ENGG*3130 Modelling Complex Systems

01

Winter 2021
Section(s): C01

School of Engineering
Credit Weight: 0.50
Version 1.00 - January 11, 2021

---

1 Course Details

1.1 Calendar Description

This course explores the application of systems thinking to complex global issues. Key topics will include: systems theory, complex adaptive systems, systems tools, and systems approaches. The course will emphasize the role of computational modelling and simulation as a central tool for applying systems thinking to real-world settings.

Pre-Requisites:	ENGG*2400, STAT*2120, (CIS*1300 or CIS*1500)
Restrictions:	This is a Priority Access Course. Enrolment may be restricted to the ESC specialization in the BENG and BENG:C programs. See department for more information.

1.2 Course Description

This course aims to introduce the basic principles of systems thinking. We will see how complex patterns and behaviours can emerge from simple structures and rules. We will draw on these insights to develop a deeper understanding of the world around us.

Examples presented in class will be chosen to relate directly to students' experiences and focus on current issues. These may include globalization, climate change, conflict, democracy, cryptocurrency, artificial intelligence, health, and food security.

1.3 Timetable

Lectures:

Tuesday 11:30–12:50 Virtual (Zoom link posted to CourseLink)

Thursday 11:30–12:50 Virtual (Zoom link posted to CourseLink)

Laboratory

Thursday 8:30–10:30 Virtual (Zoom link posted to CourseLink)

1.4 Final Exam

There is no final exam.

---

2 Instructional Support

2.1 Instructional Support Team

Instructor: Graham Taylor
Email: gwtaylor@uoguelph.ca
Telephone: +1-519-824-4120 x53644
Office: RICH 3515

Lab Co-ordinator: Matthew Kent
Email: mattkent@uoguelph.ca
Telephone: +1-519-824-4120 x54113
Office: THRN 2332

2.2 Teaching Assistants

Teaching Assistant: Shashank Shekhar
Email: sshekhar@uoguelph.ca

---

3 Learning Resources

3.1 Required Resources

Course Website (Website)
https://courselink.uoguelph.ca/
Course material, news, announcements, and grades will be regularly posted to the ENGG*3130 CourseLink site. You are responsible for checking the site regularly.

Think Complexity: Complexity Science and Computational Modeling (Textbook)
http://greenteapress.com/wp/think-complexity-2e/
Allen B. Downey, 2nd edition, Green Tea Press, 2018

Note that this book is available as a free PDF at the URL above.

Think Python: How to Think Like a Computer Scientist (Textbook)
https://greenteapress.com/wp/think-python-2e/
Allen B. Downey, 2nd edition, Green Tea Press, 2016

Note that this book is available as a free PDF at the URL above.

The Alignment Problem: Machine Learning and Human Values (Readings)
https://brianchristian.org/the-alignment-problem/
Brian Christian, 1st edition, W.W. Norton & Company, 2020.

There are several options for obtaining this book in either e-book or hardcover formats via the URL above.

3.2 Recommended Resources

Thinking in Systems: A Primer (Textbook)
Donella H. Meadows, 1st edition, Chelsea Green Publishing, 2008.

In previous offerings, this was a required text. We have adapted the course due to the ongoing pandemic and optimized it for a virtual offering. Therefore we are no longer using this text. However, it is a wonderful introduction to Systems Thinking and complements the more technical parts of the course.

3.3 Additional Resources

Lecture Information (Notes)
http://uoguelph-engg3130.github.io
Notes to accompany lectures will be available at http://uoguelph-engg3130.github.io. Because these notes are a collaborative effort, they will be updated as the course progresses (usually at least once per week). Every student is expected to contribute to the development and maintenance of these course notes. Information on how to contribute, as well as how to generate the notes in alternative formats (e.g. PDF) will be provided.

Lab Information (Notes)
http://uoguelph-engg3130.github.io
The directives for all the virtual lab sessions will be provided in the online course notes. Deliverables for the labs will be submitted electronically (via CourseLink Dropbox) and are due one week after the lab session.

Miscellaneous Information (Other)
Other information related to Modelling Complex Systems will be posted on the course website.

---

4 Learning Outcomes

4.1 Course Learning Outcomes

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

1. Synthesize your own definition of systems thinking.
2. Construct a system study, first identifying the system to be investigated and its important behaviours. Identify the purpose of the study, hierarchy, important processes and structures, elements and their interconnections, feedbacks, and environmental context.
3. Discuss real world systems that demonstrate nonlinear, emergent, self-organizing, and resilient behaviour.
4. Choose from a variety of systems tools given a context, justifying the choice.
5. Model and simulate a complex system in software.
6. Write code that demonstrates good software engineering practices: e.g. modularity, efficiency, use of appropriate data structures and algorithms, readability.
7. Communicate a systems approach to modelling both orally and in written form.

4.2 Engineers Canada - Graduate Attributes (2018)

Successfully completing this course will contribute to the following:

#	Outcome	Learning Outcome
1	Knowledge Base	3
1.1	Recall, describe and apply fundamental mathematical principles and concepts	3
1.2	Recall, describe and apply fundamental principles and concepts in natural science	3
1.3	Recall, describe and apply fundamental engineering principles and concepts	3
1.4	Recall, describe and apply program-specific engineering principles and concepts	3
2	Problem Analysis	2
2.1	Formulate a problem statement in engineering and non-engineering terminology	2
2.2	Identify, organize and justify appropriate information, including assumptions	2
2.3	Construct a conceptual framework and select an appropriate solution approach	2
2.4	Execute an engineering solution	2

#	Outcome	Learning Outcome
2.5	Critique and appraise solution approach and results	2
3	Investigation	3
3.1	Propose a working hypothesis	3
3.2	Design and apply an experimental plan/investigative approach (for example, to characterize, test or troubleshoot a system)	3
3.3	Analyze and interpret experimental data	3
3.4	Assess validity of conclusions within limitations of data and methodologies	3
4	Design	5
4.1	Describe design process used to develop design solution	5
4.2	Construct design-specific problem statements including the definition of criteria and constraints	5
4.3	Create a variety of engineering design solutions	5
4.4	Evaluate alternative design solutions based on problem definition	5
4.5	Develop and refine an engineering design solution, through techniques such as iteration, simulation and/or prototyping	5
5	Use of Engineering Tools	4, 6
5.1	Select appropriate engineering tools from various alternatives	4, 6
5.2	Demonstrate proficiency in the application of selected engineering tools	4, 6
5.3	Recognize limitations of selected engineering tools	4, 6
6	Individual & Teamwork	2, 5
6.1	Describe principles of team dynamics and leadership	2, 5
6.2	Understand all members' roles and responsibilities within a team	2, 5
6.3	Execute and adapt individual role to promote team success through, for example, timeliness, respect, positive attitude	2, 5
6.4	Apply strategies to mitigate and/or resolve conflicts	2, 5
6.5	Demonstrate leadership through, for example, influencing team vision and process, promoting a positive team culture, and inspiring team members to excel	2, 5

#	Outcome	Learning Outcome
7	Communication Skills	1, 7
7.1	Identify key message(s) and intended audience in verbal or written communication as both sender and receiver	1, 7
7.2	Interpret technical documentation such as device specification sheets, drawings, diagrams, flowcharts, and pseudocode	1, 7
7.3	Construct the finished elements using accepted norms in English, graphical standards, and engineering conventions, as appropriate for the message and audience	1, 7
7.4	Substantiate claims by building evidence-based arguments and integrating effective figures, tables, equations, and/or references	1, 7
7.5	Demonstrate ability to process oral and written communication by following instructions, actively listening, incorporating feedback, and formulating meaningful questions	1, 7
9	Impact of Engineering on Society and the Environment	2, 3
9.1	Analyze the safety, social, environmental, and legal aspects of engineering activity	2, 3
9.2	Evaluate the uncertainties and risks associated with engineering activities	2, 3
9.3	Anticipate the positive and negative impacts of introducing innovative technologies to solve engineering problems	2, 3

4.3 Relationships with other Courses & Labs

Previous and/or Current Courses:

ENGG*1500: Solving systems of linear equations, matrix algebra, complex numbers

CIS*1500, CIS*2500, CIS*2430, CIS*2520: Object-oriented programming, data structures, analysis of algorithms

PHYS*1130: Analytic problem solving, physical systems

STAT*2120: Bayes' theorem, probability distributions, probability densities, descriptive statistics

ENGG*2400: Modelling and simulation of linear systems

Follow-on Courses:

ENGG*41x: Interdisciplinary design

---

5 Teaching and Learning Activities

5.1 Lecture

Tue, Jan 12

Topics: Introduction and overview

Learning Outcome: 1, 2, 3, 4, 5, 6, 7

Thu, Jan 14

Topics: Complexity science

References: Think Complexity, Chapter 1

Learning Outcome: 1, 3, 4

Tue, Jan 19

Topics: Python 1

- IPython, Jupyter notebook
- Arithmetic operators

- Values and types
- Formal and natural languages
- Variables, expressions and statements
- Functions

References: Think Python, Chapters 1-3

Learning Outcome: 4, 5, 6

Thu, Jan 21

Topics: Python 2

- Conditionals and recursion
- Fruitful functions
- Iteration

References: Think Python, Chapters 5-7

Learning Outcome: 4, 5, 6

Tue, Jan 26

Topics: Python 3

- Strings
- Lists
- Dictionaries
- Tuples

References: Think Python, Chapters 8, 10-12

Learning Outcome: 4, 5, 6

Thu, Jan 28

Topics: Python 4

- Classes and objects

- Classes and functions
- Classes and methods
- Inheritance

References: Think Python, Chapters 15-18

Learning Outcome: 4, 5, 6

Tue, Feb 2

Topics: Graphs

References: Think Complexity, Chapter 2

Learning Outcome: 2, 3, 4, 5, 6

Thu, Feb 4

Topics: Small world graphs

References: Think Complexity, Chapter 3

Learning Outcome: 2, 3, 4, 5, 6

Tue, Feb 9

Topics: Scale-free networks

References: Think Complexity, Chapter 4

Learning Outcome: 2, 3, 4, 5, 6

Thu, Feb 11

Topics: Cellular automatons

References: Think Complexity, Chapter 5

Learning Outcome: 2, 3, 4, 5, 6

Tue, Feb 23

Topics: Game of Life

References: Think Complexity, Chapter 6

Learning Outcome: 2, 3, 4, 5, 6

Thu, Feb 25

Topics:	Physical modelling
References:	Think Complexity, Chapter 7
Learning Outcome:	2, 3, 4, 5, 6

Tue, Mar 2

Topics:	Self-organized criticality
References:	Think Complexity, Chapter 8
Learning Outcome:	2, 3, 4, 5, 6

Thu, Mar 4

Topics:	Agent-based models
References:	Think Complexity, Chapter 9
Learning Outcome:	2, 3, 4, 5, 6

Tue, Mar 9

Topics:	Herds, flocks, and traffic jams
References:	Think Complexity, Chapter 10
Learning Outcome:	2, 3, 4, 5, 6

Thu, Mar 11

Topics:	Evolution
References:	Think Complexity, Chapter 11
Learning Outcome:	2, 3, 4, 5, 6

Tue, Mar 16

Topics:	Evolution of cooperation
References:	Think Complexity, Chapter 12

Learning Outcome: 2, 3, 4, 5, 6

Thu, Mar 18

Topics: Guest lecture

5.2 Seminar

Tue, Mar 23

Topics: AI and Machine Learning / Debates 1

References: The Alignment Problem, Chapters 1-3

Learning Outcome: 3, 7

Thu, Mar 25

Topics: Systems Thinkers Presentations 1

Learning Outcome: 1, 7

Tue, Mar 30

Topics: AI and Machine Learning / Debates 2

References: The Alignment Problem, Chapters 4-6

Learning Outcome: 3, 7

Thu, Apr 1

Topics: Systems Thinkers Presentations 2

Learning Outcome: 1, 7

Tue, Apr 6

Topics: AI and Machine Learning / Debates 3

References: The Alignment Problem, Chapters 7-9

Learning Outcome: 3, 7

Thu, Apr 8

Topics: Systems Thinkers Presentations 3

Learning Outcome: 1, 7

5.3 Other Important Dates

Tuesday, January 7 2021: First day of class (No lab this week)
Monday, February 15 – Friday, February 19 2021: Winter Break (No lectures or labs)
Thursday, April 8 2021: Last day of class (No lab this week)
Monday, April 12 2021: Last day to drop W21 one semester courses

---

6 Assessments

6.1 Marking Schemes & Distributions

Name	Scheme A (%)
Course Notes Development	10
Reflections and Participation in Debates	10
Oral Presentation	10
Lab Reports	40
Final Project (Teams of 3–4 students)	30
Total	100

6.2 Assessment Details

Course Notes Development (10%)
Learning Outcome: 4, 6

- Each student is expected to make individual contributions to the course notes
- Students will be assessed on the **quantity and quality** of the contributions, which may include:
  - Being the primary note taker for one lecture session
  - Correcting errors or making additions to existing notes (or labs)
  - Opening issues and participating in discussion where more clarification is needed
    https://guides.github.com/features/issues/
  - Responding to these issues
- Contributions must be submitted as a Github pull request
  https:/help.github.com/articles/about-pull-requests/
- Since there are not enough spots for every student to be a primary note taker,

students will have the opportunity to be an **in-class debater** in lieu of primary note taker
- A spreadsheet will be distributed at the beginning of the term to register to be either a primary note taker or an in-class debater. More details on the expectations of each of these roles will be discussed in the lecture period

Reflections and Participation in Debates (10%)
Date: Tue, Mar 16 - Tue, Apr 6
Learning Outcome: 1, 2, 3, 7

- Between March 16 - April 6 you will be required to read *The Alignment Problem* and contribute to a series of asynchronous and in-class discussion and debates
- If you start the reading on March 16 you are required to read three chapters each week. You are welcome to begin the readings earlier, before debate topics are posted
- You are required to contribute at least one "reflection" on Microsoft Teams. The reflection can be as short as a single sentence or as long as an essay. Reflections can be responses to that week's discussion questions or general observations, questions, opinions, facts, or anything else that you feel like writing that is inspired by the reading. Details will be posted on CourseLink
- The in-class debates will be in the lecture periods on March 23, March 30 and April 6

Oral Presentation (10%)
Learning Outcome: 1, 2, 3, 7

- Each student will research and prepare a 5 minute pre-recorded presentation on a prominent systems thinker of their choice
- The presentations will be scheduled and broadcast in the March 25, April 1 and April 8 lecture periods
- Further instruction will be provided in the second half of the term (details about signing up will be posted on CourseLink)

Lab Reports (40%)
Learning Outcome: 2, 3, 4, 5, 6

- Lab reports will be submitted as Jupyter notebooks. They are due (by

CourseLink Dropbox) exactly one week from the start of the lab
- There will be 13 labs
- Lab reports will be marked according to a ternary scheme:
  - High pass (more than average effort, essentially complete)
  - Pass (reasonable effort, may be missing some components)
  - Fail (less than average effort, mostly incomplete)
- The three lab reports with the lowest grade will be dropped. However, **reports that are not submitted will not be dropped.**

Collaboration Policy

I expect you to try solving each lab on your own. However, when you are stuck on a problem, I encourage you to collaborate with other students in the class, subject to the following rules:

1. You may discuss a problem with any student in this class, and work together on solving it. This can involve brainstorming and verbally discussing the problem, going together through possible solutions, but should not involve one student telling another a complete solution.
2. Once you solve the problem, you must write up your report on your own, without looking at other people's reports or giving your report to others.
3. In your solution for each problem, you must write down the names of any person with whom you discussed it. This will not affect your grade.
4. Do not consult the official solution notebooks or other people's solutions from similar courses. You are encouraged to make use of open source tools and libraries unless otherwise instructed. Don't reinvent the wheel — just give proper attribution. If unsure, ask the instructor. It is ok to consult solutions once your lab is submitted and final.

Final Project (Teams of 3–4 students) (30%)
Learning Outcome: 2, 3, 4, 5, 6

- The project will focus on a case study of complex system modelling
- See the *Think Complexity* book (version 1) for examples of case studies written by students
- Deliverables (report and associated code) are due April 27th 2021 at 23:59 via CourseLink Dropbox

- More information on the format and expectation of deliverables will be provided on CourseLink

---

7 Course Statements

7.1 Course Grading Policies

Missed Assessments

If you are unable to meet an in-course requirement due to medical, psychological, or compassionate reasons, please email the course instructor. See the undergraduate calendar for information on regulations and procedures for Academic Consideration: http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-ac.shtml

Accommodation of Religious Obligations

If you are unable to meet an in-course requirement due to religious obligations, please email the course instructor within two weeks of the start of the semester to make alternate arrangements. See the undergraduate calendar for information on regulations and procedures for Academic Consideration of Religious Obligations: http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-accomrelig.shtml

Passing grade

The passing grade is 50%.

Missed labs

If you miss a lab due to grounds for granting academic consideration or religious accommodation, you are expected to complete the necessary work on your own time and still submit a report. There will be no makeup labs.

Questions concerning grades

If you have questions about the grade you received, please ask your TA within one week of

the document being returned. However, all requests for re-marking must be made to the instructor. Any item that is re-marked will be re-marked entirely. Therefore it is strongly suggested that you thoroughly review your entire document **before** making a re-marking request. Re-marking requests will not be honoured more than one week after the document has been returned.

7.2 Communication and Email Policy

Please use lectures and tutorials as your main opportunity to ask questions about the course. Major announcements and/or changes will be posted to the course website. **It is your responsibility to check the course website regularly.**

Electronic communication should be limited to the course forum, however topics of a personal and confidential nature (e.g. marks) should be emailed to the instructor: gwtaylor@uoguelph.ca. Please note that **all email communication must be made through your University of Guelph email account** (i.e. username@uoguelph.ca).

7.3 Turnitin

In this course, your instructor will be using Turnitin, integrated with the CourseLink Dropbox tool, to detect possible plagiarism, unauthorized collaboration or copying as part of the ongoing efforts to maintain academic integrity at the University of Guelph.

All submitted lab reports and projects will be included as source documents in the Turnitin.com reference database solely for the purpose of detecting plagiarism of such papers. Use of the Turnitin.com service is subject to the Usage Policy posted on the Turnitin.com site.

A major benefit of using Turnitin is that students will be able to educate and empower themselves in preventing academic misconduct. In this course, you may screen your own assignments through Turnitin as many times as you wish before the due date. You will be able to see and print reports that show you exactly where you have properly and improperly referenced the outside sources and materials in your assignment.

8 School of Engineering Statements

8.1 Instructor's Role and Responsibility to Students

The instructor’s role is to develop and deliver course material in ways that facilitate learning for a variety of students. Selected lecture notes will be made available to students on Courselink but these are not intended to be stand-alone course notes. Some written lecture notes will be presented only in class. During lectures, the instructor will expand and explain the content of notes and provide example problems that supplement posted notes. Scheduled classes will be the principal venue to provide information and feedback for tests and labs.

8.2 Students' Learning Responsibilities

Students are expected to take advantage of the learning opportunities provided during lectures and lab sessions. Students, especially those having difficulty with the course content, should also make use of other resources recommended by the instructor. Students who do (or may) fall behind due to illness, work, or extra-curricular activities are advised to keep the instructor informed. This will allow the instructor to recommend extra resources in a timely manner and/or provide consideration if appropriate.

8.3 Lab Safety

Safety is critically important to the School and is the responsibility of all members of the School: faculty, staff and students. As a student in a lab course you are responsible for taking all reasonable safety precautions and following the lab safety rules specific to the lab you are working in. In addition, you are responsible for reporting all safety issues to the laboratory supervisor, GTA or faculty responsible.

9 University Statements

9.1 Email Communication

As per university regulations, all students are required to check their e-mail account regularly: e-mail is the official route of communication between the University and its students.

9.2 When You Cannot Meet a Course Requirement

When you find yourself unable to meet an in-course requirement because of illness or compassionate reasons please advise the course instructor (or designated person, such as a teaching assistant) in writing, with your name, id#, and e-mail contact. The grounds for Academic Consideration are detailed in the Undergraduate and Graduate Calendars.

Undergraduate Calendar - Academic Consideration and Appeals
https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-ac.shtml

Graduate Calendar - Grounds for Academic Consideration
https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/index.shtml

Associate Diploma Calendar - Academic Consideration, Appeals and Petitions
https://www.uoguelph.ca/registrar/calendars/diploma/current/index.shtml

9.3 Drop Date

Students will have until the last day of classes to drop courses without academic penalty. The deadline to drop two-semester courses will be the last day of classes in the second semester. This applies to all students (undergraduate, graduate and diploma) except for Doctor of Veterinary Medicine and Associate Diploma in Veterinary Technology (conventional and alternative delivery) students. The regulations and procedures for course registration are available in their respective Academic Calendars.

Undergraduate Calendar - Dropping Courses
https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-drop.shtml

Graduate Calendar - Registration Changes
https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/genreg-reg-regchg.shtml

Associate Diploma Calendar - Dropping Courses
https://www.uoguelph.ca/registrar/calendars/diploma/current/c08/c08-drop.shtml

9.4 Copies of Out-of-class Assignments

Keep paper and/or other reliable back-up copies of all out-of-class assignments: you may be asked to resubmit work at any time.

9.5 Accessibility

The University promotes the full participation of students who experience disabilities in their academic programs. To that end, the provision of academic accommodation is a shared responsibility between the University and the student.

When accommodations are needed, the student is required to first register with Student Accessibility Services (SAS). Documentation to substantiate the existence of a disability is required; however, interim accommodations may be possible while that process is underway.

Accommodations are available for both permanent and temporary disabilities. It should be noted that common illnesses such as a cold or the flu do not constitute a disability.

Use of the SAS Exam Centre requires students to book their exams at least 7 days in advance and not later than the 40th Class Day.

For Guelph students, information can be found on the SAS website
https://www.uoguelph.ca/sas

For Ridgetown students, information can be found on the Ridgetown SAS website
https://www.ridgetownc.com/services/accessibilityservices.cfm

9.6 Academic Integrity

The University of Guelph is committed to upholding the highest standards of academic integrity, and it is the responsibility of all members of the University community-faculty, staff, and students-to be aware of what constitutes academic misconduct and to do as much as possible to prevent academic offences from occurring. University of Guelph students have the responsibility of abiding by the University's policy on academic misconduct regardless of their location of study; faculty, staff, and students have the responsibility of supporting an environment that encourages academic integrity. Students need to remain aware that instructors have access to and the right to use electronic and other means of detection.

Please note: Whether or not a student intended to commit academic misconduct is not relevant for a finding of guilt. Hurried or careless submission of assignments does not excuse students from responsibility for verifying the academic integrity of their work before

submitting it. Students who are in any doubt as to whether an action on their part could be construed as an academic offence should consult with a faculty member or faculty advisor.

Undergraduate Calendar - Academic Misconduct
https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-amisconduct.shtml

Graduate Calendar - Academic Misconduct
https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/index.shtml

9.7 Recording of Materials

Presentations that are made in relation to course work - including lectures - cannot be recorded or copied without the permission of the presenter, whether the instructor, a student, or guest lecturer. Material recorded with permission is restricted to use for that course unless further permission is granted.

9.8 Resources

The Academic Calendars are the source of information about the University of Guelph's procedures, policies, and regulations that apply to undergraduate, graduate, and diploma programs.

Academic Calendars
https://www.uoguelph.ca/academics/calendars

9.9 Disclaimer

Please note that the ongoing COVID-19 pandemic may necessitate a revision of the format of course offerings and academic schedules. Any such changes will be announced via CourseLink and/or class email. All University-wide decisions will be posted on the COVID-19 website (https://news.uoguelph.ca/2019-novel-coronavirus-information/) and circulated by email.

9.10 Illness

The University will not normally require verification of illness (doctor's notes) for fall 2020 or winter 2021 semester courses. However, requests for Academic Consideration may still require medical documentation as appropriate.