

## **Growing Future Elementary Teachers: Cross-Disciplinary Collaboration in STEM Education**

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### **Abstract**

We are involved in the development and implementation of a cross-disciplinary, 12-semester-unit (4-course) Science, Technology, Engineering, and Mathematics (STEM) Concentration in Liberal Studies at California State University, Fresno. Liberal Studies majors typically enter the credential program for elementary teaching, but interest from this group of students in science courses beyond what is required has been limited. The STEM Concentration affords a transformative science learning experience for future elementary teachers through deliberately designed integrative courses with these shared purposes: (a) increase interest in and generate excitement for teaching and learning science; (b) provide coherent and connected science learning opportunities; (c) model research-based and inquiry-oriented science pedagogy; and (d) facilitate awareness of the *Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas* of the *Next Generation Science Standards*. In this paper, we share our approach to the design of these connected courses and our plan for multidisciplinary faculty collaboration and professional development.

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## Introduction

With the adoption of the *Next Generation Science Standards* (NGSS) in California, science instruction in elementary classrooms is poised for dramatic change (California Department of Education, 2013). Science content has been reorganized into three dimensions: Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. Engineering is explicitly included, not only as part of the practices, but also as a specific set of disciplinary core ideas focusing on design and linkages among engineering, technology, science, and society. Learner performance expectations in the standards integrate key ideas from the three dimensions, resulting in learners acquiring and applying knowledge and thinking and reasoning scientifically. This approach necessitates learners' engaging actively and directly in the practices of science and engineering in order to construct scientific understanding (NGSS Lead States, 2013). The *Common Core State Standards* (CCSS) present another stimulus for integrative learning, as represented in Figure 1.

In addition to the changes to curriculum and pedagogy called for in the NGSS and CCSS, other reports have identified the importance of improving the science learning experience of future elementary teachers (California Council on Science and Technology, 2010; Dorph, Shields, Tiffany-Morales, Hartry, & McCaffrey, 2011). To that end, we developed a proposal to the California State University (CSU) Undergraduate Science for Future Elementary Teachers program, which provided funding for the alignment of coursework with the NGSS (California State University, 2013).

## **STEM Concentration in Liberal Studies**

At California State University, Fresno, students who plan on becoming elementary teachers typically select Liberal Studies as their undergraduate major. Within this comprehensive program of study, Liberal Studies majors also select a twelve-unit upper division set of courses as a concentration. A recent survey of campuses in the CSU system found upper division coursework in science for these students did not focus on the integration of content ideas with scientific practice, as advocated in the NGSS (CSU Faculty Work Group on Undergraduate Science Preparation of Elementary Teachers, 2012). At Fresno State, a Science concentration has been available. The concentration description lists the various science courses that students may select from the different departments. Despite this variety of course offerings, only a small percentage of Liberal Studies majors select the Science concentration, and the courses do not represent the sort of integrative approach to scientific literacy called for in the NGSS. There is a need, therefore, to make improvement to the science learning experiences for future elementary teachers.

To that end, with the support of the S. D. Bechtel, Jr. Foundation and the CSU Chancellor's Office, we began a collaboration of faculty. In the spring of 2013, we extended an invitation to relevant departments in the university to participate in this project. Interested faculty from the Curriculum and Instruction, Earth and Environmental Sciences, and Physics Departments and Lyles College of Engineering responded, and soon a consensus developed for a STEM concentration in Liberal Studies. We identified a set of four three-unit upper division courses to be included in the concentration:

(a) Environmental Earth & Life Science; (b) Physics Pedagogy and Outreach; (c) Energy, Technology, and Society; and (d) Engineering Literacy. Our purposes in the development and implementation of this concentration are to (a) increase interest in and generate excitement for teaching and learning science; (b) provide coherent and connected science learning opportunities; (c) model research-based and inquiry-oriented science pedagogy; and (d) facilitate awareness of the *Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas* of the *Next Generation Science Standards*.

### **Faculty Collaboration**

Faculty met to consider how to approach the design of these four courses so that an appropriate emphasis on the NGSS was embedded into the curriculum. We decided to focus explicitly on the Crosscutting Concepts dimension as a way to make connections across content in the four courses. These concepts include

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter: flows, cycles, and conservation
- Structure and function
- Stability and change (NGSS Lead States, 2013).

We agreed to use these ideas in each course, building a common language from the NGSS in course syllabi and assignment descriptions.

A signature aspect of our collaboration was a faculty professional development workshop held prior to the fall 2013 semester. This workshop provided time for us to interact in an informal setting, with each of us sharing our plans and goals for our courses. To provide a common experience with the Science and Engineering Practices dimension of the NGSS, we participated in a Maker workshop (Young Makers, 2013), involving tinkering in small groups to learn about electric circuits (Figure 2), followed by an individual task of building a fan car in a project-based lab (Figure 3). We then discussed how this experience related to our goals for individual courses, and how the NGSS, particularly the Crosscutting Concepts and Science and Engineering Practices, provided a natural framework for connecting content.

Two revised courses in the STEM concentration were delivered in the fall 2013 semester: Environmental Earth & Life Science and Physics Pedagogy and Outreach. Energy, Technology, and Society and Engineering Literacy are scheduled for spring 2014. We have continued to meet throughout the semester to review progress plans for the future. Scheduling courses to maximize enrollment and recruiting students to enroll in the courses is an ongoing effort. We each visited class sessions of the Environmental Earth & Life Science course and other lower division courses on our campus and at local community colleges to promote the STEM concentration and the comprehensive support available for students in the concentration.

### **Environmental Earth & Life Science Revision**

Environmental Earth & Life Science is a high enrollment (~50 students), upper-division General Education course that explores interactions among

environmental systems as well as human influences on those systems. The course meets for two 75-minute lecture periods per week, is required for Liberal Studies majors, and can also be taken by students from other majors on campus. The course redesign focused on reorganizing course topics to facilitate explicit integration of the NGSS Crosscutting Concepts (Figure 4) and transitioning from lecture-based instruction to learner-centered approaches that engage students in small-group activities and problem-based learning. The redesigned course promotes students regularly interacting with other students, and the instructor. Course material is now aligned with NGSS Disciplinary Core Ideas and NGSS Crosscutting concepts that act as an organizing framework for the course (Figure 5).

Using the NGSS Crosscutting Concepts as an organizing framework facilitates students making connections between new topics and prior knowledge. For example, when introducing the Carbon cycle, in-class activities asked the students to identify stocks, i.e. places that hold Carbon, versus flows, i.e. processes that exchange Carbon (*Flows, cycles, and conservation*). We then discuss the magnitudes of the various Carbon stocks and the importance of evaluating the rates at which the flows exchange Carbon (*Scale, proportion, quantity*). The students then use the same framework to investigate the Water and Nitrogen cycles. The students' understanding of Crosscutting Concepts is assessed through written reflections, which ask students to explain the significance of the concepts in the context of course material, examples, and discussions.

## **Successes and Challenges**

We have identified several successes and challenges of our project to date. In spring 2014, the first semester in which all four courses of the concentration will be offered, we have satisfactory enrollment in each course. Course syllabi for our courses now manifest explicit integration of NGSS, largely due to our ongoing collaboration. College and department administrators at our institution have shown enthusiasm for our efforts, and we have identified opportunities for expansion of the project. We are engaged in ongoing research on how these innovations impact preservice teacher learning and faculty beliefs.

The Environmental Earth & Life Science course is a large enrollment course, with multiple sections taught by different instructors in different departments. Scheduling of courses provides many challenges, as we need to optimize the availability of our course offerings for Liberal Studies students. Many of these students transfer to Fresno State from community colleges with some of the lower division science courses not yet completed. As these lower division courses are prerequisite to our STEM concentration upper division courses, enrollment becomes problematic. Students frequently have perceptions of science courses that include difficulty, lack of relevance, and didactic pedagogy, so recruiting for our courses is challenging. Further, faculty in science and engineering departments may not value curricular and pedagogical research for promotion and tenure purposes.

We have leveraged support from the Mathematics and Science Teacher Initiative (MSTI) for STEM concentration students, including stipends for enrollment in STEM

concentration courses (Bohlin, 2013). We feel the development of a professional identity as a teacher of science is critical to the retention of our students throughout the undergraduate and post-baccalaureate teaching credential program, so a comprehensive system of support is available. Memberships in professional organizations (e.g., California Science Teachers Association, National Science Teachers Association, California Mathematics Council, and National Council of Teachers of Mathematics) are provided for STEM concentration students. MSTI also provides funding to support student attendance at local and state mathematics and science workshops and conferences.

### **Moving Forward**

With the success of our first faculty professional development workshop, we would like to expand this opportunity to address Mathematics and English Language Arts Common Core Standards as additional organizing frameworks for our STEM concentration courses. We are actively exploring funding to increase the scale of the project, enlarging the course offerings in the concentration, engaging new faculty in our pedagogical development, and bringing the community college science departments into the collaboration. We would also like to develop and validate an instrument to measure student learning of Crosscutting Concepts, as well as continuing to research the effectiveness of our efforts and disseminating our findings.

Another opportunity that we have identified from our learning about the NGSS concerns the increased presence of Earth and Space Science in the Disciplinary Core Ideas. Both preservice and inservice teachers may lack the content knowledge

necessary to design relevant learning experiences for K-12 students. We envision the implementation of a summer workshop, where preservice teachers in the STEM concentration collaborate with inservice teachers to develop learning modules on specific Earth and Space Science Disciplinary Core Ideas, including a classroom set of materials that teachers could be check out from the university.

### **Conclusion**

The changing climate of science education, due in a large part to the integrated approach to content articulated in the *Next Generation Science Standards*, calls for a different design of the science learning of future elementary teachers. Our purposes in this project are to (a) increase interest in and generate excitement for teaching and learning science; (b) provide coherent and connected science learning opportunities; (c) model research-based and inquiry-oriented science pedagogy; and (d) facilitate awareness of the *Science and Engineering Practices*, *Crosscutting Concepts*, and *Disciplinary Core Ideas* of the *Next Generation Science Standards*. It is our aspiration that the project we have described here will result in the development of enthusiastic elementary teachers well-prepared to teach science.

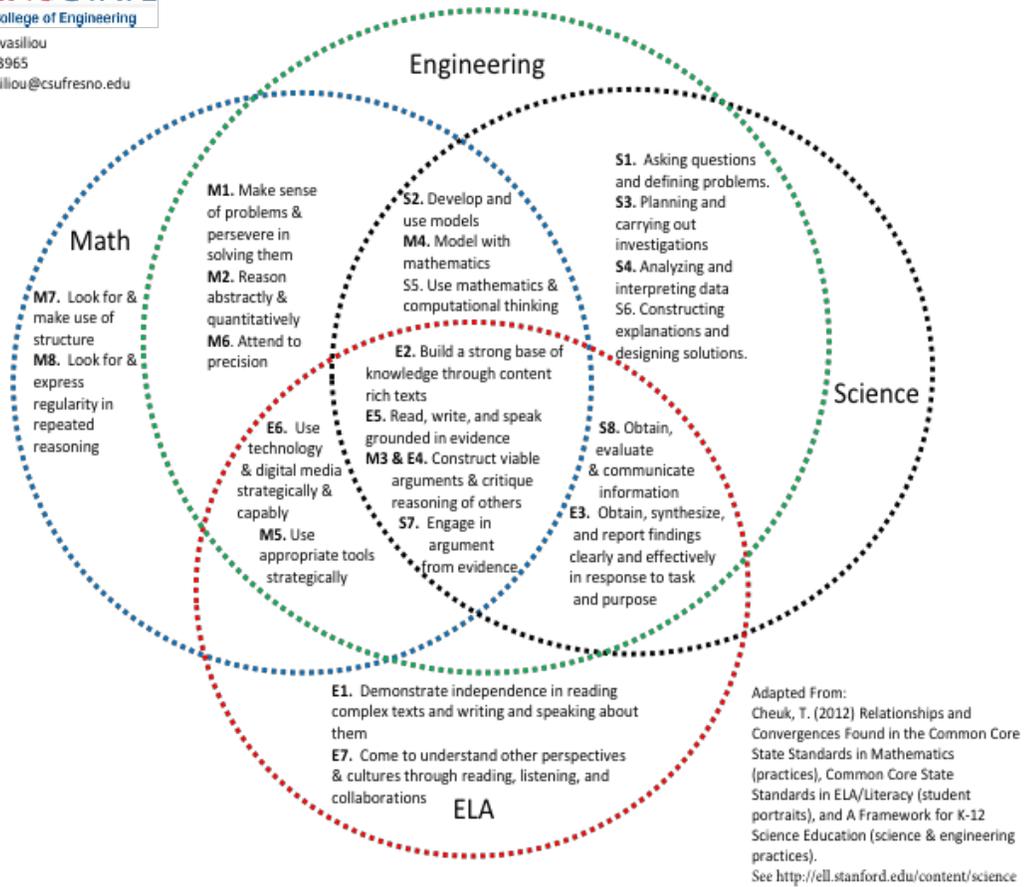


Figure 1. Interrelationships among the Next Generation Science Standards and Common Core State Standards.



Figure 2. Faculty tinkering with electric circuits.



Figure 3. Faculty building fan cars in a project-based lab.

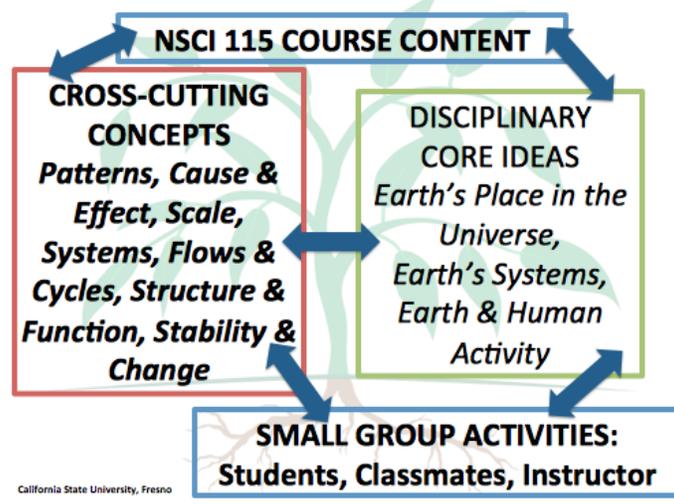


Figure 4. Curriculum revision in Environmental Earth and Life Sciences course.

## NEW Revised Syllabus Topics

Week	Dates	Topic	textbook	Assesment	Cross-cutting concept introduced
1	8/22	Welcome & Introduction			<i>Patterns</i>
2	8/27 & 8/29	Introduction	1.1-1.3	e-quiz due 8am Tu Focus Question	<i>Systems and systems models</i>
3	9/4 & 9/6	Carbon Cycle	2.1	e-quiz due 8am Tu Focus Question	<i>Flow, cycles, and conservation</i>
4	9/10 & 9/12	Water Cycle	2.2	e-quiz due 8am Tu Learning Log #1 due 8am Th	<i>Scale, proportion, and quantity</i>
5	9/18 & 9/20	Nitrogen Cycle	2.3	e-quiz due 8am Tu Focus Question	<i>Stability &amp; Change</i>
6	9/17 & 9/19	Biodiversity	2.4	e-quiz due 8am Tu	<i>Structure &amp; Function</i>
7	10/1 & 10/3	Discussion, Review & Exam		Learning Log #2 due 8am Tu <b>Quiz #1 - Thurs, Oct. 3</b>	
8	10/8 & 10/10	Water Resources: impacts	3.1.1	e-quiz due 8am Tu Focus Question	<i>Cause &amp; Effect</i>
9	10/15 & 10/17	Water Resource: solutions	3.1.2 +	e-quiz due 8am Tu Focus Question	
10	10/22 & 10/24	Energy Resources: impacts	3.2.1	e-quiz due 8am Tu Learning Log #3	
11	10/29 & 10/31	Energy Resources: solutions	3.2.2	e-quiz due 8am Tu Focus Question	
12	11/5 & 11/7	Food Resources: impacts	3.3.1	e-quiz due 8am Tu Focus Question	
13	11/13 & 11/15	Food Resources: solutions	3.3.2	e-quiz due 8am Tu Peer Draft due Thu Focus Question	
14	11/19 & 21	Discussion, Review & Exam		<b>Quiz #2 - Thurs, Nov 21</b>	
15	11/26	Sustainability	4.1	e-quiz due 8am Tu Learning Log #4 due Tu Instructor First Draft due Thu	

Figure 5. Revised course schedule for Environmental Earth and Life Science course.

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