing through verification and validation of a proof-of-concept prototype.
3. Reflect on your growth as an engineer and transition into the workforce.

This document provides you with information about the course and the rationale for various choices we made in design the course. It answers the questions:

- What are you getting yourself into by taking this course?

- Why is the course structured this way (and how do we hope the structure helps in your personal development)?
- What can you expect as resources to support you during the course?

We recognize that it is difficult to put together a comprehensive document that covers all relevant information so if there is information that you feel should be captured here that is missing, please let us know and we'll make sure to revise this document.

Philosophy

Before diving into the specifics of the course structure and activities, we feel it is important to let you know what philosophy has guided our design of this course (and expose some of our biases). This mixes a bit of the "what are you getting yourself into" and "why is the course structured this way".

Focus on Learning and Development

You are about to enter the "real world", as they say. We want to make this course as close to an experience in the "real world" as possible so that this experience can be most useful to your transition. However, this is still an educational experience, so we want to create an environment where you can *learn* as much as possible as well. This means, as much as possible, we have gotten rid of course structures and elements that get in the way of learning or reduce the authenticity of the experience. For example, you will mostly get qualitative feedback on your progress. This is intended to help you learn and improve as you make progress on your project. In addition, all the "Assignments" are structured to help your process and progress through the project.

Also, this is one of the last opportunities to learn in a low stakes environment so take advantage and get out of your comfort zone to explore areas and approaches you may have had the chance to get exposed to in the past. We understand that by this time you would have developed some preferences for kinds of projects and topics in ECE you are most interested in, but we believe it is important to strike the balance between depth in familiar areas and developing breadth in unfamiliar areas. Learning happens when one can try things, make mistakes, and identify ways to improve.

Our Role as Facilitators of Learning

The capstone will require you to actively apply creativity, critical thinking and problem-solving skills. We believe our best role in this is to provide an environment where you can experiment with new tools and methods, apply your own "style" and individuality to your work and product, and learn, not only from us and your teammates, but from the whole class. We also plan to expose you to different perspectives through guest lectures.

Staying True to the EngSci Motto

On the Engineering Science website, it says (emphasis added):

> **Our motto in EngSci at U of T is Engineers for the World (E4TW)** because our goal is to educate engineers who: seek to solve the world's most critical problems; have compassion for the human condition; want to collaborate with people across multiple disciplines, cultural backgrounds and 'thought perspectives' to achieve a better world; and encourage technological progress that improves life for citizens across the globe.

You will notice that the big emphasis is on "people". Although, your project will culminate in a "product", How you engage with each other and others external to the course, and the "process" you follow to arrive at that product will be most critical. A big part of the course will be orienting you to focus on the people, process, and product (the order is important), and how these affect each other.

Course Structure and Activities Overview

The following structures are in place for the course to help you in your development over the term:

1. *The Capstone Project.* This forms the basis for your learning and development. Majority of the course structure is built around this project.
2. *Scheduled Course Meetings.* These valuable times are for us to discuss topics relevant to your project work and general professional development.
3. *Assignments.* These are designed to help pace you through the term. They also provide some guidance on how to approach various aspects of your project. Some assignments are also to help you reflect on your individual growth.
4. *Assessments and Feedback.* These are to help you improve as you progress through the term. Some assessments and feedback are related to your project. Others are related to your individual growth, including your ability to contribute to the learning of your colleagues.
5. *Support and External Resources.* These are there to support you in your work. Much of what you need to accomplish this semester is not possible without proper support. We have worked with other units in the faculty to ensure that as much as possible you can access material and informational resources you need on your project. In addition, the university provides a number of life resources that support the balance of your academic work with your personal life and goals. We have highlighted some of these resources in the end of the document.

The course will proceed according to the rough schedule below. We will make adjustments as necessary. However, since this is a one-term capstone, the course moves quickly through the phases to ensure students can move to a verified and validated prototype quickly.

Dates	Activity
Jan 11th	Classes Start
Jan 11th to Jan 20th	Course logistics and team formation
Jan 21st to Feb 3rd	Framing of opportunity and design process
Feb 4th to March 3rd	Design and initial prototype planning
March 4th to March 31st	1st iteration of prototype (production, verification, and validation)
April 1st to April 16th	Quick 2nd iteration based on lessons learned from 1st iteration.
TBD (week of April 12 or after)	Demos/showcase
By April 30th	Finalize reports

Project Work

As we mentioned before, you will be learning by working on an authentic project going from initial framing through verification and validation of a proof-of-concept prototype.

Engineering almost always takes place in collaborative fashion with teams of people working together and with external stakeholders. You will therefore **work on a team** with other students. Given the expected enrollment, **teams will be sizes of three or four students**. You will also be expected to engage with external stakeholders to inform your design work.

Although we have scheduled meetings, we are expecting that **much of your project work will take place outside of the scheduled meeting times**.

Process and Product Dimensions

There are a number of dimensions along which to view your project work experience that we want to highlight. Within each dimension, project work may take various forms.

Mode of Operation

There are two major modes of operation that are related to each other:

1. Full/traditional entrepreneurial: where the team identifies a market and creates value for this "market" through their "product".
2. Client-based: where the team has a client, for whom the team creates value, by developing a product that creates value for a "market"

You will notice that in both cases, value is created for some "market". The main difference between these two modes of operation is that in the client-based case the team needs to

argue/demonstrate that by creating value for the market they have also created value for the client.

Different teams may be assigned to different modes of operation.

Nature of the Product

In all cases, the product must represent an integrated system that has distinct, identifiable components working together to achieve the overall system function.

The product may be embodied purely as hardware, purely as software, or a combination of both. Regardless of the form of embodiment, design efforts should demonstrate a crossing of the system hierarchy.

Nature of Knowledge Leveraged

As mentioned previously, this course integrates knowledge from previous experiences. As an ECE major, EngSci student, engineering student, and general university student, it is expected that you will use (as much as possible) knowledge from all these backgrounds, including, but not limited to theoretical knowledge, concepts, models, approaches from

- The discipline (ECE, broadly defined)
- General engineering
- Engineering design (Praxis and other course things)
- Relevant non-engineering disciplines (*e.g.*, social science, humanities, domain in which your "product" resides)

Nature of the Contribution

Your project can be seen as a contribution to technological progress. The contribution (or parts of it) may fall into one or more of these categories (there may be other ways to categorize):

- System integration: Addressing a market need by creatively integrating commercial off-the-shelf components. The stakeholder could be a consumer or other engineers. For example, integrating motions and GPS sensors with a platform connected to a cellular network to track the impact of courier shipping practices on mailed packages.
- Application domain expansion: Applying, in novel ways, existing knowledge or technology to a task. This can take the form of repurposing or finding new opportunities, uses or avenues for ECE methods and tools, or making new connections between ECE and other domains. The stakeholders are other engineers and those in the application domain. For example, using circuit theory to analyze and optimize the design of a transportation network.

- Engineering science: research and propose a novel technology, tool, or method with broad application. The stakeholder might be other engineers or technical domain expert. For example, developing an algorithm that efficiently (in terms of memory use and speed) implements artificial intelligence (AI) computations and tasks on microcontrollers to enable AI at the edge.

Graduate Attributes

The CEAB has a list of twelve graduate attributes that they believe every engineering student must be well-versed in by the time they graduate and continue to develop throughout their engineering career. Generally, a course will focus on a small subset of these attributes; however, since the capstone is supposed to be the culminating experience where you integrate all your knowledge, it is expected that your experience in this course addresses the following nine out of the twelve attributes in some way. The list of attributes is below, and you can find more information on them in this document provided by the CEAB: https://engineerscanada.ca/sites/default/files/accreditation-criteria-procedures-2016-final.pdf#page=15

3.1.4 Design
3.1.5 Engineering tools
3.1.6 Teamwork
3.1.7 Communications kills
3.1.8 Professionalism
3.1.9 Impact of Engineering
3.1.10 Ethics and equity
3.1.11 Economics and project management
3.1.12 Lifelong Learning

You should endeavor to bring the various considerations the attributes point to to your project work.

Scheduled Course Meetings

The course meeting times are

Tuesdays	11:00 am to 12:00 pm EST
Wednesdays	10:00 am to 12:00 pm EST

We will honor UofT time and start at 10 minutes after the hour.

We will use the session on Tuesday to review or introduce students to concepts in Engineering design, to discuss assignments or other topics of interest to the class, or for discussions with invited guests.

We will use the Wednesday session primarily for us to meet with teams and discuss progress and plans for coming weeks. When not in a meeting with us, your team can use the Wednesday session to work on project development or course assignments. However, we expect you to be present for the Wednesday session so that, if needed, we may pull you from your team meetings to discuss topics that may be relevant to the whole class.

Each Wednesday starting the second week, **a student in the class will lead us in acknowledging the land that the university operates on**. We will send out instructions and a schedule for this task in the first week. For information on the history and rationale for land acknowledgment :

Assignments

There are a number of individual and team-based assignments designed to help you as you work towards the course outcomes.

Personal Statement

This is the first assignment. It is designed to help you describe your background, experience in engineering design, and interests, in ways that are helpful in team formation as well as developing a workable team dynamic that leverages your strengths as well as provides room to grow in areas that need improvement.

Process and Product Document

One of the most valuable artifacts that comes out of engineering design is documentation of the process that led to the recommended design candidate, as well as details on how to reproduce the design candidate. Some of the key questions this document is supposed to answer are

- What is the product?
    - Why is it important?
    - How does it produce value and potential negative consequences, and for whom it produces value and potential negative consequences?
    - How does the product work?
- What is the engineering process followed to arrive at the final design?

This document is the final deliverable, but it will be developed iteratively over the course of the term with regular check-ins.

Weekly Team Meeting Presentations & Writeups

As mentioned previously, each week, we will meet with your team to discuss progress so far and plans for the upcoming week. One member of the team will be responsible for leading the informal presentation (this responsibility will rotate to give everyone the opportunity). During this meeting, we will ask questions and offer comments based on the information presented to

us. After the meeting, your team is responsible for writing up how this discussion is incorporated into your new plan for the upcoming week and submitting both what was presented (including the original plan for the upcoming week) and the adjustments made based on the discussion.

Reflections

You will develop three relatively short reflections on your past and current experiences in engineering design and how these have shaped your growth in this space. The first will be closer to the beginning of the course and focused more on your past experiences and initial experiences in this course. The second will be around the middle of the course focusing on any new insights you have gained about yourself working on the project in this course and how past experiences factor into this insight. The last one will be an overall reflection of both the course and your time at the university written in the style of a letter to a future student.

Assignment Schedule

The schedule below gives a sense of tentatively when particular assignments are due (note that list is not fully chronological). We may make adjustments to this as the course progresses and will work with you on these adjustments so they are not too disruptive.

Deliverable	**Due Date & Time (EST)**	**Submission**
Personal Statement	Sunday, Jan 17th at 23:59	Individual
Weekly Team Writeups	(once projects start) Each Friday at 23:59	Team
1st Reflection	Friday, Feb 12th at 23:59	Individual
2nd Reflection	Monday, Mar 22nd at 23:59	Individual
3rd Reflection	TBD Exam Week	Individual
Product and Process Document		Team
Iteration 1: Initial Ideas and Framing	Wednesday, Jan 27th at 9:00	
Iteration 2: Plans for Moving Forward	Wednesday, Feb 10th at 9:00	

Iteration 3: Design Considerations and Production Plan	Wednesday, Mar 3rd at 9:00	
Iteration 4: Component Design and Verification	Wednesday, Mar 17th at 9:00	
Iteration 5: Initial System Verification and Validation	Wednesday, Mar 31st at 9:00	
Iteration 6: Full Report Draft and Demo	TBD Last week of class or Exam Week	

Assessments

We will assess your work in three major areas summarized in the table below. Implicit in these assessments is **how well you communicate your work**. Note that the percentages given are to provide you a rough sense of how much weight that area takes in our overall assessment. They are not to be interpreted as mutually exclusive categories of points where you can, for example, earn all points in the "Process and Product" category while neglecting points in the "Participation" or "Reflections" category.

Category	**Description**	**Rough Weighting (%)**	**Focus**
Process + Product	How you are approaching your design process, including (but not limited to) working with each other and external stakeholders, managing resources available to you, and documenting your process. How you are documenting the design of your product so others can understand the engineering decisions that factor into your design.	60	Team + Individual
Reflection	How you are reflecting on your growth as an engineer throughout this process.	24	Individual

Participation / Engagement	How you are contributing to enriching the course and the learning of your teammates and classmates.	16	Individual

Our assessments will be holistic and designed not to penalize learning. Work that is below expectations earlier in the term is okay so long as there is demonstrated improvement in work by the end of the term.

Support and Resources

The university provides general resources available to students to help with academic life. We have also worked with a number of units on campus to provide support for specific activities in the course

Mental Health and General Life Support

Inclusivity

You belong here. The University of Toronto commits to all students, faculty and staff that you can learn, work and create in a welcoming, respectful and inclusive environment. In this class, we embrace the broadest range of people and encourage their diverse perspectives. This team environment is how we will innovate and improve our collective academic success. You can read the evidence for this approach here.

We expect each of us to take responsibility for the impact that our language, actions and interactions have on others. Engineering denounces discrimination, harassment and unwelcoming behaviour in all its forms. You have rights under the Ontario Human Rights Code. If you experience or witness any form of harassment or discrimination, including but not limited to, acts of racism, sexism, Islamophobia, anti-Semitism, homophobia, transphobia, ableism and ageism, please tell someone so we can intervene. Engineering takes these reports extremely seriously. You can talk to anyone you feel comfortable approaching, including your professor or TA, an academic advisor, our Assistant Dean, Diversity, Inclusion and Professionalism, the Engineering Equity Diversity & Inclusion Action Group, any staff member or a U of T Equity Office.

You are not alone. Here you can find a list of clubs and groups that support people who identify in many diverse ways. Working together, we can all achieve our full potential.

Accommodations:

The University of Toronto supports accommodations for students with diverse learning needs, which may be associated with mental health conditions, learning disabilities, autism spectrum, ADHD, mobility impairments, functional/fine motor impairments, concussion or head injury, blindness and low vision, chronic health conditions, addictions, deafness and hearing loss, communication disorders and/or temporary disabilities, such as fractures and severe sprains, or recovery from an operation.

If you have a learning need requiring an accommodation the University of Toronto recommends that students register as soon as possible with Accessibility Services at https://studentlife.utoronto.ca/service/accessibility-services-registration-and-documentation-requirements/.

Phone: 416-978-8060
Email: accessibility.services@utoronto.ca

Mental Health

As a university student, you may experience a range of health and/or mental health challenges that could result in significant barriers to achieving your personal and academic goals. Please note, the University of Toronto and the Faculty of Applied Science & Engineering offer a wide range of free and confidential services that could assist you during these times.

As a U of T Engineering student, you have an Academic Advisor (undergraduate students) or a Graduate Administrator (graduate students) who can support you by advising on personal matters that impact your academics. Other resources that you may find helpful are listed on the U of T Engineering Mental Health & Wellness webpage, and a small selection are also included here:

- Accessibility Services & the On-Location Advisor
- Graduate Engineering Council of Students' Mental Wellness Commission
- Health & Wellness and the On-Location Health & Wellness Engineering Counsellor
- Inclusion & Transition Advisor
- U of T Engineering Learning Strategist and Academic Success
- My Student Support Program (MySSP)
- Registrar's Office
- SKULE Mental Wellness
- Scholarships & Financial Aid Office & Advisor

If you find yourself feeling distressed and in need of more immediate support resources, consider reaching out to the counsellors at My Student Support Program (MySSP) or visiting the Feeling Distressed webpage.

Course Specific Support & Resources

Project Budget

We have worked with the Division of Engineering Science to provide each team with a budget of $500 CAD. We have also put mechanisms in place so your team can use this money without having to pay out of pocket first and getting reimbursed later. This includes a material and parts ordering system put together by the Myhal Light Fabrication Facility staff. We will provide more information on this system and ways to request use of funds once projects and teams have been resolved.

Support for Fabrication and Ordering Parts and Materials

The Myhal Light Fabrication Facility is providing digital fabrication services for students where you can order parts to be 3D-printed or laser cut remotely. In addition, for this course specifically, the LFF has some parts and materials in stock that you can order for use in your prototype (if need be). If parts are not stocked locally, we have a mechanism in place for you to still order from the relevant vendors. Regardless of where the parts come from, the LFF staff have been kind enough to put together an order request system for this course that will allow to place orders, get them approved by us, and get them fulfilled.

Support for Test and Measurement Equipment and Experimentation

The folks in the ECE teaching labs have also offered to work with us to figure out how you can conduct tests and measurements of your prototypes. This will be done on a case-by-case basis as it is difficult to anticipate ahead of time what the needs here are.

Useful Policies and Procedures

Students in Capstone Design are expected to comport themselves professionally and act according to the following University policies, guidelines and interpretations:

- Code of Behavior on Academic Matters
- Code of Student Conduct
- Academic Integrity
- Petitions and Appeals
- University of Toronto Inventions Policy
- University of Toronto Policy on Official Correspondence with Students

Note on Intellectual Property

When engaging in a design course, there is always a potential to develop artifacts and ideas that are considered intellectual property (IP). You also need to recognize what is others' IP that may be incorporated in your work. Generally, owners or IP provide information on permissions of use and when to request explicit permission for use. It is important to review the university's Inventions Policy to understand the IP implications of your work in this course.

Public Disclosure and Use of Student Work

** Adapted from ESC472 Winter 2020 Syllabus*

Students agree that by taking this course all submitted deliverables may be used for teaching and learning purposes in this course or others, or to support research into improving Engineering education. Any such use will confirm to the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans. **Students who are concerned about the intellectual property ramifications of potential disclosure must notify the course instructors at the very least prior to the end of the academic session (earlier if possible)**. Students who have questions about the University of Toronto Inventions Policy should inquire with the course instructors.

Change Log

Version	Date	Major Changes
1	January 14th, 2020	Added the due date for Personal Statement assignment Added link to course Piazza site