

What is Science?

BSU102

Semester 1

Credit Hours 03

COURSE DESCRIPTION:

Science and Technology have completely transformed the way we live. The development we have seen in the past few decades is unprecedented but very few understand the principles through which the scientific progress is achieved. This course, especially designed for first year students introduces various fields of natural science, how scientists operate within these fields, what methods they deploy to make new discoveries, and how they communicate the advances in their fields to the world.

The course starts with an introduction to the development of the scientific approach. It discusses the modern use of the scientific method and the tools and resources that scientists deploy to ensure that they produce authentic and reliable bodies of knowledge. Students are then introduced to three main branches of science (Physics, Chemistry and Biology), their core underlying principles, major developments in these fields and their applications in modern life. Students will work on case studies and lab experiments to understand how scientists discover various workings of nature and the missteps that they can take while conducting any scientific inquiry. The final part of the course focusses on the skills to separate valid science from fringe science. Students are also exposed to the fundamentals of scientific communication and strategies to identify reliable bodies of knowledge.

COURSE OUTCOMES:

Through successful completion of this course, students will be able to:

1. Clearly articulate the development of scientific thought through various parts of human history and compare it to the modern scientific method.
2. Describe various branches of Science, their underlying core ideas, and compare their applications.
3. Using case studies and demonstrations, practice application of the Scientific Method in the natural sciences.
4. Determine whether a given claim or belief is scientifically valid or not and provide a clear rationale for doing so.

Outline

1. Overview of Science and the Scientific Method

What is science?

What qualifies as science?

Why does it matter?

Who practices it?

Introduction to important terminology: Fact, hypothesis, theory, law

2. Evolution of the Scientific Method across Civilizations

Prehistory, Mesopotamia & Egypt, Greeks, China, South Asia, Arab/Islamic, European

Examples of scientific contributions from different regions are used to show different forms of reasoning that were used to determine the nature of reality and develop science as a process, e.g. inductive, deductive, abductive, hypothetico-deductive, falsification.

3. The Modern Scientific Method

What does modern science look like today?

What are the advantages of using this method? What are the limitations?

How did science become the dominant method of understanding the natural world?

4. Introduction to Areas/Branches of Science

1 week (Intro to areas/branches of science)

2 weeks (Physics) = Major themes in Physics, Applications, Experiments

2 weeks (Chemistry) = Major themes in Chemistry, Applications, Experiments

2 weeks (Biology) = Major themes in Biology, Applications, Experiments

For each of the branches:

Introduction to core ideas and important theories (e.g. Physics: Gravity, Chemistry: Atomic theory, Biology: Evolution by Natural Selection).

Introduction to possible majors: How do they relate to various professions/fields.

Practical applications of ideas from each field

5. **How to spot FAKE SCIENCE!?**

Practices leading to pseudoscience

Case-studies from popular discourse (e.g. Cold Fusion, Telepathy, N-rays etc.)

6. **Scientific Communication**

Introduction to the Peer Review (advantages and misuse)

Importance of controls and replication (link with the replication crisis in science)

Essential Readings

1. Richard Feynman's Comments on Science (<http://www.feynman.com/science/whatis-science/>)

2. Hawking, S., Mlodinow, L (2008). *A Briefer History of Time*. Bantam Books, - Chapter 3 : Nature of a Scientific Theory

3. Chalmers, A., 2015. *What Is This Thing Called Science?* 4th ed. Indianapolis: Hackett Publishing Company, Inc., pp.24-47.

4. <https://serc.carleton.edu/teacherprep/resources/activities/ordeal.html>

5. James E McClellan III and Harold Dorn (2016) *Science and Technology in World History: An Introduction*. Second Edition. Johns Hopkins University Press – pp 39- 45, 55-62

6. Carey, S., 2011. *A Beginner's Guide To Scientific Method*. 4th ed. Boston: Clark Baxter, pp.1-7, 29-45.

7. Feynman, R., Leighton, R. and Sands, M., 2010. *The Feynman Lectures On Physics*. 1st ed. New York: Basic Books.,pp. 1-14

8. Paul G Hewitt, 2015, *Conceptual Physics*, 12th Edition., City College of San Francisco, Pearson

9. Raymond Chang, *General Chemistry: The Essential Concepts*, 2008, McGrawHill, 5th Edition

10. Nivaldo J, *Chemistry in Focus*, 2018, 7th Edition.

11. Ernst Mayr (1997) *This is Biology: The Science of the Living World*. Harvard University Press, Cambridge, Massachusetts: Ch 1-4, Ch 6

12. Dev, Sukhendu (2015) Unsolved problems in Biology – The state of current thinking. *Progress in Biophysics and Molecular Biology*, 117: 232-23

Paul G Hewitt, 2015, *Conceptual Physics*, 12th Edition., City College of San Francisco, Pearson

13. Rovelli, C., Carnell, S. and Segre, E., 2015. *Seven Brief Lessons On Physics*. 1st ed. Allen Lane, Penguin Books Ltd.

14. Raymond Chang, *General Chemistry: The Essential Concepts*, 2008, McGrawHill, 5th Edition.

15. H. Eugene, Bruce. E, Patrick Woodward, *Chemistry: The Central Science*, 2017, Pearson, 14th Edition

16. Nivaldo J, *Chemistry in Focus*, 2018, 7th Edition.

17. Ralph H. Petrucci, F. Geoffrey, Jeffry. D, Carey, *General Chemistry: Principles and Modern Applications*, 10th Edition

18. Scerri 2011, The Evolution of the Periodic System. *The Scientific American*.

19. Douglas J Futuyma and Mark Kirkpatrick (2005) *Evolution*, 4th Edition. Sinauer Press, Unit 1

20. Evidence for Natural Selection from the book, *Science and Creationism: A View from the National Academy of Sciences: Second Edition*.
<https://www.ncbi.nlm.nih.gov/books/NBK230201/>
21. Carey, S., 2011. *A Beginner's Guide To Scientific Method*. 4th ed. Boston: Clark Baxter, pp.108-128.
22. Bergstrom C. and West, J. 2020, *The Art of Skepticism in a Data-Driven World*, pp xx
23. Kelly, J., Sadeghieh, T., & Adeli, K. (2014). Peer Review in Scientific Publications: Benefits, Critiques, & A Survival Guide. *EJIFCC*, 25(3), 227–243.

Online Resources

What is chemistry, <https://www.livescience.com/45986-what-is-chemistry.html>

Jones and Mulvaney, what has chemistry ever done for you, Australian Academy of Science, <https://www.science.org.au/curious/chemistry> (accessed on 11/19/2020)

A brief history of chemistry, <https://www.youtube.com/watch?v=nXKrmOHU68k>

Three chemistry experiments that changed the world,
<https://www.youtube.com/watch?v=iRGaLRQaKOc>

Timeline of important advances in medical biotechnology -
<https://geneticliteracyproject.org/2020/09/08/biotechnology-timeline-humansmanipulating-genes-since-dawn-civilization/>

Breakthroughs that will change medicine -
<https://www.popularmechanics.com/science/health/a4180/4303407/>

Intro to atoms, elements and the periodic table, •
<https://www.khanacademy.org/science/ap-chemistry/atoms-compounds-ionsap/introduction-to-the-atom-ap/v/introduction-to-chemistry>

Origins of Chemistry,
https://www.youtube.com/watch?v=QiiyvzZBKT8&ab_channel=CrashCourse

What is chemical bonding? <https://byjus.com/jee/chemical-bonding/>

Acids and bases, <https://www.youtube.com/watch?v=vt8fB3MFzLk>

Chemical thermodynamics,
[https://chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_Chemistry_-_The_Central_Science_\(Brown_et_al.\)/19%3A_Chemical_Thermodynamics](https://chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_Chemistry_-_The_Central_Science_(Brown_et_al.)/19%3A_Chemical_Thermodynamics)

How does surface area affect the speed of a chemical reaction?
https://www.sciencebuddies.org/teacher-resources/lessonplans/surface_area_reaction_rates?from=Blog

Determining the concentration of Oxygen in the air:
https://www.pbs.org/wgbh/nova/teachers/activities/2506_everest.html

Acids & bases: https://www.sciencebuddies.org/science-fair-projects/projectideas/Chem_p013/chemistry/make-cabbage-pH-indicator

Properties of mixtures vs. solutions:
https://www.teachengineering.org/lessons/view/cub_mix_lesson3

Periodic table: <https://study.com/academy/lesson/periodic-table-activitiesgames.html>

Molecule building: How to construct molecular models?
https://www2.nau.edu/lrm22/lessons/molecule_building/molecule_building.html

Counting calories:
https://www.teachengineering.org/activities/view/cub_heat_lesson1_activity1

Getting a grip on Hydrogen bonds:
https://serc.carleton.edu/NAGTWorkshops/oceanography/activities/hydrogen_bond.html

How to separate soluble solutions: <https://www.scientificamerican.com/article/bring-science-home-separatesolutions/>

Charcoal Water purifying experiment: <https://thehomeschoolscientist.com/charcoal-water-purifying-experiment/>

Electrolysis of Water: <https://highschoolenergy.acs.org/content/hsef/en/howdo-we-use-energy/electrolysis-of-water.html>

Oxygen and fire experiment: <https://thehomeschoolscientist.com/oxygen-fireexperiment/>

World's Oldest Calendar - <https://www.ancient-origins.net/news-historyarchaeology/lunar-calendar-0012340>

• Ishango Bone -

<https://www.naturalsciences.be/sites/default/files/Discover%20Ishango.pdf>

• Kalokol Pillar's Site -

http://www.chaz.org/Arch/Turkana/Namoratunga/ASI_Kalokol.html

Whiteson, D. and Cham, J., 2020. What Are The Basic Constants Of The Universe?.

[podcast] Explain the Universe. Available at: <https://www.iheart.com/podcast/105-daniel-and-jorge-explain-t-29862087/episode/what-are-the-basic-constants-of-62715327/>

[Accessed 23 November 2020]

• Physics Girl Relevant Playlist:

https://www.youtube.com/playlist?list=PLGO_AWB1C4GQz6JF3-0yZHpoKfqZb7O5z

• Crash Course Physics • Minutephysics: Relevant Playlist on Modern Physics:

https://www.youtube.com/watch?v=p_o4aY7xkXg&list=PL908547EAA7E4AE74

Kurzgesagt – In a Nutshell: Relevant Videos:

<https://www.youtube.com/c/inanutshell/search?query=Physics>

1. Veritasium Relevant Playlist:

<https://www.youtube.com/watch?v=txmKr69jGBk&list=PLAC555EC7D3D0F4AA>

Physics Demos Playlist:

<https://www.youtube.com/c/funsciencedemos/search?query=Physics>

How was the Earth formed? <https://www.space.com/19175-how-was-earth-formed.html>

Story of Earth 4. <https://www.learner.org/series/the-habitable-planet-a-systems-approach-to-environmental-science/many-planets-one-earth/online-textbook/>

<https://www.biointeractive.org/classroom-resources/skin-color-and-human->

What is DNA? - <https://www.nature.com/scitable/topicpage/DNA-Is-aStructure-that-Encodes-Information-6493050/>

How do DNA and RNA differ? - <https://sciencing.com/dna-rna-differ4566205.html>

What is the central dogma - <https://www.yourgenome.org/facts/what-isthe-central-dogma>

The Central Dogma of Molecular Biology - <http://thebiologyprimer.com/the-central-dogma-study-guide>

RNA functions beyond transcription of protein -

<https://www.nature.com/scitable/topicpage/rna-functions-352/>

<https://online.ucpress.edu/abt/article/81/3/202/91901/Using-Shapes-amp->

<https://www.biointeractive.org/classroom-resources/fixing-gene-expression>

Prokaryotic and Eukaryotic cells -

[https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_Introductory_Biology_\(CK-](https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_Introductory_Biology_(CK-12)/02%3A_Cell_Biology/2.03%3A_Prokaryotic_and_Eukaryotic_Cells)

[12\)/02%3A_Cell_Biology/2.03%3A_Prokaryotic_and_Eukaryotic_Cells](https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_Introductory_Biology_(CK-12)/02%3A_Cell_Biology/2.03%3A_Prokaryotic_and_Eukaryotic_Cells)

Differences between animal and plant cells

<https://www.bbc.co.uk/bitesize/topics/znyycdm/articles/zmrtng8>

Tree of life showing the evolutionary split between prokaryotes, eukaryotes, and then the split of eukaryotes into animal and plant cells <https://www.researchgate.net/figure/A->

[SIMPLIFIED-TREE-OF-LIFE-MANYOF-THE-MAJOR-BRANCHES-ARE-OMITTED-BUT-A-SPLITBETWEEN fig9 301895499](#)

Mitosis and Meiosis The Cell Cycle (including Mitosis and Meiosis) -

<https://www2.le.ac.uk/projects/vgec/highereducation/topics/cellcycle-mitosis-meiosis>

Eukaryotic cell cycle and cancer – interactive module

<https://www.biointeractive.org/classroom-resources/eukaryotic-cell-cycle-and-cancer>

<https://www.stem.org.uk/resources/community/collection/136382/prokaryotic-and-eukaryotic-cells>

<https://serc.carleton.edu/sp/library/visualizations/examples/48527.html>

Detailed photosynthesis -

[https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_Introductory_Biology_\(CK-12\)/02%3A_Cell_Biology/2.23%3A_Photosynthesis_Summary](https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_Introductory_Biology_(CK-12)/02%3A_Cell_Biology/2.23%3A_Photosynthesis_Summary)

Simplified photosynthesis with context

<https://www.nature.com/scitable/topicpage/photosynthetic-cells14025371/>

Detailed cellular respiration

[https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_Introductory_Biology_\(CK-12\)/02%3A_Cell_Biology/2.26%3A_Cellular_Respiration](https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_Introductory_Biology_(CK-12)/02%3A_Cell_Biology/2.26%3A_Cellular_Respiration)

Simplified cellular respiration with context 8.

<https://www.nature.com/scitable/topicpage/cell-energy-and-cellfunctions-14024533/>

https://www.calacademy.org/sites/default/files/assets/docs/pdf/photosynthesisroleplay_lesson.pdf

Disease Biology of Malaria: <https://www.cdc.gov/malaria/about/biology/index.html>

Evolution of sickle cell anemia in humans: <https://www.biointeractive.org/classroom-resources/making-fittestnatural-selection-humans>

Why Malaria should be seen as both a medical and ecological problem

<https://www.nationalgeographic.com/science/phenomena/2014/11/26/beat-malaria-we-need-to-see-it-as-an-ecological-problem/>

Importance of ecology for Malaria eradication 8.

<https://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1000303>

Replication Crisis in Science: <https://www.vox.com/future-perfect/21504366/science-replication-crisis-peerreview-statistics>

Scientific Reproducibility: <https://plato.stanford.edu/entries/scientific-reproducibility/>

Video Resources

Development of Paleolithic Tools -

<https://www.youtube.com/watch?v=SrvPOkMs4U4&pbjreload=101>

Decoding the Astronomy of the Stonehenge –

<https://www.youtube.com/watch?v=Fx-KrvuiafE&pbjreload=101>

Babylonian Origins of Astronomy –

<https://www.youtube.com/watch?v=1vRexBVBbxQ>

Interpreting Mesopotamian Science –

https://www.youtube.com/watch?v=bnBkZ_Y18uA

Babylonian Clay Tablet Rewrites the History of Mathematics -

<https://www.youtube.com/watch?v=Rx5dCXx1SI>

Pre-Socratics –

<https://www.youtube.com/watch?v=epCOGAa7tRQ>

Plato and Pythagoras

<https://www.youtube.com/watch?v=4TgwWQ2PFwM>

Aristotle

<https://youtu.be/xrWXil5eSjg>

Cultural Globalization During the Hellenistic Period –

<https://youtu.be/yeXWpQZF-VA>

What happened to the Library of Alexandria -

<https://www.youtube.com/watch?v=jvWncVbXfJ0>

Ptolemy's Theory of Planetary Motion

<https://youtu.be/8IPdcYVhL2U>

China: <https://youtu.be/F6Su3rBxea8>

South Asia: <https://youtu.be/bDQkpNbsly4>

Mesoamerica: <https://youtu.be/dCBDUDwaeCA>

Muslim Middle East: <https://youtu.be/bkVsus8Ehxs>

Newton's scientific methods – Internet Modern History Sourcebook

<https://history.hanover.edu/courses/excerpts/111new.html5>

Baconian method of science – Encyclopedia Britannica

<https://www.britannica.com/science/Baconian-method>

Beginning of a scientific revolution in Europe - <https://youtu.be/vzo8vnxSARg>

Brahe and Kepler, a revolution in astronomy - https://youtu.be/-FYvy3_egHw

The scientific methods of Galileo, Bacon, and Descartes -

<https://youtu.be/UdQreBq6MOY>

Newton and Leibniz - <https://youtu.be/9UKGPOwR-iw>

• Intro to Scientific Method: <https://www.youtube.com/watch?v=UdQreBq6MOY>

Feynman on Scientific Method <https://www.youtube.com/watch?v=EYPapE3FRw>

Evolution of the Scientific Method <https://www.youtube.com/watch?v=xs4coMlaMJA>

Scientific Method and Contribution from the Islamic World

<https://www.youtube.com/watch?v=bkVsus8Ehxs>

2012. Questions No One Knows The Answers To. [video] Available at:

<https://bit.ly/2Ji8NNZ>

Fields of Physics <https://www.youtube.com/watch?v=ZihywtixUYo>

Many Planets, One Earth <https://www.learner.org/series/the-habitable-planet-asystems-approach-to-environmental-science/many-planets-one-earth/manyplanets-one-earth-video-2/>

To get students excited about Earth Science:

https://www.youtube.com/watch?v=T20RT0GgOB4&ab_channel=FrankGregorio

History of Earth Science:

https://www.youtube.com/watch?v=V2381IUhqc0&ab_channel=CrashCourse

What is Earth Science

https://www.youtube.com/watch?v=Ck_e4CRM82Y&ab_channel=MikeSammartano

What is natural selection - <https://www.youtube.com/watch?v=0SCjhI86grU&vl=en>

Icelfish have clear blood -

https://www.youtube.com/watch?v=WpIe8_pUSu4&pbjreload=101

Evidence for Evolution by Natural Selection -

<https://www.youtube.com/watch?v=llEoO5KdPvg&pbjreload=101>

Differences between DNA and RNA -

https://www.youtube.com/watch?v=JQByjprj_mA&pbjreload=101

Central Dogma of Life - https://www.youtube.com/watch?v=whV_CkKT7F0

Protein structure and folding -

<https://www.youtube.com/watch?v=hok2hyED9go&pbjreload=101>

Introduction to cells - <https://www.youtube.com/watch?v=8IlzKri08kk&pbjreload=101>

Prokaryotes and Eukaryotes -

<https://www.youtube.com/watch?v=Pxujitlv8wc&pbjreload=101>

Animal and Plant Cells -

<https://www.youtube.com/watch?v=8IlzKri08kk&pbjreload=101>

Mitosis and Meiosis <https://www.youtube.com/watch?v=QVCjdNxJreE&pbjreload=101>

Cell Division – Mitosis and Meiosis -

<https://www.youtube.com/watch?v=AmFPZLLbHI&pbjreload=101>

Travelling deep inside the leaf to explore photosynthesis -

<https://www.youtube.com/watch?v=pwymX2LxnQs&pbjreload=101>

What is photosynthesis -

<https://www.youtube.com/watch?v=CL9A8YhwUps&pbjreload=101>

What is cellular respiration -

<https://www.youtube.com/watch?v=CiyAs0bxoI&pbjreload=101>

Malaria life cycle (Human Host) <https://www.youtube.com/watch?v=Xaxjg9JOxug>

Malaria life cycle (Mosquito Host)

<https://www.youtube.com/watch?v=0uyE046It3o&pbjreload=101>

Blood disorders and Malaria in Humans

<https://www.youtube.com/watch?v=iOzv2AKAEIw&pbjreload=101>

Vector Biology and Malarial Transmission

<https://www.youtube.com/watch?v=FSuRfskl48w&pbjreload=101>

How to spot pseudoscience?

https://www.youtube.com/watch?v=gaDvroATyiw&ab_channel=Seeker

Confusing correlation with causation

https://www.youtube.com/watch?v=YAAHJm1pi1E&list=PLPnZfvKID1Sje5jWxt-4CSZD7bUI4gSPS&index=12&ab_channel=UWiSchool

Spurious correlations

https://www.youtube.com/watch?v=WNsLcg2GQMY&list=PLPnZfvKID1Sje5jWxt-4CSZD7bUI4gSPS&index=14&ab_channel=UWiSchool

Fermi Estimation

https://www.youtube.com/watch?v=EMQdAYb1fs&list=PLPnZfvKID1Sje5jWxt4CSZD7bUI4gSPS&index=9&ab_channel=UWiSchool

Sounds Too Good to be True

https://www.youtube.com/watch?v=LRgle3DkdVg&list=PLPnZfvKID1Sje5jWxt-4CSZD7bUI4gSPS&index=7&ab_channel=UWiSchool

What is the Peer Review Process

https://www.youtube.com/watch?v=rOCQZ7QnoN0&ab_channel=libncsu

Ethics of Knowledge production

https://www.youtube.com/watch?v=JSV4VZ8gdUQ&ab_channel=TEDxTalks

Overview of the Replication Crisis

https://www.youtube.com/watch?v=3hyMXhw2syM&ab_channel=UWiSchool

TED Ed Talk on reproducibility crisis in science

https://www.youtube.com/watch?v=FpCrY7x5nEE&ab_channel=TED-Ed