Integration of multiple research projects throughout biology and chemistry majors' curricula at Eastern Mennonite University

EASTERN MENNONITE UNIVERSITY

NSF

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RATIONALE: The traditional undergraduate science lab class has been widely rebuked as too artificial (or 'canned') for significant learning. In contrast, authentic research experience with effective mentoring has been widely praised for its learning potential. However, it is unclear what content or skills are learned by mentored research students when the goals of the mentorship are generally scholarly production rather than learning, and little explicit teaching occurs during those experiences. Also, it seems unlikely that universities could provide enough slots for robust and meaningful research experience for each and every STEM student, including k-6 pre-service teachers.

So, what if students participated in multiple short authentic research projects as a part of their traditional lab courses, with explicit reiterated instruction included? And what if those projects were all tied together with a theme?

DEVELOPMENT OF AUTHENTIC LAB PROJECTS:

We have developed new teaching materials for several multi-week authentic research projects in traditional laboratory courses across the chemistry and biology curricula. Most of these projects are based on a common theme of environmental monitoring and remediation.

"Research across the curriculum":

a. Multiple short research projects in multiple courses

1st year:

- **General Chemistry II**
  - **Antioxidant determination**
  - **Phytoremediation of Cu-contaminated soils**

2nd year:

- **Organic II**
  - **Multi-week synthesis projects**

3rd and 4th years

- Multi-week research projects in **biochemistry, analytical chemistry, environmental toxicology/ chemistry, Sustainable agriculture**
- (Several Biology course projects too, *and intro chem*)
- **At least 4 (mini)-research projects during 4 years**

b. Research course and/or research internship required for BS

Example project: Gen Chem II - Phytoremediation

Student-designed projects:

1. Students read review article on metals uptake into plants
2. Students develop an initial research question(s) and plan
3. Feedback in 1st lab session
4. Students select plants, weigh soil, plant seeds, or dig
5. Impose treatments if desired (e.g. diapers)
6. Impose $CuSO_4$ at known ppm (e.g. 0-1000 mg Cu/kg soil)
7. Manage plants for 8 weeks
8. Measure Cu (with CCLI-funded AAS), chlorophyll or antioxidants in leaves, roots, or soil

ASSESSMENT FOR LEARNING:

All of our Chemistry, Biology and Env. Science students participate in 4-8 different short research projects during the course of their four year degree program. For each they create a research product – a research paper, poster, or oral presentation. These are assessed by rubrics developed from a 22 item rubric bank. Through these experiences we expect increased learning of the nature of science, critical thinking skills, and skills in scientific communication. Because students are provided with the rubrics prior to the assignment, and see multiple iterations of the same learning goals over time, we expect greater learning of this content and skill.

These rubrics have been tested for validity and published in Kishbaugh *et al.*, CERP, 2012, **13**, 268-

Example rubric:

	5	4	3	2	1
Introduction:					
Analysis:	Clearly identifies the research question and its inherent complexities Clearly and accurately provides background information relative to the research question.		Identifies research question Provides reasonable background information		Does not clearly identify a research question or line of study Background information is not provided, is irrelevant, or insufficient
Conclusion/Discussion:					
Synthesis:	Clearly addresses the research question(s). Draws inferences that are highly consistent with the data and scientific reasoning Identifies well-reasoned directions for future research. Explicitly discusses limitations of the study.		Addresses the research question(s). Identifies conclusions based on observation. Attempts to identify directions for future research Defines limitations		Conclusions do not address a clear research question(s). Does not draw inferences based on observations Does not identify directions for future research Does not identify limitations.
Analysis:	Data are carefully and correctly evaluated for accuracy and precision		Data are reasonably evaluated for accuracy and precision		Data are not well evaluated for accuracy and precision
Evaluation:	Clearly articulates scientific and societal relevance of the study.		Identifies a general relevance of the study.		Does not identify the relevance of the study.

What students report learning:

(repeated themes from student interviews)

The primary literature:

- Gaining skill in using the scientific literature
- Reading primary literature "becomes exciting" in context of research project
- Learning *how* to read the primary literature – what to pay attention to or skip

Writing and communicating authentic science:

- Writing a research paper and lab report – understanding that writing is the main mode of communication in science, and trying to do it well
- Realizing what's important and what's not, and then how to build an argument
- Explaining negative results; What did you do that you might want to change?

Specific skills:

- "We didn't get the best results, but we learned the research technique."

Affective:

- Value in having a more substantial relationship with prof
- Working independently and figuring things out on one's own

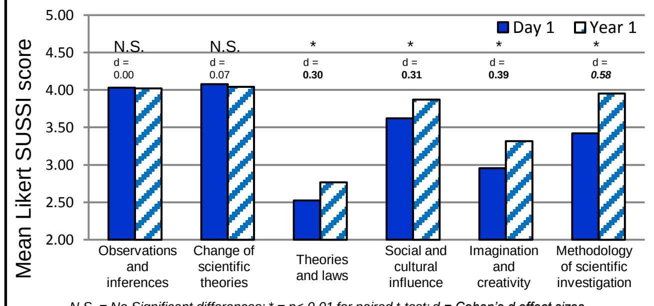
Some problems that students report:

- With many students in a lab class (~20) with only one prof, can be frustrating… The faculty members are "stretched too thin." Hence, students "stand around."

PROGRAM EVALUATION AND LEARNING ASSESSMENT:

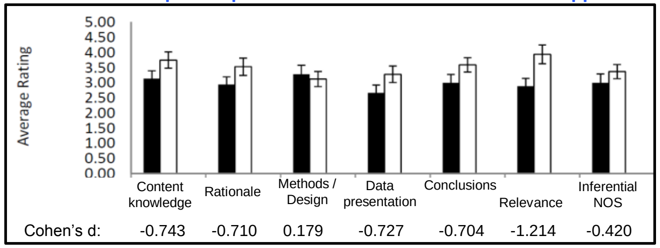
We are assessing learning with the SUSSI, a tested instrument for gauging student understanding of the nature of science and scientific inquiry. We are also measuring student development through repeated use of similar rubrics, and student surveys and interviews. Student understanding of the nature of science improves, even after one year. Student performance on the research poster rubric increases over the course of their career. Students and their teachers perceive an improvement in the scientific communication skills.

1st year students improve in their nature of science understanding:



N.S. = No Significant differences; * = p< 0.01 for paired t-test; d = Cohen's d effect sizes

Gains in research poster performance between freshmen and upper level:



Students and instructors perceive improvement in communication skills: