Course Descriptions for Research Courses

Research in Biology, Chemistry, and Physics

Our research courses in biology, chemistry, and physics all share the following general outline and structure.

The **goals**:

The overarching goal is that students will experience the entire scientific process in the same way accomplished scientists carry out their profession.

Each student will design and execute a long-term investigation that will typically be made of many individual experiments. Results from these experiments will be compiled, analyzed, and presented in a full research paper that conforms to standard practices of scientific publications. Students will also orally present their work to a group of professional scientists. Although not required, we expect many students to reach the point where they publish their work in either abstract or full paper form. For examples of previous students' work click here.

(1) Opportunities for student researchers to learn first-hand the impact, limitations, fundamental principles, and methods of scientific research;
(2) Opportunities for students to form their own hypotheses, design their own experiments, record their observations, analyze their data, and draw their own conclusions for their own scientific research project;
(3) Opportunities for students to gain an understanding of the attitudes, ethics, and problem-solving techniques needed for life in a complex technological society;
(4) Mentoring, fieldwork, and experimentation designed to enable students to:
    a. Gain experience with the methods of studying natural phenomena;
    b. Develop an understanding of the interrelationship and interdependence of living organisms and the role of a biological organism in the physical world;
    c. Advance scientific knowledge through engagement of the scientific method of investigation with an emphasis on the role of observation and experimentation;
    d. Gather scientific data through laboratory work, field work, and computational research;
    e. Present their data graphically and interpret graphically-presented data from the scientific literature;
    f. Use their experimental data to draw conclusions and make inferences;
    g. Develop scientific problem-solving skills that can be employed to solve problems in everyday situations;
    h. Communicate quantitative and qualitative data clearly and concisely through the written word, mathematical relationship, and oral presentations.

i. Understand and apply the unifying concepts and principles within the natural sciences;
j. Develop an awareness of the philosophical, ethical, legal, political, and economic impacts of science and technology;
k. Appreciate that science is a human endeavor that builds upon the work of generations of scientists;
l. Become aware of the concerns around the current and future impacts of science and technology on society and the environment.

Authentic scientific research includes, but is not limited to:

- In-person and online lessons that provide the knowledge base and background concepts required for full engagement with authentic research experiences. See example listing of lessons here.
- Creation of a written research proposal that includes:
  - Background literature search
  - Hypothesis
  - Material
  - Methods
  - Research plan with timeline
- Completion of a research project that includes:
  - Training by the instructors in the experimental techniques needed to conduct the research
  - A research plan
  - Adjustments to the research plan based on preliminary findings
  - Collection of quantitative and qualitative data
  - Statistical analysis of the gathered data, when appropriate
  - Drawing of conclusions based on gathered data
- Writing and revising a summary paper, which shall include:
  - Abstract
  - Introduction
  - Materials
  - Methods
  - Results
  - Discussion
  - Conclusion
  - Bibliography
- Presentation of research to the scientific community, which shall include at least one of the following:
  - Preparation of a scientific conference style poster for presentation to experts in the field, NHAS mentors, and student-peers

        - Oral presentation of results/conclusions to experts in the field, NHAS mentors and student-peers
        - Compilation of a summary video describing the investigation and major results/conclusions
    - After completing a revision process, the research may be:
        - Submitted for peer-review by NHAS mentors
        - Published in the proceedings of the AAAS meeting or an appropriate peer-reviewed academic journal

The **shared competencies** of the research programs in biology, chemistry, and physics include, but are not limited to:

(1) Proficiencies in experimental design including:
    a. Positive and negative controls
    b. Experimental planning

(2) Proficiencies in experimental data analysis employing:
    a. Spreadsheets for data compilation and analysis
    b. Presenting data in multiple graphical and tabular formats

(2) Proficiencies in technical writing including:
    a. Development of an experimental proposal
    b. Compilation of a summary paper outlining the key findings of the long-term investigation

(3) Proficiencies in scientific presentation demonstrated by completion of one of the following:
    a. Preparation of a professional scientific poster for presentation at a scientific conference
    b. Verbal presentation of the findings of the investigation
    c. Compilation of a video describing the investigation and its key findings

The **shared outcomes** of the research programs in biology, chemistry, and physics include, but are not limited to:

- Submission of research proposal that includes, but is not limited to:
    - Background of research to be conducted
    - Hypothesis to be investigated
    - Proposed methods to be used
    - List of required materials and instrumentation
    - Research plan with timeline for the long-term multi-experiment investigation
- Maintenance of a detailed laboratory notebook that will contain:
    - Records of observations, data collection, and results of experiments/investigations

        - Summary records of weekly correspondence or meetings between student and respective instructor
        - Records of experimental data
    - Submission of a summary paper after several rounds of edits made by the student and instructor. It will, in form and substance, resemble an article from a peer reviewed scientific journal through the inclusion of the following sections:
        - Abstract
        - Introduction
        - Materials
        - Methods
        - Results
        - Discussion
        - Conclusion
        - Bibliography
    - Communication of the results of the long-term research investigation via one, or more, of the following:
        - Preparation of a professional scientific conference style poster for presentation to experts in the field, NHAS mentors, and student-peers
        - Oral presentation of results/conclusions to experts in the field, NHAS mentors and student-peers
        - Compilation of a summary video describing the investigation and major results/conclusions
        - Submission for peer-review by NHAS mentors, if appropriate
        - Publication in the proceedings of the AAAS or an appropriate academic journal, if accepted.
    - A total of at least 140 hours is expected to be required for completion any of the three research courses.
        - A minimum of 20 hours of preparation for experimentation is expected to be done outside of the scheduled time in the lab.
        - The research project is expected to be complex enough to require at least 75 hours of experimentation.
        - It is expected that students will participate in at least 15 hours of team meetings and supplemental lectures.
        - It is anticipated that at least 30 hours will be spent by the student in the preparation of the summary paper and presentation(s).
    - In some cases, the research may lead to:
        - Abstract publication
        - Presentation to regional and or national science communities

        - Full paper publication as a pre-print or peer-reviewed paper in appropriate journals
        - Attendance as a NH student delegate to the American Association for the Advancement of Science annual meeting
        - Induction into the American Junior Academy of Science

Goals, competencies, and outcomes specific to each field of research offered are listed below.

1) Biology Research (Life Science)

- The specific **goals** of the **Biology Research course** will include, but are not limited to:
    - Empowering students to comfortably work in a biological research laboratory environment
    - Introducing of students to the variety of careers available in biological research
    - Developing students' skills in biology-specific laboratory techniques
- The **competencies** specific to the **Biology Research course** will include, but are not limited to:
    - Proper application of all safety procedures of a BSL-1 laboratory including the safe use of all instruments that will be used in the students' investigations
    - Ethics training, guided by the National Institutes of Health standards, to enable the ethical design and execution of a scientific investigation
        - With special emphasis on the ethics of model organism use
    - Proficiency in basic instruments including:
        - Scales and balances
        - Pipettes of a variety of sizes
            - Both manual and semi-automated
        - Scientific glassware for:
            - Volume measurements
            - Compound preparation and dispensation
            - Chemical and specimen storage
        - Microscopes appropriate for the investigation, which may include:
            - Stereo zoom microscopes
            - Compound microscopes
            - Fluorescent microscopes
        - Autoclave for sterilization
        - Clean/sterile hood for sterile sample preparation
    - An understanding of differences in precision, accuracy, and resolution in measurements
    - Proficiency in aseptic techniques, depending on area of investigation
    - The ability to design and apply single- and double-blind experiments when appropriate

    - Statistical analysis of large populations of data, when appropriate, including:
        - Discernment of significant differences in data sets via parametric or non-parametric analyses about a mean
            - The most common techniques used are anticipated to be the Student's t-test and ANOVA.
- The **outcomes** specific to the **Biology Research course** will include, but are not limited to:
    - Proficiency in biology specific laboratory techniques
    - An understanding of the ethical requirements of biological research
    - The ability to use statistical methods to analyze large datasets

2) Chemistry Research (Physical Science)

- The specific **goals** of the **Chemistry Research** course will include, but are not limited to:
    - Empowering students to work in a chemical research laboratory environment
    - Introducing students to the variety of careers available in chemical research related fields
    - Developing student's skills in chemistry-specific laboratory techniques
- The specific **competencies** of the **Chemistry Research** course will include, but are not limited to:
    - An understanding and appreciation of the chemical and physical hazards presented in a laboratory environment and the measures needed to mitigate those hazards including:
        - Proper use of personal protective equipment
        - Proper use of a chemical fume hood
        - Use of the Global Harmonized System for labeling hazardous materials
        - Ability to read and understand materials and safety data sheets
        - Proper storage and disposal procedures for hazardous materials
    - Ethics training, guided by the standards of the National Institutes of Health, to enable ethical design and execution of a long-term scientific investigation
        - With emphasis on ethical recording and presentation of data
    - Proficiency in basic scientific instruments including:
        - Analytical balances
        - Micropipettes
        - Volumetric pipettes
        - Transfer pipettes
        - Choosing appropriate laboratory glassware for each experiment
            - With emphasis on green chemistry techniques

    - Proficiency in the use and maintenance advanced scientific instruments appropriate to the investigation which may include:
        - Scanning ultra violet/visible spectrophotometer
        - High performance liquid chromatograph
    - Ability to make a standard curve and use the calculated curve to find the concentration of an unknown
    - Understanding of significant digits and the difference between random and systematic error including the propagation of error throughout an experiment
- The specific **outcomes** of the **Chemistry Research** course will include, but are not limited to:
    - Proficiency in chemistry-specific laboratory techniques
    - An understanding of chemical laboratory safety
    - Proficiency in reporting data with appropriate statements of error

3) Physics Research (Physical Science)

- The specific **goals** of the **Physics Research** course will include, but are not limited to:
    - Empowering students to feel comfortable working in a physics/engineering laboratory environment
    - Introducing students to the variety of physics/engineering research related careers available
    - Developing students' skills in physics/engineering-related laboratory techniques
- The specific **competencies** of the **Physics Research** course will include, but are not limited to:
    - Proper assessment and mitigation of research related physical hazards
        - Proper use of personal protective equipment
        - Rigorous safety instruction on the use of low-powered lasers
    - Ethics training, guided by the standards of the National Institutes of Health, to enable ethical design and execution of a long-term scientific investigation
        - With emphasis on the ethical repercussions of eventual research application
    - Proficiency in basic scientific equipment including:
        - Scales and balances
        - Digital Vernier calipers
        - 3D printers
        - CAD software
    - Basic computer coding
    - Understanding of the iterative process of design
    - When applicable, the proper use of error propagation and statistical analysis

- The specific **outcomes** of the **Physics Research** course will include, but are not limited to:
    - Proficiency in physics-specific laboratory techniques
    - An understanding of the safety procedures needed in a physics laboratory
    - An understanding of the design process from model to prototype to final product