

SAMPLE LEARNING OUTCOMES FOR UNDERGRADUATE MAJORS IN THE PHYSICAL SCIENCES (INCLUDING MATHEMATICS AND STATISTICS)

The following pages contain examples of learning outcomes from other educational institutions in the area of the **physical sciences, including Mathematics and Statistics**. These examples may be used as a point of departure for developing learning outcomes for the majors in your department or program.

Other educational institutions have posted links to learning outcomes assessment, including Marquette University (<http://www.marquette.edu/assessment/>, with specific learning outcomes at <http://www.marquette.edu/assessment/outcomes/index.shtml>); the University of South Florida, with specific learning outcomes at <http://www.ie.usf.edu/OA/>; and the University of Hawaii at Manoa (<http://manoa.hawaii.edu/assessment/>, with specific learning outcomes at <http://manoa.hawaii.edu/assessment/update/view.php>).

A compilation of other examples of learning outcomes is expected to be posted on a web page on UCR's Institutional Research for Undergraduate Education website (<http://irue.ucr.edu/>) by the time of the Summit on Learning Outcomes and Assessment. A link to this website will also be posted on the UCR WASC website (<http://wasc.ucr.edu>).

The primary resource document regarding learning outcomes assessment is the Assessment Guide from the University of Virginia (<http://www.web.virginia.edu/iaas/assessment/Assessment%20guide.pdf>).

Last year some workshops on learning assessment were held on campus through the Scholarship of Teaching Seminar series. Video tapes of the following sessions are available for review on the Scholarship of Teaching website (<http://www.teaching.ucr.edu/SoT.html>):

- (a) Strategies for establishing educational goals and evaluation procedures for all undergraduate programs: The UC Berkeley Experience [Winter 2008]
- (b) Using ePortfolios for Teaching, Learning, and Assessment [Winter 2008]
- (c) Establishing Measures of Student Outcomes: A Debate on Methods [Fall 2007]

Learning Outcomes in the Physical Sciences, adapted from those developed at the University of Virginia in the Sciences:

Basic Outcomes (knowledge and comprehension)

- In a final exam taken at the end of their second year, Chemistry majors can describe the structure and reactivity patterns of carbon compounds and the nature of these compounds in living systems.
- Chemistry majors can describe the molecular structure, stereochemistry, physical properties, and reactions to metallic and main-group element compounds orally and in writing.
- Chemistry majors demonstrate understanding of fundamental concepts of chemistry by definition, explanation, and use of these ideas in examinations and laboratory exercises.
- During an exit interview, Chemistry or Physics majors can discuss the unity and beauty of physics.

Higher-Order Outcomes (application, analysis, synthesis and evaluation)

- Third-year Chemistry majors, during a laboratory exercise, can separate and purify a selection of chemicals.
- Chemistry majors have the knowledge and ability to apply, during a laboratory exercise, the methodologies of chemistry including
 - a. separation and purification,
 - b. synthetic methods,
 - c. data collection and analysis,
 - d. structure determination and
 - e. access to chemical information.
- During a final exam, Chemistry and Physics majors can provide examples of quantitative relationships describing physical states, and solve problems requiring the use of such relationships.
- All Chemistry majors can, during a laboratory exercise, prepare, purify, and characterize carbon compounds.
- Chemistry majors can, in a final project, write clear and convincing essays that apply their knowledge of chemistry to science problems and public concerns.

Sample Learning Outcomes for Specific UCR Physical Sciences Majors (including Mathematics and Statistics)

CHEMISTRY

The following are learning outcomes for Chemistry majors at the University of Illinois:

- Outcome 1:** A thorough knowledge of the basic principles of chemistry, including atomic and molecular structure, chemical dynamics and the chemical and physical properties of substances.
- Outcome 2:** A thorough knowledge of the subfields of chemistry, including analytical, inorganic, organic and physical chemistry.
- Outcome 3:** A thorough knowledge of cognitive areas such as mathematics and physics to facilitate the understanding and manipulation of fundamental chemical theories.
- Outcome 4:** The ability to design experiments and to use appropriate experimental apparatus effectively.
- Outcome 5:** The opportunity to pursue an individualized research experience as an undergraduate.
- Outcome 6:** The ability to read, evaluate and interpret numerical, chemical and general scientific information.
- Outcome 7:** The ability to communicate effectively both verbally and in writing.
- Outcome 8:** The expectation that students will be broadly educated in areas outside of science.
- Outcome 9:** The opportunity to acquire the knowledge and skills needed to succeed in the workplace or in professional school after graduation.

For a more detailed discussion of learning outcomes assessment for Chemistry majors at the University of Illinois, see <http://www.cte.uiuc.edu/assessment/plans/chemistry08.pdf>

For discussion of learning outcomes assessment in Chemistry at the University of Michigan, see http://www.provost.umich.edu/reports/slfstudy/ir/pdfs/assess/lsa_full_version.pdf, pp. 27-28.

See, also, the additional examples of learning outcomes at the top of this document.

ENVIRONMENTAL SCIENCES

The following are learning outcomes for majors in Environmental Science at the University of Alabama:

1. Environmental Science majors will be prepared for professional employment or advanced studies in this field and related disciplines.
2. We expect to attract students seeking an interdisciplinary science curriculum and provide those students with appropriate courses to (1) be knowledgeable in fundamental ecological and earth surface patterns and processes and (2) understand the linkage between earth sciences and life sciences.
3. We expect to provide students with courses that complement their science background, and include the following subjects: (1) environmental planning and management, and (2) geographical and/or ecological spatial analysis and modeling.

4. We expect our students to gain a comprehensive understanding of the physical and biological components of landscapes and to acquire the technical skills necessary for detailed spatial analysis.

For further discussion of learning outcomes assessment for Environmental Science majors at the University of Alabama, see
http://uaops.ua.edu/right_arm_x.cfm?col=18&dpt=155&yr=2007&dg=12&prg=164#test.

For discussion of learning outcomes assessment in the School of Earth, Society and Environment at the University of Illinois, see
http://www.cte.uiuc.edu/assessment/plans/earth_systems_environment_and_society08.pdf.

GEOLOGY

The following are learning outcomes for Geological Sciences majors at the University of Michigan:

1. An understanding of the nature and origin of the materials that compose the Earth.
2. An understanding of the physical and chemical processes that operate in the deep interior, outer shell, and at the surface of the Earth.
3. An understanding of geologic time and how it is determined.
4. An understanding of the geologic record of earth processes and of life.
5. The ability to apply concepts and methods learned in mathematics and the other natural sciences to geology.
6. Basic skills in reading comprehension of the scientific literature and in oral and written communication of scientific results.

For further discussion of learning outcomes assessment in Geological Sciences at the University of Michigan, see
http://www.provost.umich.edu/reports/slfstudy/ir/pdfs/assess/lisa_full_version.pdf, pp. 39-40.

For discussion of learning outcomes assessment in the School of Earth, Society and Environment at the University of Illinois, see
<http://www.cte.uiuc.edu/assessment/plans/geology08.pdf>; for discussion of learning outcomes assessment in Geological Sciences at the University of Alabama, see
http://uaops.ua.edu/right_arm_x.cfm?col=3&dpt=61&yr=2007&dg=16&prg=168#test.

GEOPHYSICS

Specific examples of learning outcomes from other universities in the area of Geophysics have not been located; please see examples from related majors for general guidance.

GEOSCIENCE EDUCATION

Specific examples of learning outcomes from other universities in the area of Geoscience Education have not been located; please see examples from related majors for general guidance.

MATHEMATICS

The following are learning outcomes for Mathematics majors at the University of Alabama:

1. Upon graduation, our undergraduate students will demonstrate a good understanding of differential, integral, and multivariable calculus. And the student will be able to apply these concepts to a wide variety of problems.
2. Upon graduation, our undergraduate students will have a basic understanding of Euclidean vector spaces, matrix theory, and ordinary differential equations. And the student will be able to apply these concepts to a wide variety of problems.
3. Upon graduation, students in the pure mathematics track will demonstrate proficiency in the comprehension and writing of mathematical proofs. They will be able to write well-organized, grammatically correct, and logical sound mathematical arguments.
4. Upon graduation, students in one of the applied mathematics tracks or mathematical statistics track will demonstrate the ability to apply mathematics to real situations, using deterministic or probabilistic models, and will be able to employ a variety of techniques to solve these systems.
5. Bachelor of Science graduates will have a fundamental understanding and problem solving ability in at least one area of specialization within mathematics.

For further discussion of learning outcomes assessment in Mathematics at the University of Alabama, see

http://uaops.ua.edu/right_arm_x.cfm?col=3&dpt=85&yr=2007&dg=36&prg=26#test.

For discussion of learning outcomes assessment in Mathematics at the University of Michigan, see

http://www.provost.umich.edu/reports/slfstudy/ir/pdfs/assess/lisa_full_version.pdf, pp 15-17, 53-54; for discussion of learning outcomes in Mathematics at the University of Illinois see <http://www.cte.uiuc.edu/assessment/plans/mathematics08.pdf>.

MATHEMATICS FOR SECONDARY SCHOOL TEACHERS

The following are the learning outcomes for Teaching in Mathematics at Marquette University:

At the completion of the Teaching in Mathematics major, the graduate is able to:

1. Demonstrate in-depth knowledge in one of the foundational areas of the mathematical sciences.

2. Communicate mathematical ideas using numerical, graphical, and symbolic representations.
3. Use content-specific materials and Standards-based methods to teach secondary-level mathematics courses.

PHYSICAL SCIENCES

Specific examples of learning outcomes from other universities in the area of Physical Sciences have not been located; please see examples from related majors for general guidance.

PHYSICS

The following are learning outcomes for Physics majors at the University of Illinois:

The bachelor's degree graduates of the Department of Physics should have:

1. A thorough knowledge of the basic fields of physics, including mechanics, electricity and magnetism, thermodynamics, and quantum mechanics.
2. A thorough knowledge of mathematics to facilitate the description and manipulation of fundamental physical constructs.
3. The ability to use this knowledge to assess and solve real physics problems.
4. The ability to communicate effectively, both verbally and in writing.
5. The ability to use basic experimental apparatus common to the study of physical phenomena.

For further discussion of learning outcomes assessment in Physics at the University of Illinois, see <http://www.cte.uiuc.edu/assessment/plans/physics08.pdf>.

For discussion of learning outcomes assessment in Physics at the University of Michigan, see http://www.provost.umich.edu/reports/slfstudy/ir/pdfs/assess/lsa_full_version.pdf, pp. 58-59; for discussion of learning outcomes assessment in Physics at the University of Alabama, see http://uaops.ua.edu/right_arm_x.cfm?col=3&dpt=101&yr=2007&dg=43&prg=40#test.

See, also, the additional examples of learning outcomes at the top of this document.

STATISTICS

The following are learning outcomes for Statistics at the University of Michigan:

1. Train undergraduate concentrators [majors] in statistical theory, methodology, applications, computing and data analysis.
2. Prepare concentrators [majors] for careers in the private and public sector as well as prepare them for graduate studies in statistics.

3. Provide non-concentrators [non-majors] with basic understanding of the principles of statistics and data analysis, including variation, quantitative reasoning, and scientific investigation.

For additional discussion of learning outcomes assessment in Statistics at the University of Michigan, see

http://www.provost.umich.edu/reports/slfstudy/ir/pdfs/assess/lsa_full_version.pdf, pp. 68-69.

For discussion of learning outcomes assessment in Statistics at the University of Illinois, see <http://www.cte.uiuc.edu/assessment/plans/statistics08.pdf>.