PROPOSAL FOR TRAINING PROGRAM

Waterloo Institute for Complexity & Innovation
University of Waterloo

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Working Internal Document

EXECUTIVE SUMMARY

The Waterloo Institute for Complexity Innovation at the University of Waterloo is examining opportunities to incorporate a teaching element to their existing offerings, in line with their mandate develop a formal education program on complex systems. This report summarizes the proposed recommendations.

Summary of Recommendations

- Through an exploratory review of similar program structures at the University of Waterloo and beyond, along with several consultations with program leads, we considered six program structures and ten program offerings.
- Recommendations were assessed based on criteria such as ease of implementation and potential for multiplier effects.
- Favored program recommendations include a certificate program targeted to working professionals and a collaborative program for graduate students.
- Favored program offerings include graduate electives, project based courses, summer institutes, and graduate internships graduate internships.

Summary of Implementation

- We recommend that WICI take a phased approach to the development of a complexity program, which will span a five year period.
- The Professional Development office highlights that a certificate offering is a revenue generating stream, with the potential to earn the institute upwards of $100,000 per year.

Summary of Course Offerings

- A systematic review of over 7,500 courses offered at the University of Waterloo, found that 166 courses references complexity and systems thinking.
- Text analysis of course descriptions indicate that the University of Waterloo takes a clear focus on tools to address complexity, but is also applied across both technical solution oriented topics, like mathematics and qualitative process based topics like environment and management.
- Topic modelling was applied to delinate latent fields of instruction on complexity and systems thinking. Topics on healthcare, managenement, engineering were notable topics of interest.

MOTIVATION

The Waterloo Institute for Complexity Innovation at the University of Waterloo is examining opportunities to incorporate a teaching element to their existing offerings, in line with their mandate develop a formal education program on complex systems. WICI's 2019 annual report states 'members have strongly emphasized that training in the science behind complex systems targeted to students, research staff, and faculty is a missing piece on campus' (p 7) and thus, a Graduate Research Assistant was hired to explore avenues to incorporate a teaching element into WICI's offerings.

Various models have been discussed including cross-university core courses, a certificate, workshops, and/or summer schools. One option being strongly considered is a certificate in complexity, which targets working professionals looking to acquire the increasingly sought technical and strategic competencies required to incorporate 'big picture' thinking into organizations. Another option being considered is a collaborative complexity program, which is a cross-disciplinary graduate program offering a suite of master's and doctoral program with a specialization in complexity and systems thinking. A certificate in complex systems that targets working professionals could be a precursor to a multi-disciplinary graduate program in complex systems, laying the foundations of course offerings, which could be translated into a collaborative program for current graduate students. This training would be the first of its kind offering in Ontario.

Our training will take a multidisciplinary approach, with course offerings that target quantitative and qualitative analysts and decision makers across industries. WICI currently spans several key departments and faculties across the University of Waterloo. Our steering committee encompasses several departments including planning, knowledge integration, environment and resource studies, systems design engineering, public health, and psychology. Thus the steering committee incorporates voices of four of the seven faculties.

There is a compelling case for WICI to offer training in complex systems. WICI members have emphasized that complex systems training for students, research staff, professionals, and faculty is a missing piece on campus. There also appears to be demand for training that targets working professionals who desire technical and strategic competencies to incorporate 'big picture' thinking into organizations. In the past year, the Waterloo Institute for Complexity & Innovation (WICI) has been approached independently by two professionals working on community development projects (one an international development fund, the other an American professional based out of Washington, DC) for advice, collaborative opportunities, and/or professional development training in complexity that might make poverty alleviation efforts more successful. Finally, other Universities such as the University of Texas, University of Arizona, and University of Michigan have begun offering executive, professional development, and continuing education courses to meet this increasing demand. Both internal members and external partners are specifically requesting training in systems thinking, problem identification, and complex-systems appropriate methods for program evaluation.

EXPLORATORY REVIEW

Our exploratory review began by identifying select programs and offerings from other institutes at the University of Waterloo and complexity related offerings from other institutions in North America. Notably, this is not an exhaustive list of offerings at the University, but rather some illustrative examples of different options to consider when developing a complexity program. The table below summarizes some exemplary programs and offerings identified.

Program	Type	Multi-disciplinary	Course Offering	Seminar Participation	Internship	Experiential Education	Summer Institute
Collaborative Water Program	Collaborative Program						
Theoretical Neuroscience	Diploma						
SWaGUR	Graduate Program						
Climate Risk Management	Diploma						
Bioengineering & Biotechnology	Graduate Program						
CSCS	Graduate Certificate						

The ***Collaborative Water Program***, co-ordinated by the Water Institute offers 15 interdisciplinary Master's offerings and 9 interdisciplinary PhD offerings, in partnership with 11 academic units across the University of Waterloo. The academic units span all 7 faculties at the University. Graduate students in the collaborative water program are required to take two "WATER" courses. The first, WATER 601 provides an overview of current issues and challenges across a variety of disciplines, such that students have a broad knowledge base of theories, concepts, and terminologies from various water-related fields. This is taught collaboratively by faculty members and professionals from multiple disciplines. The second, WATER 602 course includes a 6-8 day field trip to the Grand River Watershed, to learn about watershed issues and management approaches first hand by water practitioners, managers, scientists, volunteers and others concerned with watershed health. Finally, students will present their respective research at a Water Institute organized research seminar, intended to develop the student's ability to communicate their research. This approach of mandatory course and seminar requirements encourages graduate students from multiple faculties to collaborate across disciplines.

The ***Center for Theoretical Neuroscience***, offers students enrolled in one of the select Masters of PhD programs to receive a diploma in Theoretical Neuroscience. Students working with one of 12 supervisors associated with the center are eligible for the diploma. The associated members span 8 departments, including psychology, applied math, systems design engineering, statistics, computer science, biology, philosophy, and applied health sciences. The diplomas are offered in conjunction with a graduate degree, adding an additional, usually interdisciplinary, qualification to the higher degree. Students are required to complete 4 courses, including one mandatory research seminar, one of two offerings in systems design engineering, and two courses from a cross-disciplinary list of recommended courses. The mandatory course, TN 700 consists of attending and reporting on 10 seminars presented by the center, including presentations from students, faculty, and visiting researchers. SYDE 556/750 subsequently ensures all

students have a base level understanding of the topic. Finally, students select 2 of a list of 24 approved courses, providing disciplinary expertise across the student's respective field of study.

SWaGUR is an interdisciplinary program co-ordinated by the Games Institute for students completing a Master's or PhD degree at either the University of Waterloo or the University of Saskatchewan. Students in the fields of computer science, English, psychology, management sciences, and systems design engineering may apply through one of 11 potential supervisors across the two universities. In addition to the degree requirements, Masters and PhD students will take an additional 4 to 5 courses to meet the SWaGUR requirements, including a foundation level course, and related courses of interest. Graduate students must also complete a mandatory internship.

The ***Climate Risk Management diploma***, coordinated by the Interdisciplinary Center on Climate Change is an offering for early- to mid-career professionals interested in integrating climate risk management within their field of work. The program is offered fully online and part time through the department of Geography and Environmental Management. Students in this program are required to take one mandatory course and 3 of 4 additional offerings. The mandatory course, GEMCC 600 ensures all students have a base understanding of global climate challenges. The other courses offer students knowledge in a range of competencies, from analytics, business, community planning, and carbon accounting.

The ***Center for Bioengineering and Biotechnology*** was recently awarded the NSERC CREATE grant to develop a biomedical technology graduate program. The proposal prioritizes building competencies in both the research side and the business side of the industry, by partnering with the Grand River Hospital, Starfish Medical, and Synaptive Medical. The curriculum will include clinic and industry partnerships, commercialization courses, international exchanges, and professional skills workshops. Each student will be part of a team that includes a research supervisor, a clinician, and the manager of a biomedical engineering company. Before they begin their research, students will need to prove that they've spent time with clinicians and patients in settings relevant to their area of research. This will help ensure that the solutions they develop are viable and easier to commercialize.

The **Center for the Study of Complex Systems (CSCS)** at the University of Michigan is a multi- and interdisciplinary program designed to encourage and facilitate research in the general area of nonlinear, dynamical and adaptive systems. Affiliated researchers apply cross-disciplinary techniques, incorporate models, measures, and insights from traditional disciplines (physics, biology, computer science, economics, and mathematics) in novel ways, to identify properties that hold across a wide range of complex systems. The center currently has eight core members and 32 affiliated members across nearly every college of the University. The Complex Systems Graduate Certificate allows students from different fields to integrate the rich paradigms and useful analytic and modeling techniques of complex systems into their own research. The program is accessible to students who are simultaneously enrolled in a graduate degree program or who have a Bachelor's degree or higher from any University and are U.S. citizens. Students are required to take five courses, including 2 core courses, 1 of 4 core electives, and 2 additional approved electives. Below is a brief look at each core course. In addition to the undergraduate and graduate programs, the CSCS offers additional activities, including an annual workshop in partnership with the Santa Fe Institute, which features a keynote presentation that is open to the public with other sessions by invitation only.

CONSULTATIONS

Following our review of program offerings we consulted with leads for two program offerings at the University of Waterloo; the Diploma program in Climate Risk Management and the Collaborative Water Program. These meetings were intended to provide a more detailed understanding of the program development process at the University of Waterloo. We finally consulted with the core WICI committee, providing a brief update on the exploratory review conducted to date and to garner input on which programs and offerings were favored for deeper study.

Graduate Diploma (GDip) in Climate Risk Management

We consulted with Johanna Wandel and Daniel Scott about the Geography and Environmental Management department's Graduate Diploma (GDip) in Climate Risk Management. This online diploma is available to individuals with an undergraduate degree in a related field and requires that students complete four courses on a part time basis.

In developing the GDip program, a business case was prepared and sent to the Dean of Environment. However, a multi-department approach might need the approval of multiple deans. Completing a statement of interest, including details on program type, structure, outcomes, enrolment, and tuition expectations would be the first step in this process. If required, Amanda McKenzie director of Academic Integrity and Quality Assurance, can provide more guidance on this process. To gain support, prepare a clear marketing strategy that demonstrates an interest in the course and obtain letters of support from instructors that teach related courses. Fundamentally, the program must demonstrate how it will be cost neutral to the Deans. Other notable discussions revolved around the need to obtain an open time slot for online courses (which may be difficult given current circumstances), that in-house instructors are strongly preferred to industry experts, and that the Center for Extended Learning can support with online course development.

Collaborative Water Program

We also consulted with Kevin Boehmer, Managing Director of the Water Institute. The Collaborative Water Program, co-ordinated by the Water Institute offers 15 interdisciplinary Master's offerings and 9 interdisciplinary PhD offerings, in partnership with 11 academic units across the University of Waterloo, spanning all 7 faculties at the University. It is notable that Institutes do not have academic status in supporting and facilitating education (refer to Policy 44).

The Water Institute and Collaborative Water Program was initially funded from a financial gift from CBR, which compensated instructors so departments would not have to contribute financially. The program was built from the bottom up, where key faculty committed to supporting the program approached their own departments and ultimately the senate and the province. The collaborative program was prepared as traditional new graduate program, using the same statement of interest templates mentioned above. However, the program went through the multiple various departments for comment and 'conditional approval' before being approved by faculties, provost, and senate.

Now, the Water Institute works closely with Deans to estimate funding and teaching contributions from each department. A joint committee governs the program, however there is a lead academic unit which rotates every two years under the reporting structure. Currently, engineering, environment, and science are the three main contributors to the Collaborative Water Program, however the institute is responsible for promoting the program.

Core WICI Committee

The WICI committee were provided with a summary document that delineated potential program structures and offerings based on what has been identified by our exploratory review of programs at the University of Waterloo and beyond. We identified 6 programs and 10 offerings that we proposed as recommendations to the core committee. The table below highlights the programs and offerings considered, however, the Appendix at the end of this report presents a detailed description of each along with relevant examples.

Programs	Offerings
A Undergraduate Minor	A Graduate Elective
B Graduate Certificate	B Undergraduate Elective
C Graduate Diploma	C Project Based Course
D Graduate Specialization	D Seminar Attendance
E Graduate Program	E Research Seminar
F Professional Accreditation	F Graduate Internship
	G Undergraduate Internship
	H Experiential Education
	I Summer Institute

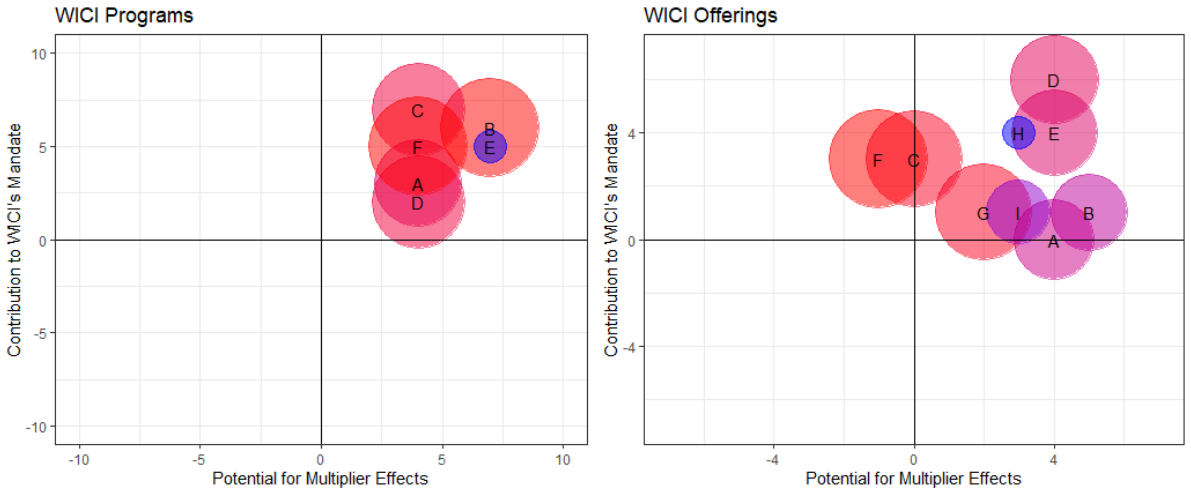
We asked the core WICI committee to consider the feasibility of each program and offering through a short online survey. The committee was asked to rank each recommendation on five criteria:

1. *Contribution to WICI's mandate*: Does the structure or offering advance the institutes mandates of complex-system training, the development of a Canadian network for complex systems, or the institute's brand?
2. *Potential for multiplier/spillover effects*: Would the structure of offering have longer term benefits - or spillover effects - for the institute? Consider the benefits that may be realized by the students, faculty, the institute, and the Canadian Network for Complex Systems (CNCS).
3. *Ease of implementation*: How quickly could this structure or offering be undertaken? Are there existing offerings that can be capitalized or will new material need to be developed? Consider whether the undertaking may face regulatory or administrative barriers. Examples of barriers may arise from financing, policy, reporting, human resources, competing offerings, and collaboration with other agencies and universities.
4. *Overall desirability*: There would be an expectation that WICI's members will need to contribute to the success of the program. This may come in the form of making formal connections with your faculties, developing course content, or co-delivering courses. How likely would you provide

support in the form of advocacy or program development if this structure or offering was implemented by WICI?

5. *Time Horizon*: How long would it take to implement this program or offering? Consider for example, administrative barriers that may arise in its development.

We concede that there are some methodological and statistical limitations to collecting the committees input through an online survey, such as a small sample size (6) and missing benchmarks. In aggregating the survey responses, we allocated greater weight based on the frequency of scores. For example, if a recommendation was rated (1, 1, 0, 1, 2, and 1) it would have a mean of 1 and a frequency weighted score of (4x1 + 1x2 = 6). Due to the simple exploratory nature of our examination we feel confident that the survey gave us a clear understanding of how the committee perceives each program and offering. We plot the perception of each recommendation based on its contribution to WICI's mandate, potential for multiplier effects. The size of the circle is proportional to its ease of implementation, whereby a smaller circle is more difficult to implement. A graduate certificate and collaborative program are both ranked highly on contribution to WICI's mandate and potential for multiplier effects. However, the graduate certificate would be easier to implement in a shorter time horizon. On offerings, graduate electives, project based courses, and a summer institute are ranked relatively high on both contribution to WICI's mandate and potential for multiplier effects. Graduate internships are also ranked highly for potential multiplier effects. The aggregated scores are presented in the appendix.



RECOMMENDATION

Through our exploratory review and consultations we recommend that WICI take an iterative approach to developing a complexity program at the University of Waterloo, beginning with a single offering to a fully developed collaborative program over the course of 5 years. The timeline below presents a stepwise process to achieve this goal.

Aug 2020 **Exploratory Report** This initial report positions WICI to develop a complexity program highlighting the steps required to achieve that goal.

Sep 2020 **Initiate Proposal for Certificate** In partnership with Professional Development at the University of Waterloo, prepare a proposal for one introductory course on complexity.

Oct 2020 **Market Research** Conduct early market research, identifying the target audience and their interests in complexity.

Jan 2021 **Course Offering** Offer an initial 'Introduction to Complexity' course. Use this course to gauge interest and conduct additional market research.

Apr 2021 **Revise Strategy** Following the success of the introductory course, identify avenues of future teaching.

Sep 2021 **Establish Certificate in Complexity** Offer a complete certificate through Professional Development.

Sep 2022 **Extended Courses to Graduate Students** Offer complementary in-class or online offerings to current graduate students.

Sep 2023 **Extend Certificate Pathways** Consider opportunities to create pathways for future teaching, whereby certificate holders can progress toward a graduate program.

Jan 2024 **Develop Collaborative Complexity Program** Begin the process of approval and design of a collaborative program.

Sep 2025 **Launch of the Collaborative Complexity Program** Offer a collection of graduate degrees in Complexity across the University of Waterloo.

Certificate

Faculties do not offer certificate programs at the University of Waterloo. Rather, certificates are offered through or in partnership with a University Office; the most prominent being Professional Development, Centre for Teaching Excellent, and the Student Success Office. The appendix below highlights a list of certificates offered through the University along with a brief description of certificate requirements. Of the University offices, Professional Development is most aligned with the type of certificate WICI is considering, targeting professionals (non-students) interested in learning applicable and in-demand skills.

To offer a certificate through the Professional Development office, begin the process by completing the 'Professional Development & Lifelong Learning Program Proposal' (attached). Justify the program, through examining the demand for this offering and how it ties to lifelong learning. WICI is also expected to propose a course design, including select topics, learning outcomes, and assessments. WICI can work in collaboration with Professional Development to strengthen the proposal, prior to the formal approval process through the Professional Development Advisory Committee.

Professional Development offers both single course offerings and multi-course certificates. It is recommended that WICI begin with a single introductory course offering, which will be easier to develop and can be used to conduct additional market research on the target audience, demand for content, and future offerings. Iterative and agile pathways of progress are favored when developing a certificate, however, long term pathways for learning are equally important.

The formal Complexity certificate will follow a similar structure to current in-class and online offerings through Professional Development, at approximately 28-30 contact hours. This can include courses content on complexity theories, methods, and applications. Learners will be required to have completed a bachelor's degree from an accredited institution, to meet the rigor of this training and by the end of the training, learners will have gained technical competencies in the theory and application of systems thinking in organizations and for partnerships, leadership competencies in effective management, and strategic competencies in adaptive capacity and operational efficiency.

For greater impact, incorporate pathways for lifeline learning. This may include additional specialized courses that target specific industries (such as healthcare), technical capabilities (such as software), or select audiences (analysists or executives). Pathways for lifelong learning can contribute to improved participation, diversity in training, and better skilled individuals. Pathways may also lead to a graduate program, where individuals who have completed the certificate program may continue their education through a graduate degree.

Capitalizing on the resources developed over the course of the certificate program, begin the process of developing a collaborative complexity program. Seek approval letters from department leads and faculty deans. Formalize the cost and reporting structure. Seek support from the Water Institute with regards to the development process.

Collaborative Program

In line with the collaborative water program, a collaborative complexity program may be designed with a combination of required courses, electives, and a research seminar. Below is a sample program structure that incorporates elements of proposed programs and offerings. The Collaborative Complexity Program may span academic units and may be offered to all current graduate students at the University, however admission into the program may be competitive. Students may be required to take three additional courses in addition to their program requirements, including a combination of core courses and approved electives; however, the select courses may count towards their elective requirements.

CMPLX601 – Seminar. In the Complexity Research Seminar Course, students must attend 10 to 12 seminars offered by WICI or affiliated institutions on a discretionary basis. Students are requred attend and prepare a two page written deliverable for each seminar they attend, summarizing the main ideas of the seminar and how the topic relates to complexity research. Students may also be required to attend at least two seminars that adopt qualitative research methods and two seminars that adopt quantitative research methods, to expand their understanding of how complexity research is applied. Students may complete these course requirements over the period of three academic semesters.

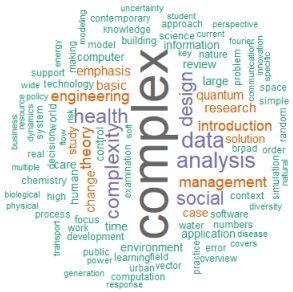
CMPLX602 – Introduction to Complexity and Complex Systems. After successfully completing the research seminar course, students attend an in-class or online graduate course on complexity studies. This course will span one academic semester. Course content will include aspects of traditional learning as well as student centered learning and active learning. Topics covered include 1 a brief outline of complexity studies, 2 theories of complexity studies, 3 quantititative and qualitative methods, and 4 applications of complexity studies across disciplines. This course will have four deliverables, including two essays on applying theories and methods of complexity studies in their field of research, one guest lecture in an undergraduate course, as selected by the student or assigned by the instructor, and the preliminary design of a capstone project and identification of a potential WICI affiliated research collaborator.

CMPLX603 – capstone. In the capstone course, students apply their expertise in complexity systems by applying to one of two national competitions. Student must partner with one current WICI affiliated researcher that is not their supervisor and submit an application to either the Map the System or the RSA student design award. The final deliverable for this course is a successful application to either competition.

Students who complete the collaborative complexity program gain 5 core competencies. First, students gain a comprehensive understanding of the qualitative and quantitative complexity research currently undertaken at the University of Waterloo and through affiliated partners. Second, students will share a base level understanding of what complexity studies entail across disciplinary lines. Third, students will be able to apply theories and methods of complexity studies into their own field of study. Fourth, students will learn and practice articulating complexity related topics to other students, researchers, and practitioners. Finally students will apply expertise in complexity studies through the successful involvement in one of two international complexity competitions

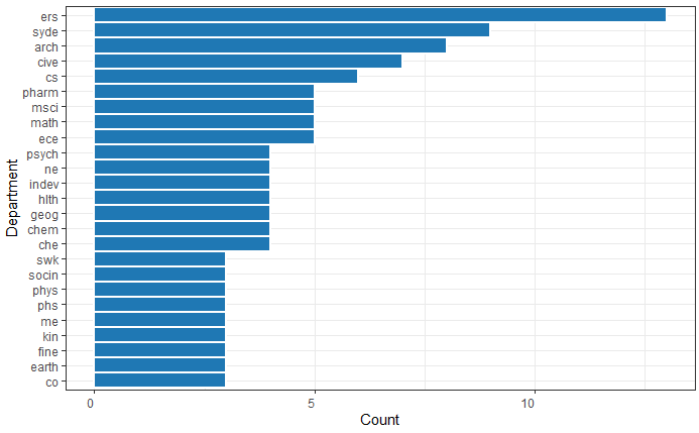
COURSE OFFERINGS

The final contribution of this report is a systematic analysis of complexity and systems thinking course offerings at the University of Waterloo. With thanks to the Office of the Registrar, we were given access to 7,533 undergraduate and graduate course offerings at the University of Waterloo, including the course code, title, description, and instructor. Of those offering, 166 reference either complexity or systems thinking. We examine these 166 courses is greater detail.

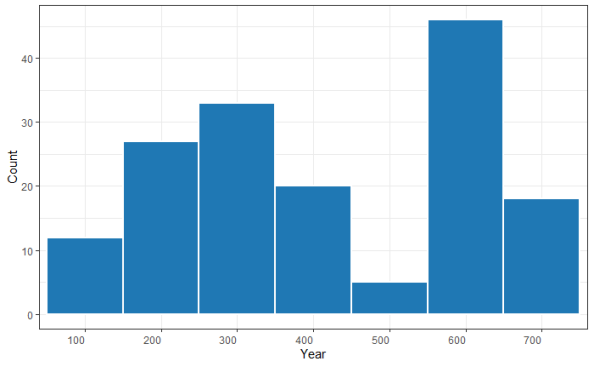


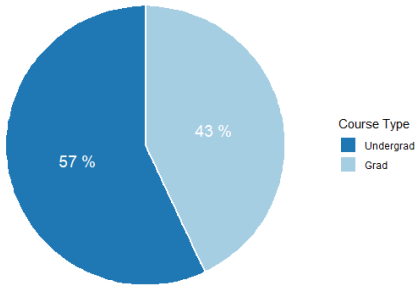
Descriptive Analysis: Complexity offerings by department and year

We begin with a descriptive analysis of complexity courses by department and year. At first glance, there is an even mix of technical and social science offerings on complexity and systems thinking Environment and Resource Studies for example, offers 16 courses on this topic. Other relevant fields include systems design, architecture, civil engineering, and computer science.

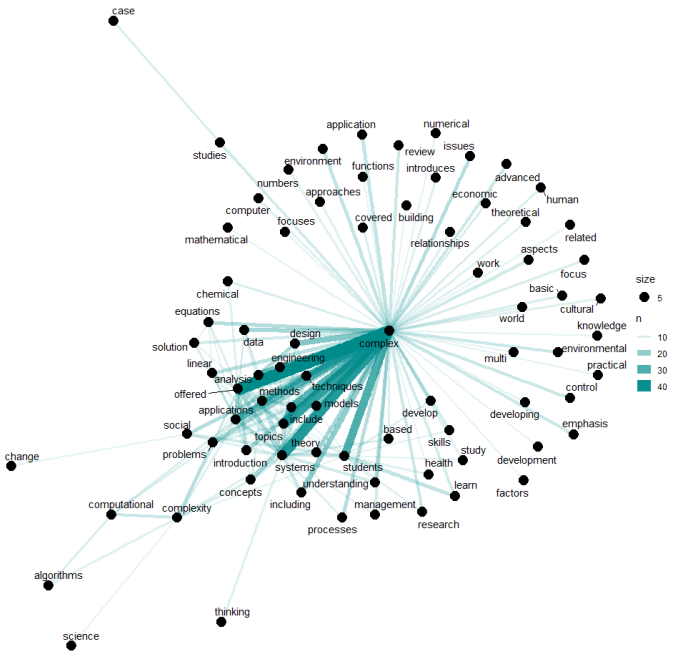


Complexity related courses are more prevalent in upper year courses, however, 57 percent of identified courses are taught at the undergraduate level.

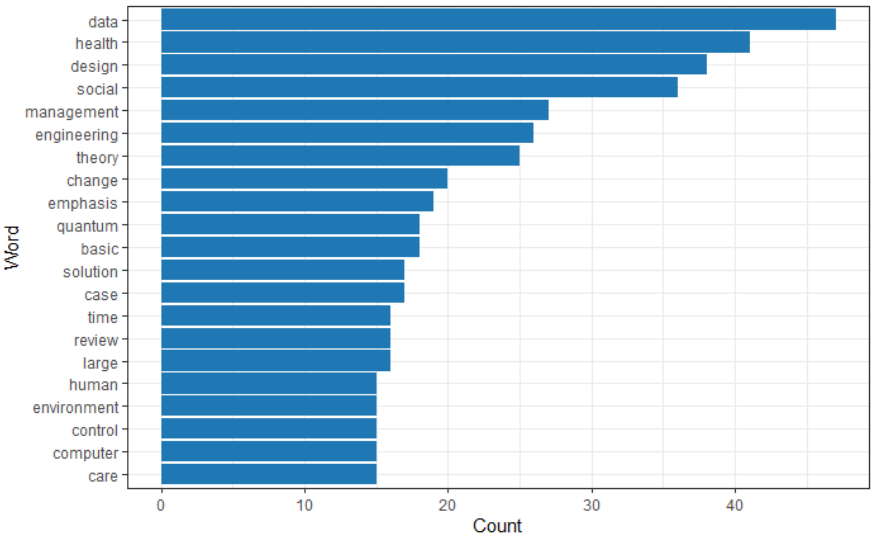




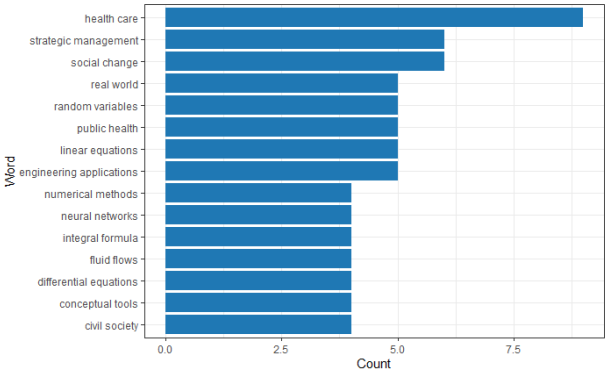
Our analysis turns next to the course descriptions. What do we mean by complexity here at the University of Waterloo? Complexity studies are most associated with words like theories, techniques, methods, and analyses, suggesting a clear focus on tools to address complexity. However, this graph also tells us that complexity is applied in various ways, from the more technical and solution oriented topics of mathematics, science, and computation, to more qualitative and process based topics of environment, development, management, and culture.

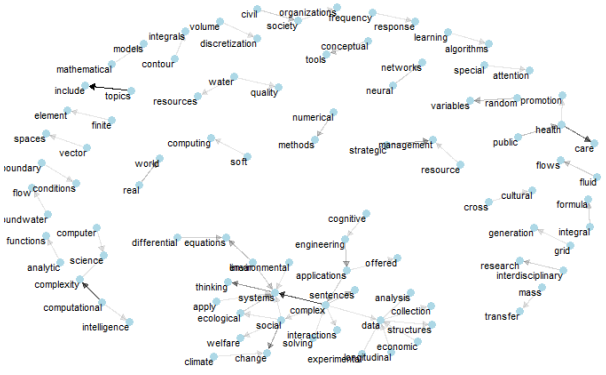


By frequency, words like data, health, and design are among the commonly used in course descriptions that reference complexity or systems thinking.

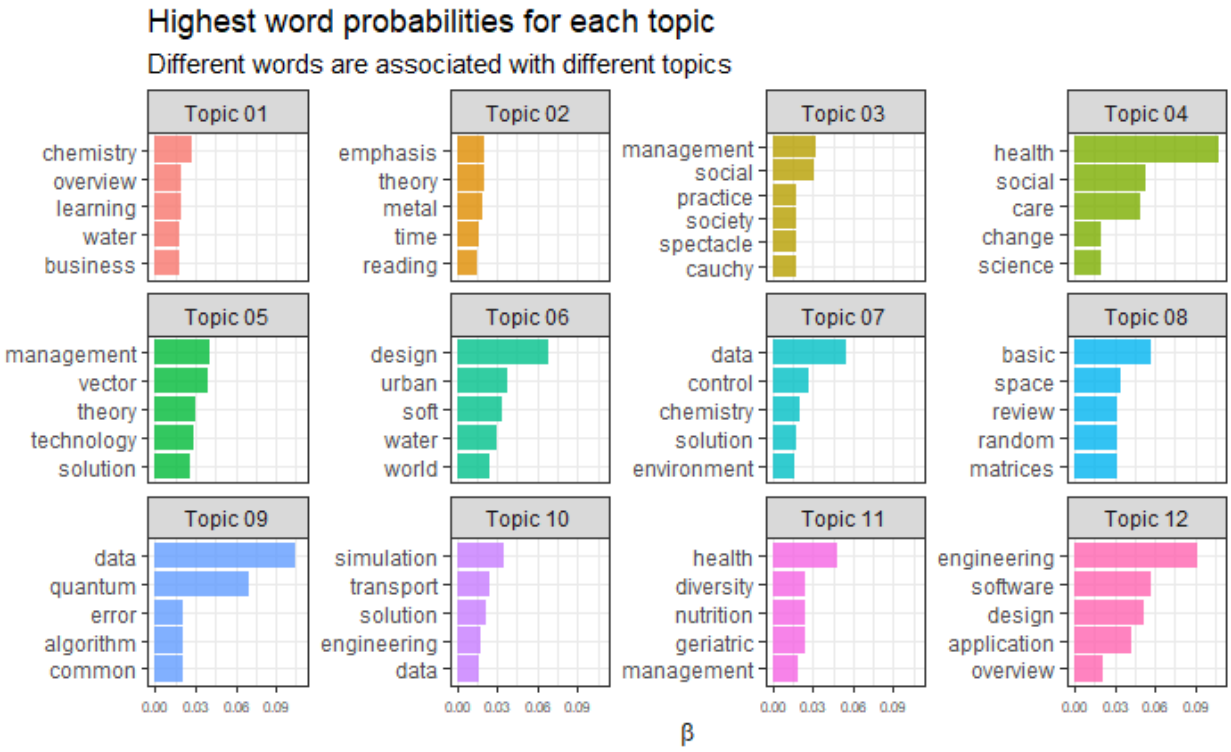


However, looking at frequent phrases gives greater context about how complexity studies is applied. Healthcare is the most common application of complexity studies at the University of Waterloo, followed by topics related to strategic management and social change. The associated word combination networks maps adjacent words based on how frequently they appear. This first gives greater nuance on complexity related topics. We see for example that water in complex systems often refers to water quality or water resources. It also infers more complex combinations, such as social ecological systems, cognitive engineering applications, or complex data analysis.





We finally run a topic model analysis on the course descriptions. This method identifies latent topics on complexity studies as well as identifies courses that fall into each topic. This may be particularly useful in developing a list of approved electives based on select areas of interest. Some notable topics include those on healthcare in the context of social change (topic 4) and in the context of nutrition (topic 11). Topics on management take a technological (topic 5) and social lens (topic 3). Topics related to engineering software, application, and design (topic 12) and quantum studies (topic 9) are also notable fields of study. Most courses fit into one of these topics; the appendix below highlights the top 3 courses in each bucket as illustrative examples of courses with similar fields of study.



Appendix – Programs and Offerings Considered for Recommendation

Programs

A. Undergraduate Minor. All undergraduate students at the University of Waterloo can enroll in the Complex Systems Minor, provided that the student has declare a major. Students may be required to take up to five courses, including a combination of core courses and approved electives.

Example: Complex Systems Minor at the University of Michigan

B. Graduate Certificate. A graduate certificate can be offered to students who are not enrolled in a graduate degree program at the University of Waterloo but have completed an undergraduate degree or equivalent from an accredited Canadian institution. Students may be required to take up to five courses, including a combination of core courses and approved electives.

Example: Complex Systems Graduate Certificate at the University of Michigan

Example: University of Toronto Policy on Certificates (For Credit and Not-For-Credit)

C. Graduate Diploma. In contrast to a graduate certificate, graduate Diplomas are designed to prepare students for employment. The typical duration is one to four semesters at the Master's level and one to six semesters at the doctoral level. Requirements are integrated throughout the program, and may include an experiential learning component and four to six graduate courses.

Example: Diploma in Theoretical Neuroscience, University of Waterloo

D. Graduate Specialization. A collaborative specialization is an intra-university graduate program that provides an additional multidisciplinary experience for students enrolled in and completing the degree requirements for one of a number of approved degree programs. A specialization is achieved at the University of Waterloo by successfully completing a set of courses defined by the academic unit that collectively contain the necessary depth of material to ensure a student's level of mastery.

Example: Master of Engineering (MEng) Specializations, University of Waterloo

E. Collaborative Graduate Program. Collaborative programs can span academic units or Universities. Students may be required to take up to three additional courses, including a combination of core courses and approved electives across disciplinary boundaries. By completing the requirements of the collaborative program, students may receive a specialization or diploma from the associated institutes.

Example: Collaborative Water Program, University of Waterloo

Example: Waterloo-Laurier Graduate Program in Geography

Example: Biotechnology Technician, University of Waterloo / Conestoga College

F. Professional Accreditation. Though structured like a graduate certificate or diploma, a professional certificate targets early- to mid-career professionals interested in integrating complexity within their field of work. The program may be offered fully online and part time and students are required to take a combination of core courses and approved electives.

Example: Climate Risk Management Diploma, IC3, University of Waterloo

Example: Masters of Environment and Business, SEED, University of Waterloo

Offerings

A. Undergraduate Internship. Undergraduate students affiliated with WICI may be directed towards partner organizations or researchers to support the advancement of complexity thinking.

Example: SWaGUR (Games Institute) Undergraduate Internship, University of Waterloo

B. Graduate Internship. Graduate students affiliated with WICI may be directed towards partner organizations or researchers to support the advancement of complexity thinking. Students are required to take one or more four-month internships related to a topic related to their program and accredited through WICI.

Example: PhD Computer Science Internship, University of Waterloo

C. Seminar Attendance and Documentation. Students may be required to attend and document their participation on a select number of seminars presented by the institute or across campus that would be relevant to their research, including presentations from students, faculty, and visiting researchers.

Example: TN700, Theoretical Neuroscience Research Seminars, University of Waterloo

D. Introduction to Complexity Undergraduate Elective. The University of Waterloo may offer an existing or new course for undergraduate students on complexity and systems thinking. This course may be available to all students across the university.

Example: SYDE332, Introduction to Complex Systems, University of Waterloo

E. Project based course / Capstone. Students may be required to participate in a project based course, perhaps related to the Map the System competition or the RSA student design awards.

Example: Water 602, Collaborative Water Program, University of Waterloo

Example: Capstone Design, Engineering, University of Waterloo

F. Research Seminar (Poster Presentation). Students may be required to present their respective research at an organized research seminar, intended to develop the student's ability to communicate their research. This approach encourages students from multiple faculties to collaborate across disciplines.

Example: Research Seminar, Water Institute, University of Waterloo

G. Summer Institute. An annual workshop between the University of Waterloo and an affiliated institution. This event may be limited to doctoral candidates and accessible by invitation only. A keynote presentation may be open to the public.

Example: Annual U-M-SFI Workshop, University of Michigan.

Example: Summer Institute, Water Institute, University of Waterloo

H. Experiential Education. Graduate students affiliated with the institute may partner with a researcher and practitioner in the field to conduct research on a topic that is relevant to practitioners.

Example: Biomedical technology graduate program, University of Waterloo

Appendix - Aggregated Results from WICI Consultation

Raw Data

ID	Name	Type	Contribution to WICI's core Mandate	Potential for Multiplier Effects	Speed/Ease of Implementation	Overall Desireability	Time Horizon (short/long)
A	Undergraduate minor	Program	3	4	-2	4	1
B	Graduate Certificate	Program	6	7	0	5	-2
C	Graduate Diploma	Program	7	4	-1	4	-2
D	Graduate Specialization	Program	2	4	-1	-1	0
E	Collaborative Graduate Program	Program	5	7	-6	2	0
F	Professional Accreditation	Program	5	4	0	1	0
A	Undergraduate Internship	Offering	0	4	0	-2	-1
B	Graduate Internship	Offering	1	5	-1	0	-1
C	Undergraduate Elective - Introduction to Complexity	Offering	3	0	6	4	0
D	Graduate Elective - Introduction to Complexity	Offering	6	4	3	6	0
E	Project based course / Capstone	Offering	4	4	2	2	0
F	Seminar Attendance and Documentation	Offering	3	-1	7	2	-2
G	Research Seminar (Poster Presentation)	Offering	1	2	6	1	-2
H	Summer Institute	Offering	4	3	-7	-2	0
I	Experiential Education	Offering	1	3	-4	-1	0

Appendix – Certificate Offerings at the University of Waterloo

Issuing Body	Certificate	Description
Professional Development	In Class Certificates	Each certificate is comprised of 3-5 courses which are offered at various times throughout the year. Some offer a selection of courses to choose from, so you can tailor your certificate to your personal needs and interests.
Professional Development	Online Certificates	Each certificate is comprised of 3 or 4 courses which are fully online and are offered every month. There are no admission requirements, and no required time to complete the certificate.
Center for Teaching Excellence	Certificate in University Teaching	Students must successfully complete three Graduate Studies (GS) courses (GS 901, GS 902 and GS 903) and have one year to complete each course. GS 901 is a pre-requisite for GS 902. Note: These courses may only be applied for credit towards the Certificate in University Teaching and may not be counted towards any degree.
Center for Teaching Excellence	Certificate in University Language Teaching	CTE and the Department of Germanic and Slavic Studies jointly offer the Certificate in University Language Teaching (CULT). CULT is tailored to language instruction and is open to all currently enrolled Waterloo doctoral students in languages. Learners are required to attend teaching workshops on language teaching and participate in three microteaching sessions.
Student Success Office	Leadership Certificate Program	Workshops are free to any current UWaterloo student (you must be registered in the term). You can complete the 12 workshops in any order and at your own pace throughout your university career. By completing all 12 workshops, you are eligible to receive the leadership certificate. This program does not qualify for university credit
Student Success Office	Global Experience Certificate	Undergraduate students are required to submit an application and a GEC milestone plan outlining how they will complete the following GEC requirements: Three for-credit courses (1.5 units), specifically two sequential language courses and one Global Studies course. One international experience for a minimum 6 consecutive weeks. One cross-cultural volunteer experience for a minimum of 20 hours during one term. Reflection piece (e.g. written reflection, photo journal, or journal entries) about your international experience or cross-cultural volunteer experience.
EDGE	EDGE	Students complete six milestones as part of the EDGE certificate: a skills identification and articulation workshop, in which students practice recognizing their skills and expressing them to employers in a confident, concise fashion; a career development course, in which students develop core career-seeking skills and align their career goals with their values, skills and interests; three work or community experiences, in which students explore a wide variety of opportunities both inside and outside of the classroom and reflect on their personal growth; and a capstone workshop, in which students

		tie everything together and develop an action plan for post-graduation success.
Sustainability	Sustainability Certificate	Waterloo's Sustainability Office, in collaboration with Organizational and Human Development, is excited to offer a free Sustainability Certificate for employees of the University. To receive the certificate, an employee must: Complete all seven sessions (can be completed over multiple terms); Come to all session having read the pre-reads and be ready to engage with colleagues; Complete the short multiple choice quizzes after each session (5 minutes each)
Economic Development Program	Certificate in Economic Development	The Economic Developers Association of Canada (EDAC) and University of Waterloo have partnered to offer a suite of professional development programming. Our courses and seminars are accredited by EDAC and will help you get your Certified Economic Developer designation (EcD). It consists of two courses, Year 1 and Year 2. Year 1 includes a 1-2 page reflection and Year 2 includes a 15 page research paper.

Appendix – Topic Modelling of Top Courses by Topic

Code	Title	Description	Topic	Score
earth621	Aqueous Geochemistry	a) Basic thermodynamics and activity-fugacity relationships. Chemical equilibria, ion association and complexing, oxidation-reduction reactions. Models for aqueous equilibria in high concentration solutions. b) Interaction of groundwater with porous media; mineral dissolution/precipitation reaction kinetics, ion exchange, surface ionization of oxides. c) Use of computer codes such as PHREEQE and GEOCHEM to simulate mass transfer in geochemical systems. Examining and modelling chemical evolution in groundwater flow systems.	1	0.9518491
enbus602	Introduction to Sustainability for Business	This course reviews the history of global environmentalism; societal expectations and business responses; and the emergence of corporate social and environmental responsibility. It systematically presents environmental (climate change, air pollution, water quality and quantity, energy and resource consumption, etc.), and social (human rights, health, poverty, ethics, fair trade, etc.) issues, their science, status and priority; technological, regulatory and policy responses; and implications for business. This course introduces concepts for business sustainability, including systems thinking, complexity and resilience, corporate responsibility, materials and energy flows and transformations, economic and market mechanisms, and relates these to business operations, marketing and strategic management.	1	0.9505613
enve275	Environmental Chemistry	Overview of risk, biosphere compartments and contaminant fate. Composition of water. Electroneutrality and activity. Reactions and speciation including reaction kinetics, mass transfer, vapor pressure, equilibrium, and chemical thermodynamics. Equilibrium chemistry including Log-concentration diagrams, titration and buffering intensity, dissolution/precipitation, carbonate system, hardness, and complex formation. Classification, nomenclature, physical/chemical parameters and partitioning of organic compounds. Basic redox chemistry including: half cell reactions, Faraday and Nernst equations, and pE-pH diagrams. Four labs. [Offered: W]	1	0.9740412
avia204	Professional Pilot Program Course IV	This course continues from AVIA 203 and provides the required Preparatory Ground Instruction to prepare students for the air exercises to be completed during in-aircraft instruction that is conducted as part of the course. Students will complete a dual cross border flight to the United States as well as a dual flight into high density controlled airspace (CYYZ). Students also complete a check-out in a complex aircraft and acquire additional cross-country pilot-in-command time. Students will have acquired approximately 110 hours total flight time by the end of the course. This course also includes the g	2	0.9729775

		round school required to prepare the student to write the Transport Canada Commercial Pilot Licence - Airplane examination.		
chem717	Advanced Transition Metal Chemistry	Magnetochemistry of transition metal compounds. Electronic spectra of complex ions including applications of molecular orbital and ligand field theories. Stabilization of unusual oxidation states and coordination numbers. Bonding, structure and reactivity of certain important classes of metal complexes, e.g. metal hydrides, metal-metal bonded species, biologically-significant model systems such as macrocycles.	2	0.9555927
syde292	Circuits, Instrumentation, and Measurements	Active and passive circuit elements, Kirchhoff's laws, mesh and nodal circuit analysis, principle of superposition; step response of first and second order networks; sinusoidal steady state analysis using complex impedance phasors; input-output relationships, transfer functions and frequency response of linear systems; operational amplifiers, operational amplifier circuits using negative or positive feedback; diodes, operational amplifier circuits using diodes; analog signal detection, conditioning and conversion systems; transducers, difference and instrumentation amplifiers, active filters, A/D and D/A conversion. [Offered: F]	2	0.9723240
ers622	Biosphere Reserves as Social-Ecological Systems	The Georgian Bay Biosphere Reserve is one of 16 UNESCO biosphere reserves in Canada, and is used as a setting to learn about sustainable community development, adaptive resource management, and social and ecological resilience. The main objective is to link practical experience "on the ground" with some of the theoretical concepts related to sustainability and complex social ecological systems.	3	0.9476866
indev308	Introduction to Social Entrepreneurship	This course uses the case study method to examine the challenges of starting, funding and operating an early-stage social change venture in a developing country. The focus is on ventures that address urbanization and poverty. Students explore the complexities of managing and sustaining growth, the role of governing boards, and the role of private sector partnerships and resources. Innovative public/private partnerships are examined. The challenges and opportunities associated with engaging diverse partners with differing agendas are considered from the perspective of the entrepreneur, investor/donor, local community leaders and legal counsel.	3	0.9500156
pacs603	Building Civil Society	This course explores operational aspects of civil society organizations such as visionary leadership, goal setting, evaluation, report writing, financial management, applied research skills, and human resource management. Students will also examine codes of conduct and practice, including rules, laws and customary understandings that guide the work of civil society organizations. Students will research contending views of civil society organizations and their complex relationships with governme	3	0.9584211

		nt and business, thereby developing a philosophical and ethical framework for evaluating civil society action.		
bme364	Engineering Biomedical Economics	This course examines key economic issues in health care and biomedical industries. Topics include the market for medical care, health insurance, various models of healthcare delivery and competition and the role of government in policy, financing and delivery of health care. This course will train students to use economic analysis to model and understand the complex interactions between health care delivery, insurance markets, health innovators, governments, and firms. [Offered: F]	4	0.9534436
indev603	Global Health	This course explores aspects of the distribution, diffusion, determinants and delivery of health and health care in a global context. Building on foundational skills (i.e. basic understandings of epidemiology; the social determinants of health) the course will review a range of case studies (e.g. infectious disease; water; access to care; global environmental change) from a variety of regions around the world. Students will gain an appreciation for the complexity of the issues, as well as science-policy bridging.	4	0.9462965
swk602r	Social Work Practice in Health	This course examines practice models and multi-level methods of intervention for effective social work practice in health care, including health promotion, disease prevention, assessment, treatment, rehabilitation, continuing care, and discharge planning within the context of social, economic, environmental, and cultural variations. The distribution, determinants, as well as psychological and behavioural aspects of health and disease across the life span are addressed. Practice models incorporate competence and empowerment as central themes. New models of care are considered, including primary health care, the impact of socio-cultural factors on health and well being, the significance of family relationships and resources in the management of chronic and complex health conditions, and interventions that support individual and family capacity to adapt to acute health crises or chronic health conditions. (Note: This is an online course).	4	0.9713270
cive774	Advanced Numerical Methods for Environmental Applications	The analyses of natural and/or manmade environmental systems commonly lead to quantitative descriptions, or mathematical models, of the underlying chemical, biological and physical processes. Numerical models are used for complex situations that may involve spatial variability of material properties, non-uniform geometry, and transient boundary conditions. The objective of this course is to introduce you to theoretical and practical aspects associated with numerical methods for environmental applications. Topics include: review of field equations, conservation laws, and continua; classification of PDEs; types of boundary and initial conditions; finite difference method, error analysis and stability; equation solvers; weighted residual techniques; finite element method; introduction to the finite volume	5	0.9439308

		method; techniques for advective dominated flows; sensitivity methods; and the solution to coupled non-linear equations.		
dm766	Strategic Management of Technology	This course focuses on the strategic management of technology and innovation established firms. We take an evolutionary process perspective. The fundamental ideas underlying the perspective are: (1) that a firms technology strategy emerges from its technological competencies and capabilities, (2) that the technology strategy is shaped by evolutionary external (environmental) and internal (organizational) Forces. The course draws on strategic management, economics and organization theory for analytical tools to address important challenges faced by senior and middle managers in technology based firms. The course is practice oriented. Case studies of various real life situations will require in-depth analysis to be complemented with specific action recommendations. * To develop an awareness of the range, scope and complexity of the issues and problems related to strategic management of technology and innovation * To develop an understanding of the state of the art of strategic management of technology and innovation * To learn how to practically apply theoretical concepts in strategic management of technology and innovation.	5	0.9663449
socin602	Design Thinking for System Change	This course covers the history of design thinking as a tool for supporting system change at local and broad scales - from designers like Bruce Mau, who uses this approach to describe what he calls "massive change", to complexity thinkers like Brian Arthur who explores the nature of technological innovation. The course also investigates the methodological implications of design thinking approaches to strategy development and implementation.	5	0.9279703
ece457b	Fundamentals of Computational Intelligence	Introduces novel approaches for computational intelligence based techniques including knowledge- based reasoning, expert systems, fuzzy inferencing and connectionist modeling based on artificial neural networks. The focus is on the use of soft computing approaches to deal effectively with real world complex systems for which their mathematical or physical models are either non-tractable or are difficult to obtain. The main thrust is on designing computationally intelligent systems with human like capabilities in terms of reasoning, learning and adaptation. Tools of computational intelligence could be used in a wide range of engineering applications involving real world problems such as in planning problems, intelligent control, autonomous robotics, speech understanding, pattern analysis, network design, face recognition, communication systems to name a few. [Offered: W]	6	0.9635278
ece657	Tools of Intelligent Systems Design	Conventional approaches for tackling complex systems are usually implemented under the assumption of a good understanding of the process dynamics/functionalities and its operating environment. These techniques fail, however, to provide satisfactory results when applied to ill-defined processes (for which analytical and experimental modeling may	6	0.9691933

		not be easily obtained) that may operate in unpredictable and possibly noisy environment. Recent developments in the area of intelligent systems and soft computing have presented powerful alternatives for dealing with the behavior of this class of systems. This course outlines fundamentals of soft computing based design approaches using such tools as approximate reasoning, fuzzy inferencing, neural networks, evolutionary algorithms, and neuro- fuzzy systems. Fundamentals and advances on these procedures are outlined along with their potential applications to various real world applications in virtually most fields of engineering including pattern recognition, system planning, classification, power generation, intelligent transportation, systems and control, intelligent mechatronics, optimization, communication, robotics and manufacturing, to name a few.		
indev612	Introduction to Water Resources	This course presents a broad survey of water resources processes and issues. How much water does the world need to support growing human populations? What factors influence water quality, droughts, floods, and waterborne diseases? What are the potential effects of climate change on the world's water resources? This course presents a thorough introduction to the complex world of water resources. The fundamentals of the science of water, aquatic ecology, geomorphology and hydrology, chemistry, and biology of lakes, rivers, and wetlands are covered. Major disease issues, worldwide water quality and quantity problems, and potential solutions are examined.	6	0.9614134
enve231	Inorganic Environmental Process Principles	Atomic theory, bonding, stereochemistry and transition metal chemistry as related to catalysis and pollution abatement. Some thermodynamic aspects of inorganic chemistry, stability of metal complexes and complex ions in solution. Principles and applications of atomic and molecular structure to environmental chemistry and engineering (e.g. ozone, CFCs, NOx, and SOx). Selected inorganic chemical processes of industrial importance, e.g. sulphuric acid, nitric acid, ammonia, phosphate, caustic, iron ore, uranium. Impact of process design and chemistry on the environment. [Offered: F, S]	7	0.9567571
hlth706	Advanced Epidemiological Methods	Building on HLTH 606, this course provides an in- depth survey of theory and methods in epidemiology, focusing on answering complex research questions using epidemiologic methods. Course topics include modeling multinomial, count, rate, and survival data and disease transmission; infectious disease dynamics; assessing the reliability/validity of measurement instruments; an in- depth examination of various study designs (e.g., case control, nested case control, case- cohort, randomized controlled trials, panel studies, and hybrid study designs); critical appraisal of the medical literature; and systematic reviews and meta-analysis.	7	0.9600246

span218	Parallel Revolutions in a Nascent Continent	This course provides a broad foundation to the varied and complex geographical, ethnic, social, and historical forces that have shaped contemporary Latin American nations from the early 19th-century independence period to current affairs. Students will be introduced to the diverse regions of the continent: Mexico, Central America, the Caribbean, the Bolivarian republics, and the Southern Cone. Students will analyze and discuss nation-building factors such as European-African-Asian-New World interactions, ethnic mixtures, military takeovers, revolutions, U.S. interventions in the region, and migratory experiences. Discussions will also be aimed at contrasting and comparing the contemporary and diverse cultural manifestations of the peoples living in Latin America and the cultural transformation of Latin Americans who have emigrated to other parts of the world, as well as the perceptions of Latin Americans in other cultures.	7	0.9601018
econ221	Statistics for Economists	This course introduces students to describing economic data and drawing inferences from features of economic data. Starting from fundamental axioms of probability, students will learn about the calculation of probabilities of basic events and the features of random variables, the most important tool for representing the outcomes of complex economic phenomena. Students will describe discrete and continuous random variables via their probability distributions and summary statistics such as means and standard deviations, as well as the relationships between two random variables in terms of covariance, correlation, and simple regression models. The concepts of hypothesis testing and confidence intervals, and the fundamentals of statistical inference are discussed for basic features of random variables and for comparing the features of more than one random variable.	8	0.9324412
sds326r	Philosophy and History of Social Welfare	Social welfare from the 18th century to the present. The effects of religious, political, economic and cultural factors on social welfare, development, and the continuing influence of inherent attitudes, philosophies, and values on this complex institution. Focus on the Canadian social welfare system.	8	0.8974880
stv303	Cross-Cultural Change, Technology and Society	The course will examine the concept of cross-cultural change as more than a consequence of contact between ethnic and national groupings. Technological change and the mutual interaction between technology and culture produce new cross-cultural change and challenges. The purpose of the course is to help students understand and identify the complex interaction between technology and culture and its impact on design and the choice of technology. Students will be expected to use this knowledge as a decision-making tool.	8	0.9354966
amath871	Quantum Information Processing	Review of basics of quantum information and computational complexity; Simple quantum algorithms; Quantum Fourier transform and Shor factoring algorithm: Amplitude amplification, Grover search algorithm and its optimality; Completely positive trace-preserving maps and Kraus representation; Non-	9	0.9754438

		locality and communication complexity; Physical realizations of quantum computation: requirements and examples; Quantum error-correction, including CSS codes, and elements of fault-tolerant computation; Quantum cryptography; Security proofs of quantum key distribution protocols; Quantum proof systems. Familiarity with theoretical computer science or quantum mechanics will also be an asset, though most students will not be familiar with both.		
co481	Introduction to Quantum Information Processing	Basics of computational complexity; basics of quantum information; quantum phenomena; quantum circuits and universality; relationship between quantum and classical complexity classes; simple quantum algorithms; quantum Fourier transform; Shor factoring algorithm; Grover search algorithm; physical realization of quantum computation; error-correction and fault-tolerance; quantum key distribution. [Offered: W]	9	0.9626394
earth458l	Field Methods in Hydrogeology	This course exposes students to a wide variety of field and laboratory techniques for collecting hydrogeologic data and to gain experience in interpreting the data. Advantages and limitations of various measurement and data reduction techniques for evaluating groundwater flow systems are demonstrated in a set of field exercises carried out at the groundwater demonstration facility located on the university North Campus. These exercises illustrate the complexity of natural systems and the need for good data collection and interpretation skills when characterizing such systems . [Offered: F,S]	9	0.9550141
cive755	Micromechanics of Soils	The theory of application of statistical mechanics to explain engineering behaviour of soils as discrete assemblies of particles. The introductory topics include mathematical descriptions of soil fabric, fabric tensor, definition of stress tensor in terms of average intergranular forces and characteristics of fabric, evolution of fabric due to shear deformations. Effects of particle shape and stiffness on macroscopic properties. Applications of micromechanics to constitutive models of granular materials. Drained and undrained response, behaviour under complex states of stress and effects associated with principal stress rotation.	10	0.9609528
earth651	Advanced Groundwater Modelling	This course covers advanced numerical modelling topics in groundwater flow and contaminant transport in the subsurface. Topics to be explored include two- and three-dimensional transport in groundwater systems, density/ heat-dependent flow/transport, flow in the vadose zone, immiscible flow of non-aqueous phase liquids, multiphase dissolution and mass transfer processes, transport of biodegrading or chemically interacting contaminants, transport in fractured systems, transport in the vapour phase. The focus is on the use of models to obtain insight into the complex coupled processes that control groundwater contamination and remediation problems. Students will work with their own as well as existing models.	10	0.9666450

me663	Computational Fluid Dynamics	This course presents the concepts and details required to develop computer codes for the simulation of complex multidimensional fluid flows. The following topics will be covered: the finite volume discretization method, discretization schemes for diffusive fluxes, iterative solution algorithms, multigrid acceleration techniques, first and second order bounded discretization schemes for advective fluxes, special treatments for the coupled momentum and mass conservation equations, pressure redistribution techniques, velocity-pressure solution techniques, and extensions to multi-dimensions. Enrichment topics will be chosen from the following research areas: grid generation, turbulence modelling, and emerging discretization and solution algorithm technologies.	10	0.9575737
bet580	Consulting	This course is useful for anyone considering working as a consultant, either for a consulting firm, as an independent entrepreneurial consultant, or as an internal consultant to large organizations. Some of the competencies skilled consultants have include understanding business needs from a holistic perspective, developing innovative ideas, expert people skills, influence, and change management. Course topics may also include key stages in the consulting process, issue diagnosis, managing difficult clients, consulting frameworks, analytical approaches to solving complex problems, engagement management, building a consulting toolset, change management processes, negotiation, and advanced presentation techniques. We will also cover aspects of the business of consulting. [Offered: F]	11	0.9524371
kin146	Introduction to Human Nutrition	An introductory course on human nutrition. Students will be introduced to core topics in nutrition including function of nutrients, nutrient requirements, diet assessment and planning, food composition and the complex interrelationships between food, nutrition, and health. Factors that affect the human diet such as biology, psychology, sociology, environment and political policy will also be examined, as well as key areas of nutrition focus for life stage groups.	11	0.9531987
swk600r	Diversity and Health	This course studies the impact of diversity on health in Canada and across nations. It provides an understanding of the complex interaction among aspects of diversity. The course examines and critiques the methods used in the study of these concepts and issues related to the measurement of health among diverse groups. The ultimate goal of this examination is to help students develop an appreciation of the impact diversity has on assessments and study of health, health status, and health promotion in Canada and other nations. The course is designed to integrate different sources of information about diversity by utilizing critical thinking skills for the consumption of health information. (Note: This is an intensive on campus course with an online component).	11	0.9594509
arch677	Survey of Digital Design Tech	This course provides an overview of the software and hardware technologies to support the design of an architecture that is more holistically conceived on cultural, social, health, technical and formal grounds that would otherwise be possible. What is taught facilitates an integrated design process where all disciplines collaborate through all phases of a p	12	0.9594797

	nologies for Architecture	roject to achieve a sustainable design. There will be an exploration of software applications including the generation of landscapes and vegetation, energy analysis, acoustics, lighting, structure, people movement, air flow analysis, microclimate analysis and various types of three-dimensional modelling software, particularly, packages that facilitate interfacing with rapid prototyping and allow complex form generation. Rapid prototyping techniques will include laser cutting, three-dimensional printing and CNC 3-axis machining. The course format is a seminar in which each student will explore some of these technologies in depth by means of a small design example and presentations to the class while obtaining an overview from the course lectures and presentations by other students on other applications.		
ece457a	Cooperative and Adaptive Algorithms	The course starts by addressing the ill-structured problems and need for computational intelligence methods. It introduces the concepts of heuristics and their use in conjunction with search methods, solving problems using heuristics and metaheuristics, constraints satisfaction. The course also introduces the concepts of cooperation and adaptations and how they are influencing new methods for solving complex problems. The course starts by illustrating how the concepts of cooperation and adaptation are manifested in nature and how such models are inspiring new types of solutions methods. Topics to be covered include: search algorithms, game playing, constraints satisfaction, meta-heuristics, evolutionary computing methods, swarm intelligence, ant-colony algorithms, particle swarm methods, adaptive and learning algorithms and the use of these algorithms in solving continuous and discrete problems that arise in engineering applications. [Offered: S]	12	0.9311148
syde642	Cognitive Engineering Methods	This course examines the fundamentals of modern perspectives on interface design for complex systems using current methods in cognitive engineering. We discuss Cognitive Work Analysis, Brunswick's' Lens Model, Goal Directed Task Analysis, Situation Awareness Oriented Design, Naturalistic Decision Making, Contextual Inquiry, Macro-cognitive Methods, Activity Theory, Concept Mapping, Cognitive Task Analysis, Social Network Analysis and their application to different types of human engineering problems. Students in this course will learn multiple methods in cognitive engineering with an emphasis on knowing the differences in foundation, assumptions and appropriate application of the methods. Students will be expected to apply the methods in a realistic research context, applying for ethics clearance and working with actual participants. Examples of appropriate topics may include understanding how people work with complex or automated systems models. Finally this course discusses aspects of the current research environment in cognitive engineering, with the objective of developing successful future researchers in this area.	12	0.9581234