Sample major in Integrated Science and Engineering, specifically aimed at 9-12 Educators

Information for this profile was provided by Horacio Ferriz. Information is also available on the program website.

Statement of the need for a new major: In the traditional preparation for 9-12 science teachers, the model in California is (a) get a B.Sc. in one of the traditional disciplines of Biology, Chemistry, Physics, Geology, or Mathematics, followed by (b) teacher training for 3 to 4 semesters (including student teaching), followed by (c) credential authorization for teaching Biology, Chemistry, Physics, Geosciences, or Mathematics.

This “traditional” model has been challenged by the nation-wide acceptance of the Next Generation Science Standards (NGSS), which emphasize the integrated and inter-disciplinary nature of science and engineering (and ethical responsibility, group work, and the core curriculum in language arts and social sciences). High schools across the nation are choosing a program of three integrated courses under the names of Physics and Planetary Science (including fundamentals of astronomy, the Solar System, and Earth’s internal processes such as earthquakes and volcanism), Chemistry and Earth’s External Processes (e.g., atmospheric science, physical oceanography, hydrology), Biology and the Living Earth (including the study of the fossil record, geologic time, and the parallel evolution of the atmosphere and plant life, oceanography and marine life, and evolution of the continents and plant and animal life).

A first major challenge to the implementation of NGSS is that our science teachers are educated in silos, say Physics, and do not have neither the breadth of knowledge to teach the new courses, not the respect for other science, math, and engineering disciplines. The pitfall is that unprepared teachers will fall back on the practice of handing out worksheets without truly guiding their students through the process of scientific discovery or engineering design.

A second major challenge is posed by the Teacher Credentialing Commissions, which have so far not responded to the 2014 unveiling of the Next Generation Science Standards. School districts, faced with credentialing laws, choose the first word in the name of the course, say Chemistry and Earth’s External Processes, to decide to accept a Chemistry authorization as the only valid credential to teach such a course. In order to prepare the teachers of the future, the National Science Foundation and the National Academies of Science and Engineering need to call for change in Federal and State laws to support the future of STEM education.

**Program Design & Assessment**

Overview

We propose an Integrated Science major, which we believe can be implemented by most universities by leveraging their General Education course offerings, and selected courses from their Science, Math, and Engineering departments. Undoubtedly a few new courses will have to be developed, but the key is to get buy in from the faculty, so they participate wholeheartedly in an Integrated Science curriculum. The courses described are based on courses available (or soon to be available) at California State University Stanislaus. Unfortunately, this small regional university does not have a School of Engineering.

Design Philosophy

Perhaps the greatest challenge to the proposed project is to provide the students with enough opportunities to integrate the humanistic and meta-knowledge aspirations of the team, to a core of foundational and teaching knowledge that is necessarily vast, because of our aspiration of providing enough inter-disciplinary connections.

Regarding fundamental values/anchors for meta knowledge, (i.e., problem solving and critical thinking, communication and collaboration, creativity and innovation), we would like to figure out a way to leverage the General Education program for our purposes. We imagine that students could take linked Lower Division courses in Humanities (e.g., Composition in Modern English), Critical Thinking (e.g., American Government Policies), and Communication (e.g., Team Discussion Processes). This would be complemented by courses in Environmental Science and Engineering, Field Limnology, or Planetary Science and Engineering, which are electives to the proposed program.

Regarding fundamental values/anchors for humanistic knowledge (i.e., life skills, job skills, and leadership; cultural competence; ethical and emotional awareness), we would like to figure out a way to leverage the General Education program for our purposes. We imagine that students could take linked Upper Division courses in Humanities (e.g., The Immigrant Experience), Ethics (e.g., Ethics in Education), and Social Science (e.g., The 21st Century Learner). This would be complemented by courses in Environmental Science and Engineering, and Development and Management of Water Resources, which are electives to the proposed program.

Program Learning Objectives

PLO 1. Prepare program graduates to propose workable solutions to societal problems related to resource exploration and development, construction with the Earth, and environmental issues related to Earth processes.

PLO 2. Prepare program graduates to incorporate sound ethical and emotional values, cultural values, open and productive communication, and group collaboration into their educational personae.

PLO 3. Prepare program graduates to formulate and test multiple hypotheses based on scientific methods.

PLO 4. Prepare program graduates to design inquiry-based lesson plans to investigate the natural world using an integrated science approach based on the California Next Generation Science Standards.

PLO 5. Provide program majors with the tools to guide K-12 learners through the processes of experimental design, collection of data in the outdoors, formulation of conceptual models, and design of relevant engineering solutions.

Student Learning Outcomes and Assessment Instruments

At the completion of the program students will be able to:

1. Apply knowledge of engineering practices to define problems, determine specifications of designed systems, and identify constraints. (PLO 1)

* Lesson plan on developing an engineering design and prototype (e.g., design of a knee support)
* Final report on an Environmental Science and Engineering project (e.g., design of a water treatment process)

1. Effectively incorporate ethical and cultural values of K-12 learners in their NGSS lessons (PLO 2)

* Lesson plan on the universal character of science and engineering (e.g., the universal right to safe water)
* Final group presentation on the contributions of indigenous knowledge regarding nature (e.g., indigenous fire management)

1. Effectively incorporate group collaboration and respectful communication/discussion in their NGSS lessons (PLO 2)

* Lesson plan on teamwork and group discussion (e.g., neighborhood survey of environmental assets)
* Final group presentation on the differences between different types of human knowledge and problem-solving (e.g., a respectful discussion on religious, artistic, and scientific approaches)

1. Demonstrate knowledge of how to ask questions that can be addressed by scientific investigation, help further understanding of observed phenomena, and help clarify scientific explanations and relationships. (PLO 3)

* Lesson plan on conducting an experimental physics experiment (e.g., pendulum)
* Final report on a Field Limnology project

1. Apply knowledge of patterns, cause-and-effect, scale, proportion, and systems characteristic of natural phenomena and engineered systems. (PLO 4)

* Lesson plan on developing a field investigation (e.g., choosing the right combination of tools for a geophysical survey)
* Final report on a Geochemistry or Planetary Science project (e.g., investigate an alkaline lake, or design a new sensor for a satellite to Venus)

1. Demonstrate ability to plan an NGSS-aligned lesson, coherently moving through the 5-E's sequence (engage, explore, explain, elaborate, evaluate). (PLO 5)

* Lesson plan on conducting astronomical observations (e.g., recording the phases of the Moon, or using an app to track the movement of Jupiter over several days)
* Final group presentation on a biological investigation (e.g., the nature and mechanics of genetics)

Assessing Program Outcomes

Please see section above for examples of assessment instruments. In brief, we plan to use sample lesson plans, and final reports or group presentations of interdisciplinary projects, or discussions about humanistic and meta-knowledge values. [Work in progress: We intend to include a sample rubric here for assessment of lesson plans and final reports.]

Although not specifically labeled a capstone, we propose a Senior-level course in Field Limnology, where students will spend up to 5 weeks doing field work, collecting data on different aspects of the hydrology and ecosystems of streams, fresh-water lakes/reservoirs, and coastal lagoons. The students will then process the data and reach tentative conclusions. After a round of internal peer review, the students will prepare a final report for each of the projects. The collected reports will be a portfolio that each student can use to demonstrate higher-level thinking in a field that has crucial implications for the health of the environment and the well-being of local populations.

**Courses and Sequencing**

Entry into the degree: Nowadays, many of our 9-12 teachers-to-be land on the idea of teaching “by default”, after figuring out that life as a professional Biologist or Geologist is too demanding. We would rather like to see us prepare some of our brightest to be the science and engineering teachers of the future from the very start. We felt the need to craft a major for these bright minds that emphasizes integrated (i.e., not in silos) science and engineering, humanistic ethics, and thoughtful reflection of what the goal of being "a teacher" is all about. We need the power of our group thinking to tear down the silo walls that teacher credentialing agencies insist on preserving, in the form of authorizations to teach only Physics, or Chemistry, or Biology, or Earth Science.

The following list of courses probably exist at a great number of American Universities:

* **General Education (up to 51 semester units)**
  + 42 lower division semester units in the areas of (A) Communication skills (9 units), (B) Natural Sciences and Mathematics (9 units), (C) Humanities (9 units), (D) Social, Economic, and Political Institutions and Human Behavior (12 units), and (E) Individual Resources for Modern Living (3 units).
  + 9 upper division units in the areas of (F.1) Natural Sciences and Mathematics (3 units), (F.2) Humanities (3 units), and (F.3) Social, Economic, and Political Institutions and Human Behavior (3 units).
  + Two of the courses listed above must meet the Multicultural requirement, and the Ethnic Studies requirement, without increasing the total number of General Education requirements (51 units)
* **General science preparation**
  + College Algebra - College Algebra is the introductory course in algebra. The course is designed to familiarize learners with fundamental mathematical concepts such as inequalities, polynomials, linear and quadratic equations, and logarithmic and exponential functions.
  + Trigonometry - Student will study relations, functions, graphs, trigonometry, polar coordinates, complex numbers, limits, and derivatives. The student will analyze and graph mathematical functions. There is an emphasis on verification of trigonometric identities using all of the basic trigonometric identities.
  + Basic Physics 1 - This an algebra-based, introductory college-level physics course. Students cultivate their understanding of physics through classroom study, in-class activity, and hands-on, inquiry-based laboratory work as they explore concepts like systems, fields, force interactions, change, conservation, and waves.
  + General Chemistry 1 w. lab - Introduction to the general principles of chemistry for students planning a professional career in chemistry, a related science, the health professions, or engineering. Stoichiometry, atomic structure, chemical bonding and geometry, thermochemistry, gases, types of chemical reactions, statistics. Weekly laboratory exercises emphasize quantitative techniques and complement the lecture material. Weekly discussion sessions focus on homework assignments and lecture material.
  + General Biology 1 w. lab - Laboratory course in general biology intended for science majors. The course includes respiration, photosynthesis, mitosis, meiosis), Mendelian genetics, operation of basic laboratory equipment, taxonomic classification, and investigations of structure and function of prokaryotes, protists, fungi, plants, and animals.
  + Intro to Earth Sciences w. lab - Examination of the Earth, its place in the solar system and universe, and its interior, surface, hydrosphere, and atmosphere. Relationships among these earth systems, major earth processes, natural resources, and climate and weather processes are examined.
* **General teacher preparation**
  + Human Development II: Adolescence - The purpose of the Child and Adolescent Development course is to provide students preparing to enter the helping professions with an in-depth understanding of the developmental needs of children and adolescents.
  + Foundations of Secondary Education - Analyzes philosophical assumptions, curriculum issues, learning theories, and history associated with current teaching styles. Emphasizes applications to all disciplines taught in secondary schools. Examines current educational trends and issues in relation to sociology of secondary school settings. Notes: 15 hours school-based field experience required. Offered by School of Education.
  + Science and Engineering for Educators - This seminar-based course focuses on the knowledge and skills necessary for teaching science and engineering in higher education. This course is designed for graduate students interested in an academic career, and anyone else interested in teaching.
  + Teaching Science in the K-12 Classroom - This is an integrated lecture/laboratory course. This course provides an introduction to the creation of science curriculum and instruction that attends to current state and national standards. The course is based in constructivist perspectives and has as a goal the teaching of science well with all children.
  + Science and Health Methods - Theory and application of basic statistical concepts for design of studies in health sciences, integrated with statistical software applications.
* **Integrated Sciences concentration**
  + Energy and Matter - The first semester of Matter and Energy focuses on the fundamentals of Physics, while the second semester focuses on the fundamentals of Chemistry. Matter and Energy A includes scientific skills and processes, mechanics (forces and motion), energy, electricity, and magnetism.
  + Descriptive Astronomy and Lab - The course is a laboratory to accompany AST 111. Emphasis is placed on laboratory experiences which enhance the materials presented in AST 111 and which provide practical experience. Upon completion, students should be able to demonstrate an understanding of the universe around them.
  + Environmental Biology - This class is an introduction to the biology of environmental problems. Environmental problems are immensely complex, involving aspects of history, philosophy, behavior, science, economics, social justice, and politics. This course is designed to engage you with a broad perspective on our relationship with land, water, air, and other living things, in order for you to become an ecologically literate citizen.
  + Geophysics -  A survey course of geophysical exploration techniques: seismic wave propagation; seismic recording instruments; seismic reflection and refraction methods; gravity surveys; magnetic surveys; and geological interpretation of geophysical data.
  + Geochemistry - This course covers the applications of chemistry commonly used by Earth scientists. Includes discussions on thermodynamics and chemical equilibrium, water chemistry, water contamination (and what to do about it), chemical weathering, diagenesis, carbonate geochemistry, crystal chemistry and behavior of trace elements and isotopes, igneous geochemistry, ore-forming processes. Practical experience in the analysis and interpretation of chemical data through a research project based on publicly available data
  + Physical Oceanography - Course examines the oceans from a geologic perspective and integrates aspects of physics, chemistry, and biology.
  + Environmental Science and Engineering -  Explores environmental responsibility, environmental remediation, mineral and energy resources, solid waste disposal, and protection of water resources.
  + The Chemicals in Your Life - The course will focus on the role of chemistry in necessities of daily life such as the chemistry of life, agriculture, food, housing, healthcare, clothing, transport and communications. In addition it will introduce various applications of chemistry in the area of arts, crime and law enforcement, consumer products, cosmetics, warfare, economics and politics.
  + Field Limnology - A practical course on professional scientific field work. Four projects, up to one week in length each, allow for experience in measurement of temperature, water composition, salinity profiles, dynamic circulation, and ecologic communities in streams, fresh water lakes/reservoirs, and coastal lagoons.  Students will prepare a report for each field project, to synthesize the field data and present professional data tables and graphs.
* **Electives (at least 8 units required)**
  + Calculus 1 - This course introduces calculus using analytic geometry functions. Topics include limits and continuity, derivatives, optimization, related rates, graphing and other applications of derivatives, definite and indefinite integrals, and numerical integration.
  + Calculus 2 - This is the second course of the Calculus sequence. In this course, we will continue the study of functions in one variable, focusing on transcendental functions, integration techniques, elementary differential equations, infinite sequences and series, conics, and polar coordinates.
  + General Physics 1 w. lab - This course covers the principles of mechanics, heat, fluids, oscillations, waves and sound. Emphasis is on conceptual development and numerical problem solving. The course consists of two hours of lecture, one hour of recitation, one hour of quiz, and two hours of lab per week.
  + General Chemistry 2 w. lab - Covers a range of topics from the course, such as measurements of heat transfer, rate and equilibrium constants, acid-base reactions, the properties and uses of buffer systems, and the effects of temperature and catalysts.
  + General Biology 2 w. lab - This course will provide a survey of biological principles with an emphasis on humans, including evolution, ecology, plant and animal diversity, and physiology. Laboratory activities will reinforce the study of these concepts.
  + History of Earth and Life -  The evolution and history of Earth and life. Emphasis on past geographic, climatic, and evolutionary changes and causes of past mass extinctions. Comparisons to today’s climate change and extinctions. Students seeking a teaching credential in the sciences must take the accompanying.
  + Planetary Science and Engineering - This course explores satellite design, spacecraft exploration, and related laboratory research on extraterrestrial materials. Focus is on geologic processes, adopting a comparative approach that demonstrates the similarities and differences between planets, and the reasons for these. Course brings together aspects of mineralogy, petrology, geochemistry, volcanology, sedimentology, geomorphology, tectonics, geophysics and remote sensing.
  + Development and Management of Water Resources -  Course explores the expanding concerns about water supply. The course has a strong global perspective and makes use of examples from all over the world. This is a technical class, that will prepare you to develop and implement strategies for developing water resources (for example, by building dams, tapping into rivers, harvesting rainfall, or drilling wells), but we will explore policy and management issues.