2024 Oxford Global Summit for Young Leaders

Mathematics Stream: Lesson Plan

Oxford Global ASYL 2024

1 Learning Objectives

The aim of this course is to provide students an inside look into the applications of mathematics to the issue of climate change. The material covered is intended to be more advanced than what students have previously seen throughout their secondary education. Students are not expected to master the material. Rather, the goal of the course should be to foster real-world problem solving and analytical thinking, as well as to understand what studying applied mathematics at an undergraduate level might be like.

2 Lesson Plan

Session 1: What is climate change? How can mathematics help?

- Climate change is the biggest challenge our planet faces today. From glacier retreat to sea level rise to extreme weather events, no corner of our world is safe from its effects. Students will first be given an overview of climate change, its causes, and the challenges it imposes on our planet.
- Over the years, climatological technology has advanced greatly alongside the urgency to assess the severity of our impact on the climate. We will cover the fundamentals of climate modeling and how mathematics may hold the solution for preventing further impacts of climate change.

1

Session 2: The mathematics of climate change

- Mathematicians around the world are heavily involved with constructing, studying and solving, models for the future climate. We will introduce some mathematical models of weather and climate, such as the Energy Balance Model, that involve the application of Newton's laws of motion and laws of thermodynamics.
- We will discuss how mathematicians can contribute to the climate debate from making and analysing climate models, and better understanding of data, to a more informed presentation to policy makers of the nature of the issues involved.

Session 3: The melting Arctic. How does climate change affect ice levels?

- The Arctic ice cap is in trouble. Measurements from submarines indicate that due to global warming, the ice has grown thinner by at least forty percent over the last two decades. Few models predict that the ice will permanently disappear from the Arctic within our lifetimes. We will look at the Gerald North's Ice Cap Model that picks out some of the main features of ice growth.

Session 4: How to make climate predictions and the uncertainty behind it.

- Will climate change leave the region you live in hotter and drier, or wetter and stormier? It's a question of utmost importance in many areas of the world, yet it's one that climate scientists can't answer. We will look at how scientists predict weather changes, the basic computing approaches they use, and how reliable these predictions can be.

Session 5: The speed of climate change.

- We will review the mathematical models involved with the processes of temperature changes and ice melting, and discuss what we know so far about the estimations made by scientists about the speed of climate change.

- We know that the catalysts for climate change are human activities which pollute the environment. What will be the catalyst for a change in human behaviour to revitalise our planet? Perhaps it will be the help of mathematical models to format more tangible and statistically verified policy options. We will have a final discussion on how we can further public understanding and avoid scepticism about the effects of climate change on Earth.

3 Course Prerequisites

Students should be acquainted with advanced calculus, preferably the notion of differential equations as well, and are recommended to have taken mathematics at a high level. Although it is not a necessity, they should be familiar with concepts that speak in favour of climate change debate, such as the change in global temperatures, the increase in mean sea level over the last 100 years, the increase in the number of extreme rainfall events, and the year on year rise in the level of carbon dioxide in the atmosphere.

4 Recommended Readings

1. Kolbert, Elizabeth. *Under a White Sky: Can We Save the Natural World in Time?* London: Vintage, 2022. Print.

2. Wadhams, Peter. *Ice in the Ocean.* Australia: Gordon and Breach, 2000. Print.

3. Palmer, Tim. *The Primacy of Doubt: From Climate Change to Quantum Physics, How the Science of Uncertainty Can Help Predict and Understand Our Chaotic World.* First edition. Oxford: Oxford University Press, 2022. Print.

* The teaching content is subject to change.

Chemistry Stream: Basic Info

Learning Objectives and Lesson Plan

Session 1

Introduction to the concept of Sustainability and it's bridging with Chemistry.

Session 2

Concept of Green Chemistry.

Walking through it's 12 principles and their respective applications.

Session 3

Green Chemistry contd.

Experimental analysis of certain Conventional procedures of reactions vs their Green alternatives.

Session 4

2 Research topic discussion and analysis

2 Case Study presentations

Session 5

1 Research topic discussion and analysis

3 Case Study presentations

** The teaching content is subject to change.*

Engineering Stream: Basic Info

Oxford Global ASYL 2024

Learning Objectives and Lesson Plan

Course Description:

This summer school course offers an exciting exploration into the world of engineering. It introduces engineering science fundamentals across various disciplines, including mechanical, electrical, biomedical, civil, chemical, aerospace engineering, etc.

In this course, students will gain a solid understanding of what engineering is and the critical role it plays in shaping the world. Each week will delve into a different engineering discipline, where students will learn the basic principles and engage in hands-on activities (mostly through simulation & coding) and projects designed to enhance understanding and stimulate creativity.

The course will culminate in a day focused on the future of engineering, where students will explore the next generation of engineering challenges and opportunities.

By the end of the course, students will have gained a broad understanding of engineering principles, developed problem-solving skills, and experienced how engineering theories become reality through projects. The course aims to inspire students and provide a good foundation for those interested in pursuing further studies or careers in engineering.

Course Format:

The course combines theoretical learning, practical activities, group discussions, and individual or group projects. The format encourages active participation and fosters a collaborative learning environment.

Course Prerequisites:

There are no prerequisites for this course. All enthusiastic young learners interested in engineering are welcome.

Session 1: A Brief History of Engineering and Ethics

Session 2: The Engineer's Language: Mathematics for Engineers

Calculus:

1. Chain, product and quotient rules
2. The fundamental theorem of calculus
3. Derivatives and anti-derivatives of standard functions such as exponentials, trigonometric functions and logarithms
4. Integration techniques
5. A note on complex numbers

Session 3: Introductions to Electronics Engineering

Introduction to Digital Electronics: Number System and Boolean Algebra

1. To introduce fundamental concepts of digital electronics
2. To provide a brief overview of different number systems
3. To illustrate the application of the binary number system in digital circuits and computation
4. To introduce Boolean algebra, its principles, laws and basic operations such as AND, NOT, OR, XOR, etc
5. To engage students in solving problems regarding number systems conversions.

Session 4: Introductions to Electronics Engineering

The simulation will be performed on Circuitverse: [https://circuitverse.org/simulator]
Note: (Students can also use other software such as Multism and LabView)

Design of Digital Electronics Circuits:

1. To demonstrate the application of Boolean Algebra in the design and simplification of digital circuits, emphasising logic gates and truth tables.
2. MiniProject: Design of combinatorial digital circuits and presentations

Session 5:Radio Waves and Mobile Communications

In this section, we shall study the propagation of wireless signals through:

- Free space
- Ground
- Atmosphere

We shall then explore how to design a wireless channel using Free Space Path Loss Model and the Hata-Okumura Model, that is, compute link budget.

Session 6:

Robotics

We give robotics a mentally stimulating yet entertaining introduction

Topics/ Objectives:
1. Introduction to robotics
2. Robot motion
3. Sensors
Some links:
i) A holonomic ground robot: https://youtu.be/xUQ4n1FmiXM
ii) Stanford's Personal Robotic program: http://personalrobotics.stanford.edu/
iii) DARPA Grand Challenge 2005 winner "Stanley": http://personalrobotics.stanford.edu/
iv) Boston Dynamics: https://youtu.be/wlkCQXHEgjA
v) Oxford Robotic Institute: https://www.youtube.com/watch?v=bMRUbZf7E7c

Future of Engineering
1. Communication Engineering: What is 6G going to look like?
2. Energy and Power Engineering: Case study on renewable energy technology

Communication Engineering
Objectives:
1. To provide students with a comprehensive understanding of the evolution of mobile communication from 1G to 5G.
2. To critically analyse the features and advancements of each generation of mobile communication.
3. To explore the proposed framework and features of the future 6G networks, developing insights into their potential impact on society and technology.
4. To examine key proposed technologies for 6G, such as Intelligent Reflecting Surfaces (IRS), and assess their potential applications and implications.
Energy and Power Engineering
Objectives
1. To engage students in an in-depth study of various renewable energy technologies, fostering a comprehensive understanding of their mechanisms and potential.
2. To facilitate student-led presentations that critically examine and discuss the challenges associated with these technologies.
3. To inspire students to investigate engineering solutions to overcome the identified challenges, promoting problem-solving skills.
4. To encourage exploration of innovation opportunities within the renewable energy sector, fostering creative thinking and forward-looking perspectives.

Session 7:
Case Studies and Project Presentations:
1. Aerospace Engineering
2. Material Science
3. Engineering Ethics (Civil and Mechanical Engineering)

Objectives:

1. To discuss the development in the area of materials engineering, which is crucial to many areas of engineering

2. To discuss the importance of ethics in the engineering profession through case studies

** The teaching content is subject to change.*

Psychology Stream: Basic Info

Session 1: Low mood
Lecture
Course intro
Understanding low mood
Tutorial: TED talk Examples

Lecture
Paper
How to turn bad days into better days

Session 2: Motivation
Lecture
Tutorial: TED talk
Lecture: Paper

Session 3: Emotion & Pain
Lecture
Tutorial: TED talk
Lecture : Paper

Session 4: Fear & Stress
Lecture
Tutorial: TED talk
Lecture: Paper

Session 5: On self-doubt and a meaningful life
Lecture
Tutorial TED talk
Lecture : Paper
Final: TED Talk Discussion

** The teaching content is subject to change.*

Law Stream: Basic Info

Oxford Global ASYL 2024

Learning Objectives and Lesson Plan

Session 1: International Environmental Law. History and international instruments.

Session 2: IEL. General principles.

Session3: Contemporary global environmental challenges and international legal frameworks. Biodiversity loss, deforestation, marine pollution.

Session 4: Case law of International Tribunals on environmental challenges. ICJ, ITLOS.

Session 5: Climate Change. The Kyoto Protocol, the UNFCCC, and the Paris Agreement. The Paris Agreement. Contents, obligations, procedures.

Session 6: Case law of international tribunals on climate change. Part I: ITLOS, ICC, ICJ.

Session 7: Case law of human rights tribunals on climate change. Part I: ECtHR, IACtHR.

Session 8: Landmark decisions of domestic courts on climate change.

Session 9: Moot Exercise Part I. Reading of the case and preparation of submissions.

Session 10: Moot Exercise Part II. Submissions of plaintiffs and defendants, and ruling of the Court.

Recommended Readings

Rajamani & Peel (Eds.) The Oxford Handbook of International Environmental Law (Second Edition)

Fisher, E., Scotford, E., & Barritt, E. (2017). The Legally Disruptive Nature of Climate Change. The Modern Law Review, 80(2), 173–201. http://www.jstor.org/stable/26646916

** The teaching content is subject to change.*

Physics Stream: Basic Info

Learning Objectives and Lesson Plan

Session1 :
Morning session

- This session will focus on the basics of electricity in the human body. This includes Electrical properties of cells, neuromuscular transmission, and electricity in the heart. These fundamentals will be followed by the application of these principles such as electrocardiograms, electroencephalogram, and electromyography.

Afternoon session

- This will be the beginning of the coding lab. We will be using Python. The first session will be focused on getting Python on everyone's PC. Following that we will start with the very basics such as the main data types, numeric operators, comparison operator and Boolean operators.
- The afternoon sessions will be flexible with the pace of the students.

Session2 :
Morning session

- This session will focus on the electricity applied to the human body, we will discuss determinants of electrical injury, defibrillators, tasers, diathermy and pacemakers.

Afternoon session

- Coding lab - Initial plan is to cover functions and classes. Coding exercises will be in the form of Jupyter notebooks which I have pre-prepared.

Session3 :
Morning Session

- This section will focus on ionising imaging: Positron Emission Tomography (PET), Computed Tomography (CT). PET's statistical nature and reconstruction methods will be discussed. We will also discuss spatial resolution, image noise and how they may confound diagnosis.

Afternoon session

- Coding lab - PET iterative reconstruction from sinogram, we will use a phantom from a SciPy library to understand the maximum-likelihood (ML) expectation-maximisation (EM) [ML-EM]

Session4 :
Morning session

- This session will focus on non-ionising imaging, Magnetic resonance imaging and ultrasound. Both will be covered in depth, ranging from nuclear spin to the doppler equation.

After noon session

- This will be a mix of coding lab as well as presentation exercise.
- Part 1: At this stage, I will ask the students to present the presentation for some late-stage feedback. (Last year I had noticed that not many students had practised presentations before, and rehearsing it with some feedback showed great improvement)
- Part 2: Coding - ECG signal processing. We will have a real ECG signal which we will process to find information regarding the patient. E.g. the heartbeat or any possible heart conditions

Session5 :

- Part1: This session will be focused on the latest applications of artificial intelligence on biomedical imaging. We will cover how some Deep Learning algorithms work (algorithm architecture) as well as what the ethical issues that deep learning may cause.
- Part 2: Pub Quiz time! I have designed a pub-style quiz on the topics that we have covered. It will be fast paced, competitive, and there will be prizes!

Previous knowledge

- Basic electricity: Ohm's law, capacitors, current, voltage etc.
- Basic statistics: mean, median, average, standard deviation, p-values.

Bibliography suggestions

- The Spark of Life: Electricity in the Human Body Frances Ashcroft
- Learn Python 3 the Hard Way by Zed Shaw

** The teaching content is subject to change.*

Biochemistry Stream: Basic Info

Oxford Global ASYL 2024

Learning Objectives and Lesson Plan

The aim of this course is to provide students an idea of the intriguing world at the confluence of chemistry and biology. The lecture series will focus on enzymology and how enzymes play such an important role in our day-to-day life. Ranging from mechanistic understanding of enzyme function to evolution, the course will encapsulate key concepts of biochemistry which lay the foundation for many STEM & medicine graduate courses.

Session 1: What are enzymes? How do they work?

- Students will deal with the basic understanding of enzymes and the concept of catalysis including energy activation barriers, kinetics, and structural importance.
- Students will be introduced to catalysis as a principle of green chemistry and will be organised in small groups to identify some enzymes used in day-to-day life.

Session 2: The biochemistry of life – enzymes run the world

- We will lay emphasis on several enzymes functional in digestion, cellular respiration, and metabolism.
- The biochemistry of glycolysis, citric acid cycle, and photosynthesis will be dealt with in detail. Intriguing exercises around the mathematics of energy (bioenergetics) will be provided.

Session 3: Menacing enzymes – not everyone is a friend!

- This lecture will address key issues arising because of enzyme evolution to counter human intervention including antibiotic resistance and herbicide resistance. It will smoothly pave a way to discuss drug discovery and development with different strategies adopted in the field of medicinal chemistry including enzyme inhibition.
- *We would also on this day do a fun experiment in 2-3 groups to see the effect of enzymes on antibiotics to better understand the concept of inhibition.*

Session 4: Biocatalysis and directed evolution – sky is the limit

- Students will understand the importance of biocatalysis in the modern world with real life examples of industrial applications.
- Special emphasis on directed evolution as means of engineering proteins for diverse applications that earned the Nobel Prize in Chemistry in 2018.

Session 5: Medical applications of enzymes

- Students will learn about the CRISPR/Cas9 system which is one of the best examples of

harnessing the potential of enzymes for medical benefit. A wide range of other therapeutic enzymes employed for treatment will also be discussed.

Prerequisites

Students should be acquainted with the basics of biomolecules and the concept of catalysts. A brief understanding of the central dogma and the eukaryotic cell would be beneficial.

Recommended Readings

Enzymes: A very short introduction, Paul Engel, *Oxford University Press*
Biochemistry: A very short introduction, Mark Lorch, *Oxford University Press*

** The teaching content is subject to change.*

Biomedicine Stream: Basic Info

Oxford Global ASYL 2024

Day 1:

Session 1:

. Overview of next-generation sequencing (NGS) methods available right now.
This will summarise the history of NGS and lead to an introduction to the different forms of sequencing that utilise NGS.

Tutorial:

. How do we prepare DNA and RNA for sequencing?

Session 2:

• An introduction into programming in R

Day 2:

Session 1:

. Single-cell DNA, RNA and protein technologies and how they have been applied in cancer research.

Tutorial:

• To what extent have single-cell technologies transformed cancer research?

Session 2: Further training in R programming.

Day 3:

Session 1:

. Experiment: We will extract DNA and RNA. Half of the class will extract RNA, the other will extract DNA.

Tutorial:

. DNA vs RNA vs protein. What are the advantages and disadvantages of studying them in (cancer) research.

Session 2:

. Spatial DNA, RNA and protein technologies and how they have been applied in cancer research.

Day 4:

Session 1:
• Analysing sequencing DNA using R.

Tutorial:
. What role does bioinformatics have in (cancer) research?

Session 2:
. Experiement: We will look a t our own cells and nuclei acids under experiment our cells

Day 5:
Session 1:
. Experiment: We will perform gel electrophoresis.

Tutorial:
. Journal club: we will read a paper that applies several molecular biology techniques
. Look at the results of the experiment in session 1.

Session 2:
. Methods for analysing the epi genome . Long-read vs short read sequencing.

TASK FOR STUDENTS

Pick one of the multi-omic methods covered over the week.
Write an essay and create a presentation on the impact it has had on the research of one type of cancer.

Prerequisites

• An understanding of basic molecular biology. Including:
-The central dogma
-DNA replication
-Transcription -Translation
. Understanding (or at least awareness) of chain-terminator sequencing and electrophoresis.

** The teaching content is subject to change.*

Economics Stream: Basic Info

Oxford Global ASYL 2024

Learning Objectives and Lesson Plan

The aim of this course is to provide students an inside look into the disciplinary foundations of microeconomics. The material covered is intended to be more advanced than what students have previously seen in the IB or AP curricula. Students are not expected to master the material. Rather, the course should be understood as a 'taster' of what taking a degree in economics at the undergraduate level might be like.

Session 1: What is Economics? What is Microeconomics?

- Students will first be given an overview of the development of the (canonical) economics discipline as a whole, starting with political economists such as Adam Smith. We will cover the distinction between macroeconomics and microeconomics.
- Students will be introduced to the basic elements of microeconomic modelling: Preferences, Utility, and Constraints.

Session 2: The Mathematics of Constrained Optimisation

- We will review and go deeper into preferences, utility, and constraints.
- Additionally, we will go over what should be a review of the methods of differential calculus that economists (and other quantitative social scientists) use to find optima.

Session 3: Utility and Profit Maximisation

- This cluster of lessons takes the mathematical knowledge from the previous session and applies them to formal models in Microeconomics.

Session 4: Introductory Game Theory: Firms, Market Structure, and Strategic Interaction

- Students will be given an overview of the historical development of Game Theory, and an introduction to what it constitutes.
- We will then build on the knowledge of microeconomics to analyse models of firm behaviour which fall under the ambit of Game Theory.
- We will play some game-theory games to illustrate.

Session 5: Normal- and Extensive-Form Games

- Students will learn how to analyse normal-form games and find equilibria.
- If there is time left over, we will analyse extensive-form games and repeated games. We will also have game-theory games here.
- A final discussion will be had on academic economics, applying for an undergraduate

economics programme, etc.

Prerequisites

Students should be acquainted with differential calculus (i.e., how to take derivatives). Maths at this level is absolutely essential for being able to understand the content of the course. Additionally, students are recommended to have taken economics at the AP or IB level, although this is not a necessity.

Recommended Readings

Dixit, Avinash (2014): *Microeconomics: A Very Short Introduction*. Oxford University Press.

Binmore, Kenneth (2007): *Game Theory: A Very Short Introduction*. Oxford University Press.

** The teaching content is subject to change.*

Statistics Stream: Basic Info

Oxford Global ASYL 2024

Learning Objectives and Lesson Plan

Session 1: Introduction and definitions of: probability, state space, events, random variables, expectation, variance and independence.

Session 2: Bayes theorem and examples; probability paradoxes.

Session 3: Distributions; how to sample from a given distribution.

Session 4: Strong law of large numbers. Central limit theorem. Monte Carlo method. Computing integrals using randomness.

Session 5: Maximum likelihood estimator in examples.

Prerequisites

Requirements: Having some idea of integration could be helpful at some moments.

Recommended Readings

We will roughly follow the lecture notes from here https://courses.maths.ox.ac.uk/course/view.php?id=606 (but not exclusively, and also these notes cover much more than what we will be able to go through).

** The teaching content is subject to change.*

Computer Science Stream: Basic Info

Learning Objectives and Lesson Plan

Name of the course: Data Science in Python – introduction to Machine Learning

In the course the students will learn how to code in python and conduct data analysis with a variety of methods. We will focus on practical knowledge of coding, usage of Pandas and NumPy libraries and introduce basic Machine Learning models. On the theoretical side of the course, we will cover the principles of data science and mathematical foundations standing behind the ML models. We will study both supervised ML models: linear regression and k-nearest neighbours, and unsupervised ML model: k-means. We will discuss the difference between regression and classification problems and the variance and bias trade-off. At the end of the course, the students will complete projects based on real world questions using publicly available data and methods learnt during the course.

The sessions plan:
Every day we will start with theoretical session which introduces the concepts mathematically in form of a lecture. The second session will be hands on coding practice where we will implement the things learnt. The exception is day 1 when we will focus on anaconda installations and usage of jupyter notebooks to code.

Session 1:
- Anaconda installation, jupyter notebooks introduction, introduction to programming: variables, dictionaries, lists
- For loops, conditionals, Introduction to pandas and numpy

Session 2:
- Intro to ML: Unsupervised vs supervised learning, regression vs classification
- Explanatory Data Analysis in pandas

Session 3:
- Linear regression - mathematically
- Implementation of linear regression in python with real data

Session4:

- K -nearest neighbours (KNN) with cross validation (theory)
- Implementation of KNN

Session5:

- K-means - mathematically
- Implementation of k-means

Session 6:

- Bias vs Variance trade-off
- Cross validation, parameter selection methods.

Previous knowledge

High school level mathematics, experience with statistics welcomed. No previous coding experience required

The students must have a laptop per pair so they can work on the code on their individual machines.

Bibliography suggestions:

Introduction to machine learning:
https://www.v7labs.com/blog/supervised-vs-unsupervised-learning

Linear regression: (hard maths – read as much as you understand, we will go slowly through it in the class):

https://www.stats.ox.ac.uk/~myers/stats_materials/pdf_notes/estimation.pdf

** The teaching content is subject to change.*