GEO 141: Geographic Information Systems I: Digital Mapping (section 102)

Cross-listed with PSC 201: Geographic Information Systems (section 102)

Autumn 2017|Department of Geography |DePaul University

LSP Learning Domain: Scientific Inquiry (SI) Non-lab

Course meets on Wednesday at 4:20-7:35 pm in SAC 224 (SAC GIS Lab)

1. Course Description

As things occur somewhere sometime, it is natural to look at and organize things through a spatial (and temporal) lens. **Geographic Information Systems (GIS)**, computer-based systems for solving spatial problems, have been widely used in many applications, such as disaster response, public health, crime analysis, market analysis, archeology, environmental modeling, and much more. With advances in **geospatial technologies** (which roughly includes GIS, remote sensing, and GPS) and information technology, the geospatial industry is growing. The **geospatial industry** is defined as an information technology field of practice that acquires, manages, interprets, integrates, displays, analyzes, or otherwise uses data focusing on the geographic, temporal, and spatial context. DePaul's GIS certificate program provides training for geospatial workforce.

GEO 141, as a required course for **GIS certificate**, is an introductory-level course covering the fundamentals of GIS. Course contents are aligned with Core Geospatial Abilities and Knowledge in Geospatial Technology Competency Model (GTCM) adopted by US Department of Labor in 2011. Instruction is accomplished through lectures and hands-on computer lab exercises using ArcGIS for Desktop 10.4. This course will provide foundation for GIS career if the goal is to obtain GIS certificate. The course, fulfilling LSP SI domain, will demonstrate how math, science, and technology are applied to solve geographic problems. Students will also get to reflect on how technology affects social practice. Prerequisite(s) of GEO 141 is LSP 120 or HON 180 or MAT 130 or instructor's permission.

2. Course Topics: through this course you will learn

- What is GIS and why study GIS?
- What kinds of data can you work with in GIS, and how are those data digitally represented?
- How can data be retrieved using query?
- How does a map represent real world, and what are distinguishing characteristics of a map?
- What constitutes a well-designed map, and what are principles of effective map design?
- How are thematic maps made from census data?
- How are street addresses mapped in GIS?
- How does GPS work, and what is GPS used for?
- How is terrain represented and used for analysis in GIS?
- How are positions on the Earth's surface measured?
- What coordinate reference systems (CRS) are commonly used in GIS?
- What methods of spatial analysis can be performed on vector data, and how do they work?
- What methods of spatial analysis can be performed on raster data, and how do they work?
- What is the impact of the internet on GIS?

3. Required Text: Bradley A. Shellito, 2016, Introduction to Geospatial Technologies 3rd Edition (ISBN-13: 978-1464188725; ISBN-10: 1464188726). $67.99 for e-book at Amazon and the college book store. Other readings are provided on D2L.

4. Instructors' Contact and Office/Lab Hours

	Instructor	Teaching Assistant	GIS Coordinator
Name	Sungsoon (Julie) Hwang	Elisabeth Gadbaw	Cassandra Follett
Contact	shwang9@depaul.edu (773) 325-8668	baspork22@gmail.com	CFOLLETT@depaul.edu (773) 325-3267
Where	990 W Fullerton, 3133	Geography GIS Lab	990 W Fullerton, 3134
When	T, W, TH 2-3 pm or by appointment	Wed 11:20 AM - 2:20 PM	when technical issues arise in Geog GIS Lab

5. Learning Outcomes: At the completion of GEO 141, you should be able to

- Enumerate what specific functions you can perform with GIS in different application areas
- Retrieve data using both attribute and spatial query in GIS
- Employ principles of cartographic design to make maps suited to a given problem
- Process spreadsheet (census, addresses) for mapping by employing appropriate GIS techniques
- Collect location data using a GPS receiver, and import GPS data into GIS for mapping
- Use common coordinate reference systems appropriately
- Conduct suitability analysis by applying buffer, overlay, and map algebra to spatial data
- Apply GIS appropriately to address a geographic problem/question that interests you
- Develop basic ArcGIS skills, including query, thematic mapping, geocoding, table join, field calculation, and spatial analysis

6. Outlines of Topics & Tentative Schedules

Wk	Date	Topic	Lab Activities	Assignment due
1	09.06	Course overview Introduction to GIS	1. Introduction to ArcGIS Desktop	
2	09.13	Get to know geospatial data Retrieve data using query	2. Explore geospatial data 3. Select by attribute, location	
3	09.20	Map reading Map design	4. Make thematic maps I 5. Make thematic maps II	[09.26] HW1
4	09.27	Census mapping Address geocoding	6. Perform table join 7. Perform geocoding	[10.03] HW2
5	10.04	**Midterm** Help for labs and HW3		[10.10] HW3
6	10.11	GPS Terrain modeling	8. Collect location data with GPS 9. Visualize terrain	
7	10.18	Datum and map projection Coordinate Ref. System (CRS)	10. Display XY and project data 11. Define and change CRS	
8	10.25	Vector spatial analysis Raster spatial analysis	12. Vector suitability analysis 13. Raster suitability analysis	[10.27] Proposal
9	11.01	Web GIS Work on project	14. Make a web map application	
10	11.08	**Final** Work on project		
11	11.15	**Presentation**		[11.15] Report

7. Grading Scheme

Components	Breakdown (out of 100 points)	Notes
Participation	11 points	See below for rubric
14 **lab activities**	28 points	Each 2 points
2 **exams**	18 points	Midterm 8 points, Final 10 points
3 **homework**	18 points	Each 6 points
Project	25 points	Proposal 5 points, Report 20 points

Participation: learn better by being prepared for the class. You are expected to participate in the class discussion actively. The score for participation will be assigned according to the following criteria:

- 10-11 = Student is present in all or nearly class meetings, and prepared, at all times, to respond to questions; student is active participant in and out of class, and stays on task in class-time activities.
- 8-9 = Student participates as above, 75% of the time.
- 6-7 = Student does not volunteer comments; responses demonstrate vague familiarity with course readings. Student is passive participant in and out of class, and/or does not stay on task during class-time activities.
- 0-5 = Student never volunteers, cannot respond to direct questions, keeps silent during class discussions and is unable to summarize readings if asked.

To participate actively, complete assigned readings for each unit and be prepared to discuss questions (or learning objectives) posted below in Detailed Plan the Class before the class.

Lab activities: learn basic GIS skills by doing. Lab activities are to help you make sense of concepts covered in readings and lectures. Submit answers to few questions in those activities. Unless noted otherwise, lab activities are due one week after the handout for activities are given out in the class. You will do activities in the class when instructors are present. Although reasonable amount of time is given to complete activities in the class, it is expected that you will complete remaining part of activities outside of the class if you can't complete activities in the class. In that case, I recommend you get help from instructors to complete activities during office hours well before the deadline of lab activities as you might encounter technical issues that you may not be able to troubleshoot on your own.

Exam: check your knowledge of GIS fundamentals. The exam is non-cumulative, closed-book. The format of exams is fill the blank, true and false, multiple choices, and short answers/essays. All are written tests. That is, no ArcGIS skills are tested.

Homework: solidify GIS concepts and skills by applying them to a new problem set. Homework assignments are to be done on your own outside of the class. It is recommended that you try to do it on your own, but you can always reach out for help.

Project: apply GIS to a problem that interests you. Propose and conduct a GIS project that demonstrates comprehensive use of GIS knowledge (multiple techniques) using empirical data to address an issue of interest. Project can be proposed and conducted by a group. GIS projects from the previous quarters include (a) mapping crime in Chicago, food deserts in Northwestern Indiana, and health indicators by US Counties; (b) analyzing whether cancers are more prevalent near hazardous waste sites, how income affects policing and crime, how Chicago Public School closings are related to income and race; and (c) identifying suitable sites for crop production in Africa, desirable Canadian Provinces; suitable hospital locations for HIV care in South Africa, and potential nesting sites for red-headed Woodpeckers in IL.

Late Work Policy: Late work will NOT be accepted. Extensions can be requested if needed, but will be only granted under understandable circumstances (e.g., clients did not provide data in time; you had to be in a funeral).

Makeup Exam/Incomplete Grade Policy: A makeup exam or an incomplete grade can be arranged or granted only when credible dire and documented medical or family situations arise and these circumstances are communicated in a timely fashion.

8. Detailed Plan of the Class: readings, and learning objectives

Week 1: September 6, 2017

Unit 1. What is GIS and why study GIS?

Read a text chapter 1: 1-16, Longley: 11-13, 24-25 (on D2L > Content > Readings)

- What is geospatial technology, and how does GIS relate to remote sensing and GPS?
- What fields have utilized geospatial technology?
- G in GIS: what is special about geospatial data, and what advantages does GIS offer over non-spatial information systems?
- I in GIS: how does GIS add value to supporting decision making, keeping in mind the difference among data, information, and knowledge, as well as applications of geospatial technology?
- S in GIS: what components would be needed to do a GIS project?

Watch a video Geospatial Revolution Episode One (we will watch the first 5 min.)

Lab 1: Get familiar with ArcGIS for Desktop, including user interface, terms, and basic functionality

- ✓ Add geospatial data (layers) such as shapefiles to ArcMap
- ✓ Explore geospatial data in both map view (spatial data) and table view (attribute data)
- ✓ Use basic tools (eg. add data, zoom, identify) in a standard toolbar and tools toolbar
- ✓ Save a map (ESRI Map Document .MXD)

Week 2: September 13, 2017

Unit 2. What kinds of data can you work with in GIS, and how are those data digitally represented?

Read a text chapter 5

- How does GIS represent real-world items viewed as discrete objects (eg. land parcels)?
- How does GIS represent the real world phenomenon as continuous fields (eg. elevation)?
- How is non-spatial data (eg. spreadsheet) represented in GIS?
- What other kind of information do you need to work with data in GIS?
- What file types are commonly used, and how do you view those data in GIS?

Lab 2: Explore different geospatial data in ArcGIS

- ✓ Use ArcCatalog to manipulate (copy, move, delete, rename) geospatial file types
- ✓ Use ArcMap to explore geospatial data through a Layer Property dialog box
- ✓ Distinguish between vector and raster data models by browsing data in ArcGIS
- ✓ Work with (eg. sort, select) non-spatial (attribute) data in ArcMap

Unit 3. How can data be retrieved using query?

Read a text chapter 6: 177-184

- Understand the syntax for building queries based on attribute values (select by attribute)
- Distinguish different field data types (eg. long, double, text) used in ArcGIS
- Build compound query using a Boolean operator
- Retrieve features based on spatial relationship (select by location)

Lab 3: Retrieve data using attribute and spatial query in ArcMap

- ✓ Use a "Select By Attribute" tool in ArcMap
- ✓ Use a "Select By Location" tool in ArcMap

Review Homework 1: explore and retrieve data in ArcGIS Desktop (due 9/26)

Week 3: September 20, 2017

Unit 4: How does a map represent geographic phenomena, and what are distinguishing characteristics of a map?

Read a text chapter 7, Monmonier: 18-24 (visual variables)

- What different types of maps can be made using GIS, and how do they differ in terms of cartographic representation?
- What visual variables make up map symbols, and for what purpose are they used?
- How does the scale of the data affect the map?
- What are some design elements included in maps?

Lab 4: Make thematic maps I

- ✓ Make a point map
- ✓ Make a categorical (unique value) map
- ✓ Make a choropleth (graduated color) map
- ✓ Make a dot density map
- ✓ Make a graduated symbol map

Unit 5: What constitutes a well-designed map, and what are principles of effective map design?

Read Slocum: 85-91 (comparison of thematic maps) and Dent: 251-253 (visual hierarchy)

- How to choose visual variables in map symbol appropriately
- How to choose thematic maps appropriately
- How to use color and text wisely
- How to achieve (promote) visual hierarchy

Lab 5: Make thematic maps II

- ✓ Use a map template
- ✓ Make an isarithmic map
- ✓ Make an isopleth map
- ✓ Make a graph (chart) map
- ✓ Make a prism (3D) map

Review Homework 2: sketch out and execute a map design plan to make thematic maps (due 10/3)

Submit Homework 1 on D2L by 9/26 (Tuesday)

Week 4: September 27, 2017

Unit 6: How are thematic maps made from census data?
Read ArcGIS Help on joining tables, Montello: 95-101 (U.S. Census)

- Use census mapping applications (visit the Census Data Mapper, SocialExplorer website)
- Get familiar with data products of U.S. Census (visit American FactFinder, TIGER/Line website)
- What census geographic entities are used for census mapping, and how are they organized?
- How is table join performed?

Lab 6: Perform table join to make a census map

- ✓ Download census data (American Community Survey) from American FactFinder
- ✓ Download TIGER/Line cartographic boundary files (tracts) from TIGER/Line
- ✓ Normalize (format) a spreadsheet (or flat file) to make tabular data compatible with ArcGIS
- ✓ Join a table to geospatial data to make a thematic map

Unit 7: How are street addresses mapped in GIS?
Read a text chapter 8: 277-286

- How is a network (eg. roads, streams) represented on a computer?
- How is address matching (or geocoding) performed?
- Explore options for batch geocoding (ArcGIS to online geocoder)

Lab 7: perform geocoding to turn an address data in spreadsheet to geospatial data

- ✓ Format a spreadsheet containing addresses for geocoding
- ✓ Perform batch geocoding
- ✓ Perform manual geocoding for any unmatched records
- ✓ Use label classes

Review Homework 3: make a map showing POIs overlaid on demographic data (due 10/10)
Submit Homework 2 on D2L by 10/3 (Tuesday)

Week 5: October 4, 2017

Midterm exam
Help for lab activities and homework
Submit Homework 3 on D2L by 10/10 (Tuesday)

Week 6: October 11, 2017

Unit 8: How does GPS work, and what is GPS used for?
Read a text chapter 4

- What does the GPS consist of?
- How does GPS find a position on the Earth?
- Why isn't GPS perfectly accurate (what are sources of GPS measurement errors)?
- What are some applications of GPS?

Lab 8: Collect point data using a GPS receiver (this is an outdoor activity)

- ✓ Get familiar with functionality of a GPS receiver

- ✓ Collect waypoint data with a GPS receiver
- ✓ Import GPS data into GIS software using DNRGPS (freeware)
- ✓ Collect location data using a GPS Logger app installed in your smartphone (this is optional)

Unit 9: How is terrain represented and used for analysis in GIS?
Read a text chapter 13: 450-465

- How can terrain be represented on topographic maps?
- How is terrain represented in GIS?
- How can digital terrain models be utilized?

Lab 9: model and visualize terrain

- ✓ Work with DEM (Digital Elevation Model)
- ✓ Make a perspective (3D) map from DEM using ArcScene
- ✓ Work with TIN (Triangulated Irregular Network)
- ✓ Make hillshade, slope, aspect, and viewshed maps derived from DEM

Review final project requirements and proposal guidelines (proposal due 10/27 Friday on week 8)

Week 7: October 18, 2017

Unit 10: How are positions on the Earth's surface measured?
Read a text chapter 2: 39-50

- What is datum?
- What is a geographic coordinate system (GCS)?
- How can real-world data be translated onto a 2D surface (what is map projection)?

Lab 10: Display different parts of the world in appropriate map projection

- ✓ Turn a spreadsheet containing XY coordinates to geospatial data in reference to datum
- ✓ Project regions at various geographic scales (global to local) on the fly

Unit 11: What coordinate reference systems (CRS) are commonly used in GIS, and how are coordinate values defined in those CRS?
Read a text chapter 2: 50-57

- What is Universal Transverse Mercator (UTM)? (visit USGS EROS data center)
- What is State Plane Coordinate System (SPCS)? (visit Chicago Data Portal)

Lab 11: Work with geospatial data stored in UTM and SPCS

- ✓ Use a XY tool to make sense of UTM and SPCS
- ✓ Define CRS for data with missing spatial reference
- ✓ Change coordinate systems permanently for spatial analysis

Have a one-on-one discussion on project proposal

Week 8: October 25, 2017

Unit 12: What methods of spatial analysis can be performed on vector data, and how do they work?
Read a text chapter 6: 182 - 186

- What is buffer used for, and how does it work?

- What is overlay used for, and how does it work?
- What is spatial join used for, and how does it work?
- What other basic geoprocessing tools can be used to manipulate geospatial data?

Lab 12: Identify suitable sites that satisfy multiple criteria
- ✓ Perform buffer
- ✓ Perform spatial join
- ✓ Perform overlay

Unit 13: What methods of spatial analysis can be performed on raster data, and how do they work?
Read a text chapter 6: 186 - 193, ArcGIS Help on inverse distance weighted interpolation
- What is inverse distance weighting (IDW) used for, and how does it work?
- What is map algebra used for, and how does it work?
- How are data layers put together to construct a suitability index?

Lab 13: Assess site suitability using map algebra
- ✓ Perform IDW to create a smooth surface from point sample data as continuous field
- ✓ Use a reclassify tool to convert data in different measurement levels to an ordinal level
- ✓ Use map algebra to combine data layers together (to construct a suitability index)

Have a one-on-one discussion on project proposal
Submit Proposal on D2L by 10/27 (Friday)

Week 9: November 1, 2017

Unit 14: What is the impact of the internet on GIS?
Read a text chapter 15: 520-530
- How is the cloud used with geospatial technology?

Lab 14: Create an interactive web map application
- ✓ Use ArcGIS Online to publish a map online

Work on project

Week 10: November 8, 2017

Final exam
Work on project

Week 11: November 15, 2017

4:20 pm Presentation and final report due

References

ArcGIS Help > Essentials of Joining Tables http://desktop.arcgis.com/en/arcmap/10.4/manage-data/tables/essentials-of-joining-tables.htm
ArcGIS Help > How inverse distance weighted interpolation works http://pro.arcgis.com/en/pro-app/help/analysis/geostatistical-analyst/how-inverse-distance-weighted-interpolation-works.htm

Dent. 1998. *Cartography: Thematic Map Design*. 5th Edition. William C Brown Pub.
Longley, Paul A., Goodchild, Michael F., Maguire, David J., and David W. Rhind. 2010. *Geographic Information Systems & Science*. 3rd Edition. Wiley
Monmonier. 1991. *How to Lie with Maps*. University of Chicago Press.
Montello, D. and Sutton, P. 2006, An Introduction to Scientific Research Methods in Geography, Sage Publications
Slocum et al. 2008. *Thematic Cartography and Geographic Visualization*. 3rd Edition. Prentice Hall.

9. Access to ArcGIS

Labs with ArcGIS for Desktop

- SAC GIS lab (SAC 224), SAC 268
- Geography GIS lab (990 W Fullerton, Room# 3135)
- Richardson Library, Loop Library, Daley 1327

GIS lab open hours

- Geography GIS Lab (990 W Fullerton, Room# 3135): https://las.depaul.edu/academics/geography/geographic-information-systems-certificate/Pages/gis-lab.aspx or the lab door.
- SAC GIS lab (SAC 224): http://qrc.depaul.edu/hours.htm or the lab door.

Options for installing ArcGIS in your computer that runs on Windows (Mac is not supported for ArcGIS)

- Purchase a 1 year ArcGIS for Desktop Advanced for $ 100 with free ArcGIS online subscription at http://www.esri.com/software/arcgis/arcgis-for-home
- Buy one of ESRI Press books that come with a 180 day evaluation copy

To access ArcGIS in both PC and Mac remotely: go to DePaul Virtual Lab http://vlab.depaul.edu after week 1. Quality of user experiences vary by internet speed. At least 8 Mbps is recommended.

10. Miscellaneous

Attendance/Absentee Policy: Consistent with university's policy, all students are expected to attend class meetings. Unless absence is explained on medical or compassionate grounds (documentation is required), absence from any classes is grounds for a grade adjustment.

Academic Honesty and Plagiarism: Academic honesty and integrity are expected at all times. Academic dishonesty, such as cheating or copying during exams, will be punished severely. Plagiarism – using someone else's work without acknowledgment and, therefore, presenting their ideas or quotations as your own work – is strictly forbidden. DePaul University officials will be informed of any instance of academic dishonesty and notification will be placed in your file. Please read the DePaul Academic Integrity Resources page (http://academicintegrity.depaul.edu/Resources/index.html) for definitions and explanations of plagiarism and the University's Academic Integrity expectations for students. Cutting and pasting text taken directly from a web-site without appropriate referencing and quotation marks is plagiarism and is forbidden. Submitting work that has any part cut and pasted directly from the internet is grounds for an automatic grade of zero.

Accommodations: Any student who requires assistance is asked to contact the University's Center for Students with Disabilities (CSD) (Phone 773/325-1677, TTY 773/325-7296, Fax 773/325-7396, http://studentaffairs.depaul.edu/studentswithdisabilities).They will be able to assist both student and faculty. If you have a condition that requires accommodation from the Productive Learning Strategies program (PLuS Program) please contact them at the Student Center room 370 (Phone 773/3251677 or online: http://studentaffairs.depaul.edu/plus/

University Center for Writing-Based Learning: Collaborates with writers from all disciplines, backgrounds, levels of expertise, and roles within the University community. Their goal is to help develop better writers along with better writing and reflection through continual revision. If you need assistance with writing assignments, they can be contacted at: 773.325.4272 (LPC) or wcenter@depaul.edu

11. Department of Geography Learning Goals—GEO 141 addresses 1), 5), 6), and 7).

Courses in the Department of Geography teach students:

1) **Understand spatial patterns and processes of modification of the Earth's physical and cultural landscapes**
    a. **As social constructions.**
    b. **As systems that link the Earth with human society in interdependent, dialectical relationships, and**
    c. **Through mapping and visualization.**
2) Understand the concept of scale as a spatial phenomenon that ties the local, the regional, the national, the transnational, and the global in a system of interaction.
3) Understand the phenomenology of the discipline of Geography—most importantly, "space", "place", "landscape," "region," and "location".
4) Distinguish that spaces, places, and so on, may have both objective and subjective/symbolic dimensions.
5) **Develop research and writing competences that would allow you to:**
    a. **Formulate a cogent research question about the spatial character of a physical, socio-cultural, or environment-societal phenomenon,**
    b. **Write about it in ways that reflect analytical and critical thinking, and**
    c. **Ethical concern over social and environmental justice, consistent with the University's social mission.**
6) **Engage competently in qualitative and quantitative spatial analysis, and with exercises that are concerned with explaining spatial regularities (for example, the spatial calculus behind the location of retail commerce in Chicago, or transnational flows of capital).**
7) **Learn the basic utility and use competently one or more of the information technologies that are now redefining the logistical limits of spatial analysis: geographic information systems (GIS), Global Navigation Satellite System (GNSS) and remote sensing.**
8) Achieve greater general knowledge of the world, its regions, its physical systems, its cultures, and political-territorial divisions.

12. Liberal Studies Learning Domain: Scientific Inquiry

Courses in the Scientific Inquiry domain are designed to provide students with an opportunity to learn the methods of modern science and its impact on the world around us. Courses are designed to help students develop a more complete perspective about science and the scientific process, including: an

understanding of the major principles guiding modern scientific thought; a comprehension of the varying approaches and aspects of science; an appreciation of the connection among the sciences; the fundamental role of mathematics in practicing science; an awareness of the roles and limitations of theories and models in interpreting, understanding, and predicting natural phenomena; and a realization of how these theories and models change or are supplanted as our knowledge increases. Every course at DePaul must meet standards outlined by the Liberal Studies Council. Learning domain courses should demonstrate at least one learning outcome listed below

Learning Outcomes – outcomes relevant to GEO 141 are highlighted

1. Students will understand the major principles guiding modern scientific thought. Students will demonstrate a mastery of the science content knowledge of their SID courses.

2. Students will know that science, technology, and math serve as mechanisms for inquiry into the nature of the universe. Students will:

a. Identify questions that can be answered through scientific investigations

b. Design and conduct a scientific investigation to test a scientific hypothesis

c. Use appropriate tools and techniques to gather, analyze, and interpret data to support or refute a scientific hypothesis.

d. Develop descriptions, explanations, predictions, and models using evidence.

e. Describe relationships between evidence and explanations using critical and logical thinking.

f. Recognize and analyze alternative explanations and predictions

g. Communicate scientific procedures and explanations.

h. Use mathematics in all aspects of scientific inquiry.

3. Students will understand and appreciate the interrelationships among science, technology and math. Students will:

a. Use technology and mathematics to identify a problem or design a solution to a problem.

b. Give examples of how science and technology inform and influence each other.

4. Students will understand and appreciate the role of science in society and in their lives. Students will:

a. Provide examples of how science and technology impact our lives, and how social needs and concerns impact our development of technology and scientific investigation.

b. Develop positive attitudes towards science, technology, and mathematics.

c. Establish an ongoing experiential/service-learning interest in science, technology, and mathematics.

5. Students will understand the nature of science, technology, and mathematics. Students will:

a. Provide examples of the abuse of science, including the representation of unfalsifiable claims as science and other forms of pseudoscience.

b. Explain the strengths and limits of scientific inquiry.

c. Explain the difference between evidence and inference, and the provisional nature of scientific explanations by providing examples of how our understanding of the workings of the world has changed in the past.

d. Explain the difference between probability and certainty, and describe what is meant by uncertainty in the context of science, technology, and mathematics.

Writing Expectations: Writing is integral for communicating ideas and progress in science, mathematics and technology. The form of writing in these disciplines is different from most other fields and includes, for example, mathematical equations, computer code, figures and graphs, lab reports and journals. Courses in the SI domain must include a writing component where that component takes on the form appropriate for that course (e.g. lab reports, technical reports, etc.)