LCPS Science Research Courses Overview

The following are the goals for each of the courses:

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Academic Courses
• Understanding the nature of science (especially its strengths and limitations)
• Understand how science proceeds and shapes new knowledge
• Construct knowledge of science discipline knowledge
• Develop scientific reasoning skills

Students taking this class should develop an understanding of how the scientific practice generates new knowledge by examining historic and current examples of knowledge development within the various disciplines within Earth Science or Biology. Additionally, they should gain an understanding of the characteristics of science (nature of science) in order to recognize its value and limitations. They should also learn to critically evaluate scientific claims within the mass media for the authenticity and validity of statements. These students are likely to pursue careers other than those in science and engineering.

In order for students to develop an understanding of how science generates new knowledge, students:
• Will explore historical development of science concepts
• Will conduct two, in-class science research projects that will support learning science content (SOL and beyond)
• Will examine current STEM issues impacting society and examine the science content and process to validate
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Research Courses
• Understanding the nature of science (especially its strengths and limitations)
• Understand how science proceeds and shapes new knowledge
• Construct knowledge of science discipline knowledge
• Develop scientific reasoning skills
• Develop scientific process skills

Students taking this class are developing their skills as scientific practitioners. They are likely to pursue careers in science, technology, engineering, or mathematics (STEM). While they will explore the same concepts as students in the academic course, the approach is intended to help them develop science process skills and scientific thinking. Additionally, they will be expected to develop an understanding of the nature of science in order to recognize it value and limitations.

Students will develop specific science process skills that will allow them to effectively engage in the various components of research culminating in a final project of their own design (these can be done as individuals, pairs, or teams of up to four). Specific skills are associated with different components as seen in the table below.

In order for students to develop science process skills, students:
• Will conduct in-class science research projects related to class that will support learning science content (SOL and beyond)
  ○ Early projects will be largely guided by teacher and focus on particular science process skills
  ○ Later projects will allow students and teacher to work as a team reinforcing skills already learned and building new skills
• Will produce a final project, in small groups, related to questions developed by the class and is specifically related to class concepts
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The primary difference between regular and research focused courses is centered on the how students experience and learn the science process standard (ES.2, BIO.1, CH.1). Those in the regular courses will be focused on understanding how science is done and its application through historical and a couple classroom investigations. In the research courses, students are expected to build skills to potentially apply in future scientific careers. They are expected to participate in multiple classroom investigations culminating in each students conducting a scientific investigation independently or in small groups. These investigation are intended to be focused on questions tangential to one of the multiple classroom investigations.

DIFFERENCES BETWEEN EARTH SCIENCE AND RESEARCH EARTH SCIENCE – SOL ES.2 COMPARISON

ES.2 The student will demonstrate an understanding of the nature of science and scientific reasoning and logic. Key concepts include

Standard	Earth Science	Research Earth Science
science explains and predicts the interactions and dynamics of complex Earth systems	Students will be able to identify historical contributions of science and scientists in generating our current understanding of the complexity of the Earth Systems	Students will be able to identify historical contributions of science and scientists in generating our current understanding of the complexity of the Earth Systems
	Students will be able to critically evaluate the scientific accuracy of claims from media regarding Earth systems based on their own scientific knowledge and understanding of the nature of science	Students will be able to critically evaluate the claims from media regarding Earth Systems based on their own scientific knowledge and understanding of the nature of science
evidence is required to evaluate hypotheses and explanations	Students will be able to critically evaluate evidence on which claims from media based on their own scientific knowledge and understanding of the nature of science	Students will use evidence in a self-designed investigation
observation and logic are essential for reaching a conclusion	Students will be able to critically evaluate the scientific accuracy of claims from media by examining the observations and logic on which the claims were made	When given evidence derived from a scientific investigation, will be able to use the evidence to evaluate a scientific research question
evidence is evaluated for scientific theories	With teacher guidance, students will explore evidence used historically to evaluate current and past scientific theories.	Students will identify evidence necessary to evaluate current and past scientific theories.
	NA	When given evidence derived from a scientific investigation, will be able to use the evidence to evaluate a scientific theories validity
	Students will be able to critically evaluate the scientific accuracy of claims from media based on their own scientific knowledge and understanding of the nature of science	Students will be able to critically evaluate the scientific accuracy of claims from media based on their own scientific knowledge and understanding of the nature of science

DIFFERENCES BETWEEN BIOLOGY AND RESEARCH BIOLOGY – SOL BIO.1 COMPARISON

BIO.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which:

Standard	Academic Biology	Research Biology
observations of living organisms are recorded in the lab and in the field;	Guided by teacher to determine the appropriate observations and methods of recording	Independently identifies the appropriate observations and methods of recording
hypotheses are formulated based on direct observations and information from scientific literature;	Observations by student occur as a result of experiences organized by the teacher and focused on a particular research question	Independently identifies research question from observations (self identified or guided by teacher)
	Hypotheses formed from scientific literature provided by the teachers	Identify appropriate scientific literature on which to develop hypotheses
	Hypotheses formed from research questions provided by the teacher	Formulates hypotheses from observations and scientific literature
variables are defined and investigations are designed to test hypotheses	Differentiate between dependent and independent variable in an investigation	Can explain the importance of measuring the dependent and independent variables in evaluating the hypotheses of interest
	Explain the purpose of systematically changing one independent variable at a time	Designs investigations that attempt to control all variables but the one under investigation
	With guidance can design an sound investigation to evaluate a hypothesis	Independently designs sound scientific investigations
graphing and arithmetic calculations are used as tools in data analysis;	Interpret graphs to evaluate a hypothesis	Identify and create appropriate graphs to evaluate a hypothesis
	Interpret descriptive statistics to evaluate a hypothesis	Determine and calculate appropriate descriptive statistics to evaluate a hypothesis
conclusions are formed based on recorded quantitative and qualitative data	Use evidence in graphs and tables provided by teacher to evaluate scientific claims and reasoning	Use evidence in graphs and tables provided by teacher to evaluate scientific claims and reasoning
	Use evidence in graphs and tables provided by teacher to develop a scientific claim and reason	Uses self-generated graphs and tables from an investigation to be able to develop a scientific claim and reason
sources of error inherent in experimental design are identified and discussed	Evaluate an experimental procedure organized by the teacher to identify errors that might influence the results and ultimately their interpretation	Evaluate experimental procedure of self and peers to identify errors that might influence the results and ultimately their interpretation

Standard	Academic Biology	Research Biology
validity of data is determined	Can determine whether the data described in a media article making a scientific claim is valid based on their own scientific knowledge and examination of the investigation	Can determine whether the data described in a media article making a scientific claim is valid based on their own scientific knowledge and examination of the investigation
	NA	Evaluate whether data collected using a particular investigation design is valid for examining a hypothesis
chemicals and equipment are used in a safe manner	chemicals and equipment are used in a safe manner	chemicals and equipment are used in a safe manner
appropriate technology including computers, graphing calculators, and probe ware, is used for gathering and analyzing data, communicating results, modeling concepts, and simulating experimental conditions;	Guided by teachers to use appropriate technology during a teacher or teacher/class designed investigation	Uses appropriate technology during a self-designed investigation
research utilizes scientific literature	Uses teacher provided scientific literature within knowledge development or forming conclusions	Uses self-identified scientific literature during knowledge development or forming conclusions
	Can determine the validity and reliability of a media source making a scientific claim	Can determine the validity and reliability of a media source making a scientific claim
differentiation is made between a scientific hypothesis, theory, and law	differentiation is made between a scientific hypothesis, theory, and law	differentiation is made between a scientific hypothesis, theory, and law
alternative scientific explanations and models are recognized and analyzed	Can identify competing scientific explanations of biological concepts and evaluate their claims and reasoning based on evidence (e.g., origin of cell organelles in eukaryotic cells, defining species, blending inheritance and Mendelian genetics, Mendelian genetics and quantitative genetics)	Can identify competing scientific explanations of biological concepts and evaluate their claims and reasoning based on evidence (e.g., origin of cell organelles in eukaryotic cells, defining species, blending inheritance and Mendelian genetics, Mendelian genetics and quantitative genetics)
	NA	Can develop an investigation to evaluate alternative explanations/models for a phenomena

Standard	Academic Biology	Research Biology
	NA	Can evaluate competing scientific explanations/models using data from an scientific investigation
	NA	Synthesizes new scientific explanations/models for a phenomena
current applications of biological concepts are used.	Can identify relevant and current examples of biological concepts from mass media	Develops investigations to explore relevant and current examples of biological concepts

DIFFERENCES BETWEEN CHEMISTRY AND RESEARCH CHEMISTRY – SOL CH.1 COMPARISON

CH.1 The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include:

Standard	Academic Chemistry	Research Chemistry
designated laboratory techniques;	Guided by teacher in using appropriate laboratory techniques	Independently applies appropriate laboratory techniques for use to answer a research question
safe use of chemicals and equipment	Guided by teacher in safe use of chemicals and equipment	Guided by teacher in safe use of chemicals and equipment
	During laboratory activities students will follow safe techniques for using chemicals and equipment	During laboratory activities and class investigations students will follow safe techniques for using chemicals and equipment
	Explain and use MSDS sheets to describe safety concerns for chemicals used in a lab	Independently applies safe techniques, including use of MSDS, for using chemicals and equipment when conducting independent research
proper response to emergency situations	Guided by teacher in proper response to emergency situations	Can use MSDS sheets to identify proper response to emergency situations for a given lab or investigation
manipulation of multiple variables, using repeated trials;	Explain the role of the dependent and independent variable in an experiment	Independently identify the dependent and independent variable in an investigation and discuss how one might influence the other
	Explain the purpose of repeated trials in an experiment	Independently choose to use repeated trials in an investigation
accurate recording, organization, and analysis of data through repeated trials;	Explain the importance of professional behavior and conscientious approach to data collection	Independently uses professional behavior and a conscientious approach to data collection
	Explain the impact that a conscientious approach to data collection will have on the ability to analyze data	Independently examines the potential impact that data collection and organization might have had on the outcome during the analysis and discussion
mathematical and procedural error analysis	Can calculate mathematical and procedural error analysis	Independently uses mathematical and procedural error analysis
mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis;	Can use SI units and scientific notation correctly	Independently uses SI units and scientific notation during an investigation
	Guided by the teacher to use appropriate mathematic procedures to explain a phenomena or outcome	Independently uses appropriate mathematic procedures to explain a phenomena or outcome

Standard	Academic Chemistry	Research Chemistry
chemicals and equipment are used in a safe manner	Performs lab and investigations in a safe manner	Performs lab and investigations in a safe manner
use of appropriate technology including computers, graphing calculators, and probe ware, for gathering data, communicating results, and using simulations to model concepts;	Guided by teachers to use appropriate technology during a teacher or teacher/class designed investigation	Identifies and uses appropriate technology during a self-designed investigation
construction and defense of a scientific viewpoint	Guided by teacher to use evidence from laboratory experiments and investigations to create a claim supported by scientific reasoning	Independently uses evidence to formulate a claim and provides support using scientific reasoning
	NA	Independently uses scientific reasoning to identify what evidence would be need to answer a research question
current applications to reinforce chemistry	Can identify relevant and current examples of chemistry concepts from mass media	Develops investigations to explore relevant and current examples of chemistry concepts

HOW SHOULD THE RESEARCH PROCESS SKILLS AND SCIENTIFIC THINKING BE ORGANIZED ACROSS EARTH SCIENCE, BIOLOGY, AND CHEMISTRY? Below is the current science process skills aligned for each major research component and organized across Earth Science, Biology, and Chemistry. Notice the development begins in Earth Science with skills and thinking to develop the ability to use data to develop a scientific argument while modeling the remaining components. In Biology, the previous year's skills are reinforced while working to develop a deeper understanding of how to communicate and analyze data as well as develop a research question and design an appropriate investigation to answer a research question. Chemistry will require many of the prior skills, broadening them with chemistry application. In addition, students will develop an ability and appreciation of the role that math plays in the analysis and modeling concepts.

Science process skills aligned with research component and organized across earth science, biology, and chemistry:

Research Component	Skills	Earth Science	Biology	Chemistry
Research question/potential hypothesis/explanation – based on scientific principles	Students should be able to explain the scientific principles on which the research question/hypothesis/explanation is based. This can be done by requiring the students to generate a "knowledge" *model* explaining their current understanding of the	Introduce and model for students	Develop in students	Reinforce and broaden ability
Research design that will result in collected data that answers the research question	Students should be able to design a data collection that reduces the possibility that bias might occur during the data collection.	Introduce and model for students	Develop in students	Reinforce and broaden ability
	Students should be able to predict, how the data will turn out if the null hypothesis is supported or if the alternative hypotheses are supported.	Develop basic ability in students	Reinforce and broaden ability	Reinforce and broaden ability
	Proper and safe use of chemicals and equipment	Introduce where appropriate	Introduce where appropriate	Develop basic ability in students
Data Collection	Students should be able to determine if the data they are collecting is appropriate.	Develop in students – behaviors unique to ES especially	Reinforce and broaden in students - develop behaviors unique to Biology also	Reinforce and broaden in students – develop behaviors unique to Chemistry also
	Students should be aware of the possibility of ways in which bias might be added during data collection	Develop in students – behaviors unique to ES especially	Reinforce and broaden in students – develop behaviors unique to Biology also	Reinforce and broaden in students – develop behaviors unique to Chemistry also
Data Summary, Communication, and Analysis	Students should be able to summarize data using appropriate graphical and tabular (descriptive statistics) communications that will allow them and readers to look for patterns in their data. In particular, the communications should describe the central tendency, the spread of the data, and the shape of the data distribution (question of variation or difference) or the strength and direction of a relationship (question of relationship).	Develop basic understanding in students	Reinforce and broaden understanding	Require, broaden understanding with unique chemistry application

Research Component	Skills	Earth Science	Biology	Chemistry
	Incorporate mathematical manipulations and modeling, procedural error analysis	Introduce where appropriate	Introduce where appropriate	Develop basic ability in students
	Students should be able to use their communications to evaluate the appropriate hypotheses	Develop basic understanding in students	Reinforce and broaden understanding	Require, broaden understanding with unique chemical application
	Students should be able to evaluate data using the p-value generated from an inferential test	Introduce and model for students	Develop basic understanding in students	Require, broaden understanding with unique chemistry application
Conclusion	Students should be able to answer their research question specifically using data	Develop basic ability in students	Reinforce and broaden ability	Require, broaden understanding with unique chemistry application
	Students should be able to generate an explanation, framed within scientific knowledge, of why the results might have occurred especially addressing competing, alternative hypotheses/explanations	Develop basic ability in students	Reinforce and broaden ability	Require, broaden understanding with unique chemistry application
	Students should be able to identify sources of error and explain its effect on results and subsequent conclusions	Develop basic ability in students	Reinforce and broaden ability	Require, broaden understanding with unique chemistry application
	Students should be able to describe future work that will further verify/elaborate current findings or to evaluate competing, alternative hypotheses/explanations	Develop basic ability in students	Reinforce and broaden ability	Require, broaden understanding with unique chemistry application