Confronting the challenge of student understanding of experimental design with an open inquiry-based approach at a community college

Cynthia A. Kelm-Nelson, Ph.D.[1,2] and Mary Savage, Ph.D.[3]

[1] Department of Surgery, University of Wisconsin-Madison; [2] Delta Teaching and Learning Internship, University of Wisconsin-Madison; [3]Department of Arts and Sciences, Madison College

Background and Rationale:

The Skill: Experimental design is an important skill for students; it facilitates an understanding of how biological knowledge is generated and gives them the critical thinking tools to perform their own investigations.[1,2]

The Problem: Students in introductory science often struggle to identify a central hypothesis and define experimental variables.

The Course: Principles of Animal Biology (4 credit lecture/lab) is a mandatory, first-year course in the veterinary technician (vet-tech, n=18) program at Madison College, a diverse community college. The course focuses on general biological principles, cell structure and function, genetics, comparative anatomy and physiology, evolution, and ecosystems. Students observe that this course is difficult and covers a great deal of content. The current laboratory curriculum contains the scientific method; *however, many vet-tech students fail to identify experimental design principles and understand the real-world application*.

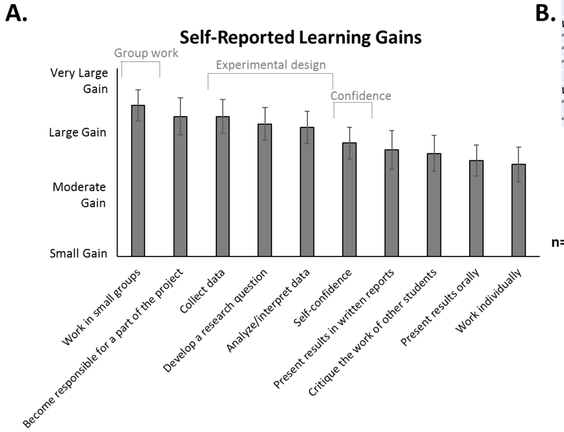
Our Approach: Open inquiry-based activities are used to increase understanding by investigating topic-related questions that are student formulated.[3] In science education, an open-inquiry based approach promotes skill development. We designed an in-class activity to increase student understanding of experimental design by simulating authentic science exposure.

We hypothesized that a group activity would improve understanding the application of the scientific method to a common student-designed hypothesis; and, that group work would increase student confidence in this course.

Learning Goals	Lab Activities	Assessments
1. **Describe** the scientific method and **identify** variables. 2. **Create** an experiment to answer the proposed hypothesis (including proper controls, variables, and replicates) and **analyze** the data. 3. **Gain** confidence in group work and individual ability to **perform** well in this course.	Instructional lecture • Overview: why this concept is important to a vet-tech • Vocabulary and definitions Group Work • Experimental design activity (scaffolding provided)(• Lab report • Presentations Class Work • Class discussion of pseudoscience	Pre-activity • Student assessment of learning gains survey/demographics • Experimental design and ability (EDAT) pre-test Post-activity • EDAT post-test • Surveys on: confidence, group work and learning gains • Minute paper reflection

Table 1. *Outline of project.* We assessed student gains using the published and validated Experimental Design and Ability Test (EDAT) for use in undergraduate populations as well as a variety of pre- and post-survey tools.[4] The EDAT is an open-ended prompt used to reveal students' ability to design a simple experiment to test a product claim. Student responses are scored by looking for the presence or absence of ten basic elements of experimental design.[4]

Freedom to design lab experiments increased student confidence going into a difficult course:



B.

Sample responses from post-lab minute paper

What did you enjoy about the lab?
"Freedom, we got to design our own experiment."
"Working in groups."
"Creativity of designing an experiment."

What is one thing that you learned?
"That you can use the scientific method for almost anything."
"Better understanding of scientific theory."

Fig 1. *Self-reported post-laboratory student gains as recorded by the individual*. A. We chose to interpret the scales as numeric and assignment values 1-4 to survey categories, then took the average and SEM. X-axis labels are the survey question content; y-axis labels are the categories for respondents. Sample student responses from the post-lab minute paper are aligned with survey findings. Samples size is 18.

Incorporation of group work into the first lab improved the learning community of the course:

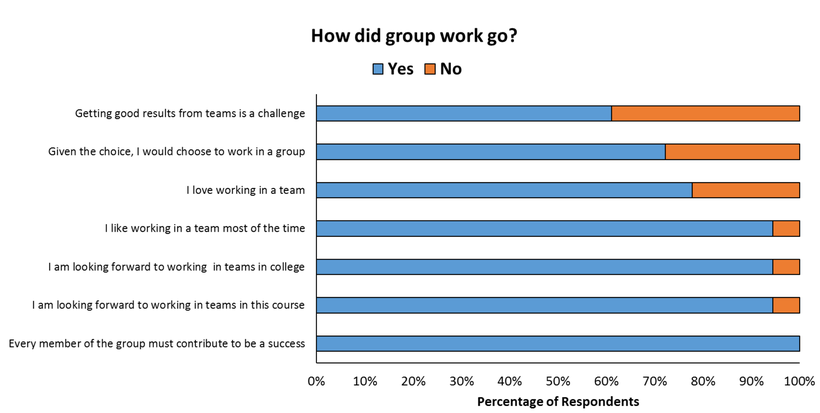


Fig 2. *Group attitude survey results*. Y-axis is survey questions, x-axis is the percentage of responses ("Yes" coded in blue, "No" coded in Orange). Sample size was 18 per question.

Students were enthusiastic about lab's impacts on process of and interest in science:

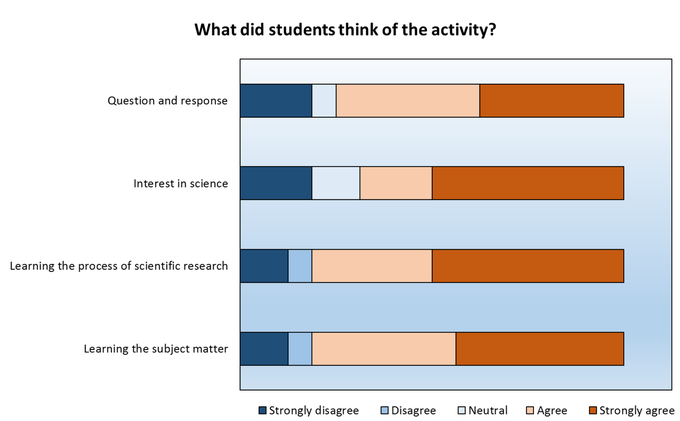


Fig 3. *Student responses regarding the laboratory activity*. Responses were largely uniform across items, measures were combine to evaluate the activity for process of and interest in science. Post-lab survey questions were "Was/Did this lab..."(Q1: a good way of learning about the subject matter; Q2: a good way of learning about the process of scientific research; Q3: have a positive effect on my interest in science; Q4: allow me to ask questions and get helpful responses). Students were asked to rate their own agreement with the following items (1: Strongly disagree, 2; disagree, 3: neutral, 4: agree, 5: strongly agree). We chose to analyze the average of the assigned values (1-5). Sample size is 16.

Lessons Learned & Recommendations:

- ✓ Open-inquiry and group work impact a common challenge across science courses, the fundamental understanding and importance of the experimental design process.
- ✓ **In this project, we demonstrated that an open-inquiry activity paired with group work improves participation and increases student confidence in an introductory biology course.**
- ✓ Additionally, the community college context of this project suggests a novel way to implement a new experimental design activity and assess its efficacy in a diverse undergraduate classroom.

Experimental design and ability test (EDAT) Implementation:

- EDAT evaluation of performance was largely unchanged (Mann-Whiney U=156.5 p=0.48, n= 18).
- Some improvement in identifying main concepts (variables, controls) suggests student increases in learning.
- More guidance on EDAT was needed (including written directions). [5,6,7]
- Other aspects including understanding the placebo effect, and sources of error remain challenges for students.

Project Limitations:

- Sample size should be increased
- Increase repeatability across multiple lab sections
- Add controls by comparing results of EDAT to previous lab activity participants

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References:

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