Exploring how undergrads approach the design and analysis of experiments?
Jia Shi
Mike Klymkowsky
Jenny Knight
MCDB
University of Colorado at Boulder
Introduction: The ability to design and analyze scientific experiments is a goal of most undergraduate biology programs.

We developed a survey designed to reveal how students think about experimental design. The results indicate that there are essential experimental elements that students commonly overlook, including the identification of necessary and appropriate controls and the analysis of simple data sets.
197 students (predominantly biology majors) at the University of Colorado completed this survey online in the spring semester, 2011.
Main Findings:

Do you consider the field in which you are majoring an “experimental” science? Why?
~35% of students gave explanations that make sense(?)

What defines an experiment in your major/discipline?
~15% of students mentioned controls.
~39% of students recognized the limitations associated with taking a single measurement.

Graph interpretation:
~10% of students correctly interpreted the information communicated by error bars in a graph.

Do experiments in your major/discipline require random sampling or random assignment of variables? Explain.
~46% of students understood the role of random sampling in biological experiments.
Summary of DEBR Expert Responses

- If the error bars overlap, it is not statistically “different”.
- Small sample size and self-reporting do not lead to reliable data.
- Controls are necessary in biological experiments.
- Double-blind placebo-controlled design can remove bias.
- Though almost all chemistry and physics experiments don’t use human subjects (no placebo), they still use controls of some sort (a few comment that chem/phys should run more double blind studies).
Q1. Do you consider the field in which you are majoring an “experimental” science?

- Test new ideas: Yes
- All science is experimental: No
- Experiments can be done: Yes
- Can't think beyond school: No
- Not experimental, already know everything: No
- Not sure what experiment means: Yes
Q2. What defines an experiment in your major?

Example of student responses

<table>
<thead>
<tr>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses scientific methods</td>
</tr>
<tr>
<td>Advancing knowledge</td>
</tr>
<tr>
<td>Uses #, technology, data</td>
</tr>
<tr>
<td>Test hypothesis</td>
</tr>
<tr>
<td>Using known conditions, controls</td>
</tr>
<tr>
<td>Collecting data/make observations or…</td>
</tr>
<tr>
<td>Irrelavent answers</td>
</tr>
</tbody>
</table>
By looking at the bar graph below, can you get a rough idea statistically about the test scores between group A and group B for class 1 and class 2? □ yes □ no □

Explain your answer.

**Percentage of student answers:****

- **Correct answer:** 69%
- **Most incorrect answer:**
  - Error bars don't overlap
  - Error bars mentioned
  - Using averages to make conclusion
  - Can't make conclusion
  - Others
Q4. …The only published study reported that in a group of 15 volunteers (average age 71 years) taking PS for 12 weeks, there was a 42.7% increase in the self-reported ability to remember. Is this study enough to recommend that your grandparents start taking PS?

95% said NO

Reasons:
• All three items: too small of a sample size, self-reporting is not reliable, and no controls (7%)
• Any combination of above two items (46%)
• Small sample size, side effects or both (39%)
• Need to know volunteer’s background/study not long enough (3%)
Q5. Why are experiments not done this way (e.g. double-blind) in physics or chemistry?

because...

• Phys/Chem experiments don’t have psychological components (60%)

• Don’t understand “double-blind” or no ideas (23%)

• Scientist can’t misreport data (7%)

• Phys/Chem have less bias issues (6%)

• Phys/Chem still need to run blind study (4%)
Q6. Which of the following elements is applicable to conducting experiments in your major or discipline? (choose all that apply and explain) - example

- need > one measurement
- don't need > one measurement
- don't take measurements
- unsure what this means or it depends

Percentage

<table>
<thead>
<tr>
<th>Percentage</th>
<th>need &gt; one measurement</th>
<th>don't need &gt; one measurement</th>
<th>don't take measurements</th>
<th>unsure what this means or it depends</th>
</tr>
</thead>
</table>
Q6. Which of the following elements is applicable to conducting experiments in your major or discipline? (choose all that apply and explain) - example
Student comments

“...This survey was actually pretty useful. It made me think very metacognitively about how I think of experimental design in the field of MCDB.”

“It would be very useful as a teacher in order to assess how students think about experimental design. Maybe as a pre and post test to see what mental models they are bringing into the classroom and what they come away from my class with.”

“I liked that every question required explanations rather than merely selected a pre-made answer. These explanations would help to give some insight about what a person knows rather than testing what someone doesn’t know.”
Conclusions: Preliminary findings suggest that students clearly need additional help learning about the experimental nature of biology.
What’s the next step?
We intend to extend this study to examine how students in chemistry, physics and astronomy majors respond to these questions.
Acknowledgements:

We thank the instructors for administering the survey in their courses. We wish to thank Oliver Pascal for setting up the survey online and Katie Southard for compiling the results.