Department of Statistical Sciences
University of Toronto

STA 305H1F /STA1004H1F
Design and Analysis of Experiments/Introductory Experimental Design
Syllabus – Fall 2022

Land Acknowledgement

We wish to acknowledge the land on which the University of Toronto operates. For thousandsof years, it has been the traditional land of the Huron-Wendat, the Seneca, and most recently,the Mississaugas of the Credit River. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.

Table of Contents

Course Formats Highlights

This course is an in-person course. Any deviations from this document will be announced on the course Quercus page. Please keep regularly visiting the website link for Faculty updates and supports regarding any changes in course formats: FAS student FAQs.

1. Course and Sections

STA 305H1F: Design and Analysis of Experiments
STA1004H1F: Introductory Experimental Design
Section for STA 305 H1F: L0101

2. Instructor and Team

Professor: Murari Singh
murarii.singh@utoronto.ca (mailto:murarii.singh@utoronto.ca)
Office hours (via zoom meeting): **TBA** (The link will be posted on the Quercus.)

TAs and their office hours will also be announced on the Quercus.

3. Class Time

Tuesday, BA1160, 3 – 4 pm & **Thursday,** BA1160, 2 – 4 pm
First lecture: Thursday, September 8, 2022

4. Course Content

This course will introduce the fundamental concepts of the design of scientific studies including the design of experiments and observational studies. Students will be become acquainted with statistical methods used to design and analyze experiments and observational studies. This course will cover experiments versus observational studies, clinical trial design, comparing several groups using a completely randomized design, randomized blocks, nonparametric methods, Latin squares, incomplete block designs, square lattices, rectangular lattices, factorial designs, response surface designs, causal inference in randomized and non-randomized studies, and adjusting for selection bias using propensity score methods.

The learning objectives of this course are:

- Understand the ideas, principles, and considerations that are common to the design and analysis of scientific studies including the statistical design of experiments and observational studies.
- Develop a statistical toolbox of methods for the design and analysis of experiments and observational studies.
- Identify appropriate uses and interpretations of experimental designs, and observational studies, including their strengths and limitations.
- Integrate the application with theory, of experimental designs and observational studies, using R/Rmd tools.

Topics

Experiments, observational studies, and causal inference

Experiments versus observational studies, and causal inference in randomized experiments.

Selection Bias in Observational Studies

Causal inference in randomized experiments versus observational studies. Introduction to the propensity score and three ways to use the propensity score to adjust for selection bias: matching; sub classification; direct regression adjustment.

Probability and Statistics

Mathematical statistics used in experimental design.

Comparing Several Groups

Comparing several groups in an experimental and observational setting and deciding whether differences that are found are likely to be real or due to chance.

Power and Sample Size

Power and sample size will be introduced for several designs. Applications will include the design and analysis of clinical trials with continuous or binary endpoints.

Blocking Techniques

Blocked designs, Latin squares, randomized incomplete block designs, square and rectangular lattices. Statistical analysis of data including nonparametric methods in few cases.

Factorial Designs

Factorial, blocked factorial, and fractional factorial designs will be discussed.

Experiments with Random factors

Two factor factorial – random effects models, mixed effects models

Split Plot Designs

Split plot designs will be discussed as an example of restricted randomization in the design of experiments.

Response Surface Methods

Response surfaces of first and second orders - method of steepest ascent, construction of the designs, and analyses

5. Course Books

5.1 Required

- Taback, N. (2022). Design and Analysis of Experiments and Observational Studies using R: A Volume in the Chapman & Hall/CRC Texts in Statistical Science Series. Link: http://designexptr.org/index.html
- Design and Analysis of Experiments, 10th Edition, by Douglas C. Montgomery (John Wiley, 2020). https://www.campusebookstore.com/integration/AccessCodes/default.aspx?permalinkId=1d91e757-71e6-4d73-a2ba-85f26a94c4a3&frame=YES&t=permalink

5.2 Optional

1. Statistics for Experimenters: Design, Innovation, and Discovery. Box, G.E.P., Hunter, J.S.,Hunter, W.G. Wiley 2nd Ed. 2005
2. Design and Analysis of Experiments. Dean, A., and Voss, D. Springer. 1999. UofT link toelectronic copy: http://go.utlib.ca/cat/2573215 (http://go.utlib.ca/cat/2573215)
3. Design of Observational Studies. Rosenbaum, P. R. Springer 2010. UofT link to electroniccopy: http://go.utlib.ca/cat/7890274 (http://go.utlib.ca/cat/7890274)
4. Experiments: planning, analysis, and optimization. Wu, C.F.J., Hamada, M.S. Wiley, 2009,2nd ed.
5. Causal inference for statistics, social, and biomedical sciences. Imbens and Rubin.Cambridge University

Press, 2015. http://go.utlib.ca/cat/10127748 (http://go.utlib.ca/cat/10127748)

NB: Textbooks 2,3, 5 are available electronically through the UofT library (i.e., electronic copiesof both these textbooks are available at no extra cost)

6. Course Materials, including lecture notes

All course materials are copyrighted. If they are from the textbook, the copyright belongs to the textbook publisher. If they are provided by an instructor (for example, lecture notes, computer code, assignments, tests, solutions) the copyright belongs to the instructor. Distributing materials online or sharing them in any way is a copyright violation and, in some situations, an academic offence. Course materials are provided for the exclusive use of enrolled students. Do not share them with others. I do not want to discover that a student has put any of my materials into the public domain, has sold my materials, or has given my materials to a person or company that is using them to earn money. The University will support me in asserting and pursuing my rights, and my copyrights, in such matters.

7. Assessments

7.1 Grading scheme and Assessment Environment

Students will be evaluated according to the following marking scheme.

Assessment	Weight (undergrads)	Weight (graduates)	Date/Time/Day	Assessment Formats
Homework (HW)	15% (3 x 5%)	30% (3 x 10%)	**Fridays (due dates) HW1 (Sept 30), HW2 (Oct 21), HW3 (Nov 18)**	SA questions on Crowdmark
Midterm Test [$]	30%[a] (35%)[b]	20%[a] (30%)[b]	**Oct 27, 2022 2:20 -3:50 pm**	In-person (in classroom)
Project work	10%	20%	**Dec 7**	Crowdmark & Quercus
Final Exam[$]	45%[a] (40%)[b]	30%[a] (20%)[b]	Scheduled by the Faculty	In-person (by FAS)

[$]The marking scheme will use the higher of the combined marks for course resulting from the options (a) and (b) in the above.

7.2 Assessment Formats/Platforms, Missed Assessments and Marking Concerns

7.2.1 Homework assignments

The homework assignments are short-answer questions distributed to the students via Crowdmark. Students will upload their answer on the Crowdmark platform.

Late Penalty for Homework Assignments

A **25% per day** penalty will be applied to assignments that are submitted late. For example, this means that

if an assignment is due at 17:00 ET, and is submitted at 17:01 ET, then it will incur a 25% late penalty. If it is submitted at 17:01 ET the following day, then it will incur a 50% late penalty.

Missed Homework Assignments (due to valid reasons)

If a homework is missed for a valid reason (e.g., illness or personal emergency), then within one week following the assessment you must fill out the absence declaration form on ACORN and MS form on Quercus. For each such missed assignment, for undergraduates, 50% of the total weight (5%) for that homework assignment will be shifted to the other homework assignments (i.e., 2.5% weight will be shifted to other homework assignments) and the remaining to the final assessment (i.e., 2.5% weight shifted to the final). Otherwise, a missed homework will be assigned a grade of zero. Similarly for the homework missed by the graduates, distribution of weights can be computed.

7.2.2 Midterm test

The midterm test will be **in-person** test during class time on the test day. The test will have short-answer questions including computations and proofs. Short answers may require you to interpret R output and use them to answer. You will need to know R syntax to complete for homework but will not be tested for R syntax on the test and exam. However, you will need to know how to interpret output from R.

The **in-person** exams cannot be submitted **late**.

Missed Midterm Test

- If the midterm test is missed for a valid reason (e.g., illness or personal emergency), then within one week following the assessment you must fill out the absence declaration form on ACORN and the MS form on Quercus.
- If the midterm test is missed for a valid reason, then the full weight of the midterm test will be shifted to the final exam. In this case, the final exam will be 75% for undergraduates, and 50% for the graduates (see table in 7.1).

7.2.3 Project work

The project work requires development of a report based on a well-designed study incorporating experimental design, collected/simulated data, analysis, R/Rmd codes, results and discussion and a video presentation following the guidelines issued by the instructor.

Late Project Submission

If the project report is submitted after the due date, then a late penalty of **20% per day** (i.e., for every 24 hour interval) will be applied to the component of the project handed in late. For example, if the project-report PDF file component is submitted after 5 days (including weekend days) then you will receive a grade of zero for the project-report PDF file component.

Missed Project Submission

- If the Project work is missed for a valid reason (e.g., illness or personal emergency), then within one week following the assessment and before the final exam, you must fill out the absence declaration form on ACORN and on Quercus.

- If the Project work is missed for a valid reason, then half the weight of the Project will be shifted to the homework assignment and half will be shifted to the final exam. So, for undergrads 5% weight is shifted onto the homework assignments and 5% is shifted onto the final exam. For grad students 10% weight is shifted onto the homework assignments and 10% is shifted onto the final exam.

7.2.4 Final Exam

The final exam will be **in-person** during the time, date, and place decided by the Faculty of Arts and Science (FAS). The exam will have short-answer questions including computations and proofs. Short answers may require you to interpret R output and use them to answer. You will not be tested for R syntax on the exam, but you will need to know how to interpret output from R.

The **in-person** exams cannot be submitted **late**.

Students who are eligible for **special test accommodations** will be facilitated through the university's **Accommodated Testing Services (ATS)**.

7.3 Marking concerns

- Any requests to have marked work re-evaluated must be made in writing to the instructor within one week of the date the work was returned. The request must contain a justification for consideration.

8. Computing

R

We will use R for all examples. R is freely available for download at http://cran.r-project.org (http://cran.r-project.org) for Windows, Mac, and Linux operating systems. For the tests andexam, you will need to know how to interpret output from R.

RStudio

RStudio is a fantastic integrated development environment (IDE) for R. It is freely available at https://www.rstudio.com/products/rstudio/ (https://www.rstudio.com/products/rstudio/)

I am assuming that students have never used R before. I will provide you with the R syntax for allexamples in lecture, which should be sufficient for you to complete the practice problems.

Jupyter Notebook

The Jupyter Notebook is an open-source web application that allows you to create and share documents that contain live code, equations, visualizations, and narrative text (https://jupyter.org)

R can be run in a Jupyter notebook in any web browser by logging into https://utoronto.syzygy.ca (https://utoronto.syzygy.ca) with your UTORid.

To get started using R in a Jupyter notebook, see this page (jupyterstarter.html). Additionally, you can also use R Studio through the U of T Jupyterhub, by selecting the RStudio option and logging in with your utorID and password, available here: https://jupyter.utoronto.ca.

Calculators

You will need a calculator in this course. Any calculator that has logarithmic functions will be sufficient. Calculators on phones or other devices equipped to communicate with the outside world (for example, through the internet or cellular or satellite phone networks) will not be permitted during the term tests or final exam.

9. Getting Help

9.1 Online Discussion Board

This term you will have the option to use Piazza for class discussion. If you decide not to use Piazza, it will not disadvantage you in any way, and will not affect official University outcomes (e.g., grades and learning opportunities). If you choose not to opt-into Piazza, then you can ask questions or discuss course material with the instructor or Teaching Assistants (TAs) during office hours.

Be sure to read Piazza's Privacy Policy (https://piazza.com/legal/privacy) and Terms of Use (https://piazza.com/legal/terms) carefully. Take time to understand and be comfortable with what they say. They provide for substantial sharing and disclosure of your personal information held by Piazza, which affects your privacy. If you decide to participate in Piazza, only provide content that you are comfortable sharing under the terms of the Privacy Policy and Terms of Use.

The Piazza system is highly catered to getting you help fast and efficiently from classmates, the TA, and the lecturers. Rather than emailing questions to the teaching staff, we encourage you to post your questions on Piazza. To sign up for the discussion forum click on the link for your section:

https://piazza.com/configure-classes/fall2022/sta305h1lec0101

9.2 Additional help

Need extra help with the coursework? Here are some options:

- For continued class discussion and questions outside of class, try posting on the discussion forums. The instructor and TAs will be monitoring them regularly.
- You can visit your instructor or the teaching assistants during their office hours.

E-mail should only be used for personal emergencies or personal matters.

9.3 How to communicate with your instructor

Questions about course material such as:

- How do I do Question 3.7 in the textbook?
- What is standard deviation?
- When is the midterm?

Should be posted on the discussion forums. Questions can be posted anonymously (so that the author is anonymous to other students but not to the instructors), if desired.

Before emailing your instructor, please:

1. re-read **this syllabus** to see if the answer is here,
2. check FAS student FAQs
3. check the discussion posts on Quercus,
4. ask your TA,
5. post your question to the appropriate discussion board on Quercus.
6. go to office hours

If your question is not answered after looking through these resources, or for private communication, such as: I missed the test because I was ill, then e-mail your instructor. If you refer to the contents of other emails, then be

sure to provide the contents being referred to altogether in a single email message. **When emailing your instructor, please use the subject line: STA305 – LEC0101**. Here, STA305 is your course code and LEC0101 is your section. **If this subject is not included, we may miss your email**.

Use your utoronto.ca e-mail account to ensure that your message does not automatically go to a Junk folder and include your full name and student number.

10. Accommodations

10.1 Religious Accommodation

As a student at the University of Toronto, you are part of a diverse community that welcomes and includes students and faculty from a wide range of cultural and religious traditions. For my part, I will make every reasonable effort to avoid scheduling tests, examinations, or other compulsory activities on religious holy days not captured by statutory holidays. Further to University Policy, if you anticipate being absent from class or missing a major course activity (such as a test or in-class assignment) due to a religious observance, please let me know as early in the course as possible, and with sufficient notice (at least two to three weeks), so that we can work together to make alternate arrangements. More information: https://www.viceprovoststudents.utoronto.ca/policies-guidelines/accommodation-religious/ .

10.2 Students with Disabilities or Accommodation Requirements

Students with diverse learning styles and needs are welcome in this course. If you have an acute or ongoing disability issue or accommodation need, you should register with Accessibility Services (AS) at the beginning of the academic year by visiting http://www.studentlife.utoronto.ca/as/new-registration (http://www.studentlife.utoronto.ca/as/new-registration). Without registration, you will not be able to verify your situation with your instructors, and instructors will not be advised about your accommodation needs. AS will assess your situation, develop an accommodation plan with you, and support you in requesting accommodation for your course work. Remember that the process of accommodation is private: AS will not share details of your needs or condition with any instructor, and your instructors will not reveal that you are registered with AS.

10.3 Specific Medical Circumstances

If you become ill and it affects your ability to do your academic work, consult me right away. Normally, I will ask you for medical documentation in support of your specific medical circumstances. The University's Verification of Student Illness or Injury (VOI) form is recommended because it indicates the impact and severity of the illness, while protecting your privacy about the details of the nature of the illness. You can submit a different form (like a letter from a doctor), as long as it is an original document, and it contains the same information as the VOI. For more information, please see http://www.illnessverification.utoronto.ca (http://www.illnessverification.utoronto.ca) If you get a concussion, break your hand, or suffer some other acute injury, you should register with Accessibility Services as soon as possible.

10.4 Accommodation for Personal Reasons

There may be times when you are unable to complete course work on time due to non-medical reasons. If you have concerns, speak to me or to an advisor in your College Registrar's office; they can help you to decide if you want to request an extension or accommodation. They may be able to provide you with a College Registrar's letter of support to give to your instructors, and importantly, connect you with other resources on campus for help with your situation.

11. Academic Integrity

All students, faculty and staff are expected to follow the University's guidelines and policies on academic

integrity. For students, this means following the standards of academic honesty when writing assignments, collaborating with fellow students, and writing tests and exams. Ensure that the work you submit for grading represents your own honest efforts. Plagiarism—representing someone else's work as your own or submitting work that you have previously submitted for marks in another class or program—is a serious offence that can result in sanctions. Speak to me or your TA for advice on anything that you find unclear. To learn more about how to cite and use source material appropriately and for other writing support, see the U of T writing support website at http://www.writing.utoronto.ca (http://www.writing.utoronto.ca). Consult the Code of Behaviour on Academic Matters for a complete outline of the University's policy and expectations. For more information, please see https://www.artsci.utoronto.ca/current/academic-advising-and-support/student-academic- integrity (https://www.artsci.utoronto.ca/current/academic-advising-and-support/student- academic-integrity) and http://academicintegrity.utoronto.ca (http://academicintegrity.utoronto.ca)

12. Your responsibilities

The classroom sessions for this class are designed to actively engage you in the course material.We hope you will find them interesting, challenging, and fun, and an excellent opportunity to trulylearn the material.

13. Weekly Lecture Schedule

Tentative Weekly Lecture Schedule

For the exact dates of homework, term tests and the final, please keep visiting the Course page on the Quercus. In a homework assigned in advance, if topics related to some questions are not covered by one day before the due date, an announcement will be made to withdraw such questions.

Section L0101: Tuesday (Tu) & Thursday (Th)

Week	Topics	Emphasis
1. Sept 8 Th	**Welcome and Course Design and implementation overview** Prof. Nathan Taback textbook: • Introduction to Observational Studies and Designed Studies/Experiments. • Simple Comparative Experiments- Overview of common statistical concepts. L1*.pdf: Lecture notes presented in the class and files posted on Quercus.	
2. Sept 13 Tu Sept 15 Th	• Review of Mathematical Statistics (Focus: R codes). Discuss homework (L2*.pdf) • Comparing Two Treatments (L3*.pdf)	
3. Sept 20 Tu Sept 22 Th	• R codes: Power and sample size, power via simulation; via randomization distribution (nonparametric procedures) (L4*.pdf, L5*.pdf)	

4. Sept 27 Tu Sept 29 Th	• Introduction to causal inference in randomized experiments (L6*.pdf) • Design of observational studies and propensity scores (L7*.pdf) **Homework 1.** Due **Friday Sept 30, 2022** (Coverage topics: Sept 8 - 22)	Homework 1 Due Sept 30
5. Oct 4 Tu Oct 6 Th	• (Continued) Design of observational studies and propensity scores (L8*.pdf) Prof. DC Montgomery textbook: • **Experiments with a single factor in CRD:** Randomized Plan, Analysis of Variance, Example (L9-12*.pdf)	
Oct 11 - 15	• Reading Week, no classes	
6. Oct 18 Tu Oct 20 Th	• (CRD continued) Model Adequacy Checking, Determining the Sample Size • Random model, Estimation and testing using regression approach (L9-12*.pdf) **Homework 2. Due Friday Oct 21, 2022** (Coverage topics: Sept 27 – Oct 20)	Homework 2 Due Oct 21
7. Oct 25 Tu Oct 27 Th	• **Tuesday:** Comparing more than two groups, multiple comparisons, Nonparametric Methods in the Analysis of Variance, The Kruskal–Wallis Test.(L9-12*.pdf) • **Thursday: L0101: Mid-term Test: Oct 27, 3:20 - 4:50 pm (Topics covered up to CRD: Sept 8 - Oct 25)**	Mid-term Test Oct 27
8. Nov 1 Tu Nov 3 Th	• Randomized Complete Block Designs • Latin Squares, Balanced Incomplete Block Designs, Square lattices, rectangular lattices (L13-14-15*.pdf)	
9. Nov 8 Tu Nov 10 Th	• [continued] Latin Squares, Balanced Incomplete Block Designs, Square lattices, rectangular lattices (L13-14-15*.pdf) • Factorial designs at two levels • Blocking in factorial designs of type 2^k (L16-17-18-19*.pdf)	
10. Nov 15 Tu Nov 17 Th	• (continued) Blocking in factorial designs of type 2^k • Fractional factorial designs of type 2^{k-p} (L16-17-18-19*.pdf) **Homework 3. Due Friday, Nov 18, 2022** (Covered topics: Nov 1 – Nov 17)	Homework 3 Due Nov 18
11. Nov 22 Tu Nov 24 Th	• Chapter 9 (3^k, 3^2, 3^3; AB, ABC interaction partitioning) • Blocking/confounding, and fractional 3^k (examples), 3^{k-p} Examples (L16-17-18-19*.pdf)	

12. Nov 29 Tu Dec 1 Th	• The Two-Factor Factorial with Random Factor-effects • Two-Factor Factorial Mixed Factor-effects (L20*.pdf) • Restricted randomization and split- plot designs (L21*.pdf) **Response Surface Methodology** • Introduction to Response Surface Methodology, The Method of Steepest Ascent (L22-23*.pdf)	
13 Dec 6 Tu	• (RSM continued) Analysis of a Second-Order Response Surface, CCD, and Box - Behnken designs examples; Mixture experiments (introduction) (L22-23*.pdf) **Project Report: Due Friday, Dec 7.** Dec 7 (Wednesday). Classes end in F section code courses and pause in Y section code courses	Project Report Dec 7