UC Berkeley General Chemistry Laboratories: Assessment of the tools used to measure student learning gains and attitudes

Prepared by:
Laura Armstrong, PhD Student
UC Berkeley Graduate Group in Science and Math Education

Faculty Sponsors:
Professor Anne Baranger
Dr. Michelle Douskey

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Program context and assessment team

Over the past five years the undergraduate general chemistry lab curriculum at the University of California, Berkeley has been iteratively redesigned to focus on authentic contexts, student choice, and guided-inquiry. In addition, the new general chemistry experiments were designed to introduce freshman chemistry major and non-major students to sustainability and green chemistry concepts.

This new laboratory curriculum focused on building students' laboratory technique and quantitative analysis skills and also equipping them with the appropriate knowledge for modern societal and industrial demands. This includes introducing them to modern and innovative chemistry fields such as green chemistry and toxicology. Additionally, it is important to modernize the way students are taught this information in the laboratory course by designing a new curriculum using contemporary pedagogy and learning sciences principles.

Assessing the impacts of this curriculum has always been a priority. The team that developed this new curriculum has also been instrumental in developing surveys and interview protocols to assess student learning gains and attitudes before and after completing the redesign laboratory courses. This development and assessment team includes Professor Anne Baranger, Director of Undergraduate Chemistry, Dr. Michelle Douskey and Dr. MaryAnn Robak, Lecturers in Chemistry, and several chemistry education graduate students, myself included. Throughout this project, I met weekly with Professor Baranger and Dr. Douskey. My role was to gather and organize stakeholder input, perform needed data analysis and report results, and facilitate discussion about these results and next steps with the stakeholders.

Motivation

Initiated over five years ago, the new general chemistry laboratory curriculum has been developed, implemented, and iteratively refined. Redesigning the lab curriculum impacts thousands of students each year. Systematically assessing the outcome from this curriculum is a critically important to ensure that the redesigned courses are meeting the expectations of the developers and serving the student population. Assessment of these courses has been used and will continue to be used to improve the curriculum structure, implementation, and content.

My goal as an assessment fellow was to aid Professor Baranger and Dr. Douskey in evaluating the current survey used to assess student learning gains and attitudes towards chemistry. This survey was designed by many people over many years, which has led to the survey having many different purposes and questions. Indeed, the survey has over 110 questions. The length of this survey makes it difficult to motivate student to complete the survey with good effort and the unclear goals of survey make it difficult to use the resulting responses to evaluate student learning and attitudes.

Purpose and intended use

The purpose of this assessment project is to document and better understand the structure and purpose of the current survey used to measure student learning and attitudes in the general chemistry laboratories. I will use this information to evaluate the current survey questions provide meaningful information and align with the identified outcomes for the curriculum. I also will us this information to identify if survey questions can be eliminated and if certain outcomes are not being assessed with our current survey. This will hopefully allow us to develop a more focused and purposeful survey for future use whose results can be used for curriculum improvement and assessment.

Guiding questions

My faculty sponsors and myself developed three guiding questions to focus the direction of this assessment project:

1. How can we understand the underlying structure of the current survey?
2. How can we reduce or streamline the type and number of questions on the survey?
3. How can we use our understanding of the survey structure to improve our evaluation of student outcomes and impacts?

We hoped that these guiding questions would first help us thoroughly understand the purpose and structure of our current survey and then allow us to use that information to improve this survey for future use.

Methods and tools

I used exploratory factor analysis to explore the common factors in the latent variables present in the survey (**Appendix I** shows the full survey structure) using StataSE 14. Factor analysis collapses a large number of variables into a few interpretable underlying factors by matching similar response patterns for certain variables to the same factor. I used an iterated principal factor approach which uses the squared multiple correlation coefficients as the initial estimates of the communalities and then iterates to obtains different (better) estimates. The scree plot and eigenvalues (above 1) suggested there were six factors. I retained these six factors and used varimax rotation and a factor loading threshold of 0.3 to assess loading and cross loading for each variable (**Appendix II** shows detailed results from this factor analysis).

Based on these criteria, 47 items were matched to the six factors. One item did load onto any factor (it's factor loading was less than the cutoff of 0.3). Based upon the items that loaded onto each factor I labeled the factors 1: Understanding of chemistry concepts, 2: Ability to perform chemistry techniques, 3: Confidence designing an experiment, 4: Attitude towards chemistry I, 5: Attitude towards chemistry research, and 6: Attitude towards chemistry II.

Finally, we created a logic model to detail the outcomes we expect from this curriculum change (see **Appendix III** for a thorough discussion of the creation of this logic model). Understanding what outcomes we expect from the curriculum allowed us to see if our survey was currently matching those outcomes.

Results and next steps

Table 1 shows the number of items that loaded onto each factor. Factor 1 had the greatest number of items (34% of all the items) and also had the greatest number of items that loaded onto two different factors. Indeed, all factors except factor 5 had at least one item that loaded onto more than one factor. Most of the overlapping items were between factors 1 and 2, which revolve around students' confidence in their understanding of chemistry concepts and techniques. It is not surprising that students responded similarly to these items but it does indicate that these two categories aren't as distinct as the designers of the survey may have intended.

Table 1: Total number of variables for each factor and number of variables loaded to one or multiple factors.

Factor	**Total number of variables**	**# of variables loaded onto a single factor**	**# of variables loaded to multiple factors**
1: Chemistry concepts	16	9	7
2: Chemistry techniques	10	6	4
3: Designing experiments	8	5	3
4: Attitude towards chemistry I	6	5	1
5: Attitude towards chemistry research	4	4	0
6: Attitude towards chemistry II	3	2	1
TOTAL	**47**	**31**	**16**

Overall, the six factors identified from factor analysis aligned with the sections presented in the survey (chemistry understanding, concept measurement, attitude towards chemistry, science in practice) but provided more nuance. Figure 1 shows how the six factors contain items from each of the four survey sections with most factors drawing from only one section (i.e. each section is split between multiple factors).

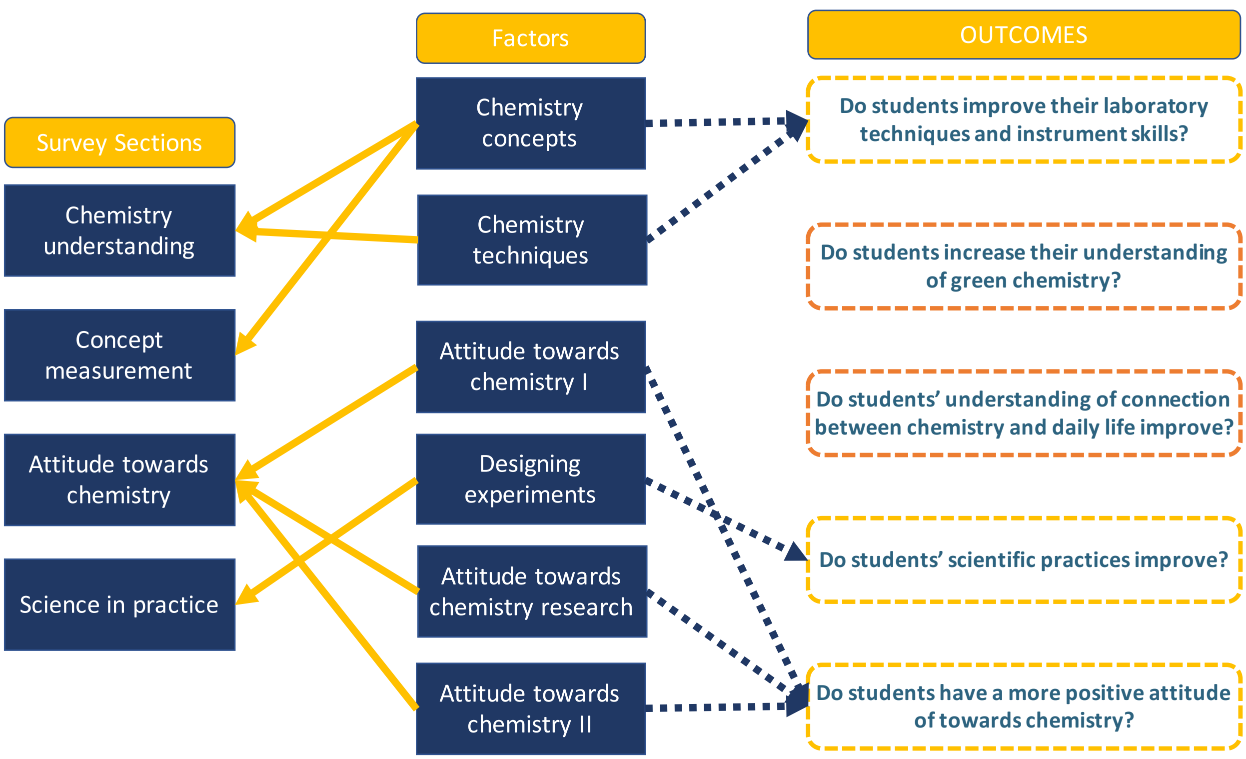

Figure 1: Mapping of survey sections and curriculum outcomes to the factors determined from exploratory factor analysis

Finally, I looked at the correspondence of the factors to the outcomes identified for the general chemistry laboratory curriculum (as determined by our logic model). The current survey corresponds to three of five curriculum outcomes (related to laboratory techniques, scientific practices, and attitude chemistry). Two of the outcomes – green chemistry understanding and connections between daily life and chemistry – are not represented in the current survey. Additionally, the factor with the greatest number of items (chemistry content) is not an explicit outcome for this curriculum redesign. Thus, my first recommendation is to realign the curriculum outcomes and survey questions. Discussions with stakeholders will help clarify outcomes and which questions can most efficiently and accurately be used to measure those outcomes. Related, I also recommend additional discussion about how to streamline the number of questions on the survey (e.g. removing some of the *chemistry content* questions) and how to improve our evaluation of additional student outcomes and impacts.

Tips and strategies for engagement

Engaging in this project provided me with an opportunity to think about how to assess and improve a survey that has been used by a department for many years. For other departments that are looking to critically examine an already designed assessment tool, I would recommend:

1. Use exploratory factor analysis to help clarify the underlying structure of your survey.
    a. Is there significant overlap between factors? Do you expect that based on the identity of these factors? If not, what can be changed about the items to reduce this overlap?
    b. Does each item load onto a factor? If not, are you comfortable removing that item from your survey or do you want to redesign your survey to better address the topic of that item?
2. Separately, discuss the outcomes that you aim to measure with relevant stakeholders. Creating a logic model may be a useful tool to clarify the expected goals of a program or curriculum.
3. Finally, determine if the results from your factor analysis and the expected outcomes overlap.
    a. Is your assessment tool actually measuring topics that are important for your program or curriculum?
    b. Are certain topics over or underrepresented in your survey?

Finally, for an assessment project to be as useful as possible, stakeholders must be kept apprised of the process and findings throughout the lifecycle of the evaluation – not only at the end of the evaluation. Regular meetings and clear communication can help make the evaluation a collaborative endeavor between the evaluation staff and stakeholders.

Reflection

I very much appreciated being an assessment fellow this semester. The in-person sessions were very informative and relevant to our assessment projects and I appreciated hearing about other students' projects. Even though our projects were disparate it was useful hearing how they engaged stakeholders in their projects and managed and incorporated multiples opinions and ideas into a coherent framework. Additionally, I really appreciated the session on how to appropriately visualize data. I have always been interested in how to best represent complex data and this was a wonderful reminder and learning experience in how to make data more accessible and useful for your target audience.

While I had previously been aware of how important it was to engage stakeholders in the evaluation process I hadn't thought specifically about how best to accomplish that. Throughout this semester, I found myself thinking not only about *what* I'd be presenting to the faculty leads on this project but also *how* I'd be presenting this information. Before each meeting, I'd plan the topics what I wanted to discuss and what outcomes I wanted to reach from that discussion. I then would think about how best to present my information or what questions I needed to ask to reach those outcomes. This didn't always go smoothly especially in the beginning. Our meetings were usually not solely devoted to this project and I found that we would often run out of time before discussing the entirety of my agenda. However, as the semester went on I become better at managing time and my faculty leads became more and more invested in the project as they began to see results. Professor Baranger was especially interested in the factor analysis results and very excited to see progress on this project. We discussed not only the results of the factor analysis but also the process that was used for this analysis, such as how to interpret the Stata output (or how to choose the correct number of factors, what the factor loadings represent, etc.).

I also felt that having the data from the factor analysis greatly helped advance my goal of survey redesign. Previous attempts to redesign this survey have not met with much success – instead these attempts usually just ended in adding more questions to the survey in an attempt to fill perceived gaps (and I must admit I was not initially optimistic this attempt would garner different results). While the results from the factor analysis were not surprising to me (i.e. the survey doesn't actually measure all of our stated outcomes from our curriculum) having completed a more thorough analysis of the survey and gathering quantitative results really illustrated why survey reform was needed. Additionally, I think having carefully prepared visualizations helped advance my goal (e.g. simplifying what factor each item loaded onto, showing survey factors versus stated outcomes).

The assessment fellows program has been incredibly useful for my professional development and I only wish it last longer. Thank you so much for a wonderful semester.

Appendix I: General Chemistry Survey

The survey responses used for factor analysis were obtained from the fall 2016 Chem 1AL (general chemistry laboratory for non-chemistry majors) class. The students were surveyed at the beginning and end of the course and I used the pretest responses for this analysis. The survey was administered online (using SurveyMonkey) and students were incentivized to complete for a course bonus point.

Only fixed response questions were used for the current analysis. Free response questions and demographics/background information questions were excluded.

Chem 1AL Fall 2016 - Survey 1

CONSENT/ASSENT TO PARTICIPATE IN RESEARCH

Investigating New General Chemistry Curriculum in the College of Chemistry

Our names are Geri Kerstiens, Beatriz Brando, Erin Palmer, Sara Tischhauser, and Laura Armstrong. We are graduate students working with the Director of Undergraduate Chemistry, Anne Baranger, and other faculty and graduate students in the College of Chemistry at the University of California, Berkeley. We are planning to conduct a research study, which we invite you to take part in.

We are inviting you to participate in this study because you are enrolled in General Chemistry. The purpose of this research is to understand the effects of this new curriculum to not only improve chemistry education at UCB but also to improve chemistry education at other institutions by sharing our results with the chemistry education community.

If you agree to be in this study, you will be asked to do the following:

- Complete a short online survey. The survey will include questions about your background in chemistry and your experiences in the course. It will take approximately 15-20 minutes to complete. The surveys will be administered at two time points throughout the semester.
- Allow us (the researchers) access to materials you submit as part of the course (assessments, homework, midterm exams, final exams, quizzes, etc.). The assessments will be administered in a variety of formats. Your work will be collected by your instructor and reviewed by members of the Chemistry Education group at UC Berkeley. This is not extra class work but material that all students enrolled in the course will complete.
- Also, we will invite some students to participate in interviews. The interview is to ask students about their experiences in the course and/or to evaluate students' understanding of course material. The interview will be conducted on the UC Berkeley Campus and will be videotaped with the student's permission. The interview will take up to one hour.

Benefits
Although there is no direct benefit to you from participating in this research, we hope that this research will benefit society by improving our understanding of chemistry curriculum.

Risks/Discomforts
You are free to decline to answer any questions you don't wish to, or to stop participating at any time.

Breach of confidentiality: as with all research, there is a chance that confidentiality could be compromised; however, we are taking precautions to minimize this risk.

Confidentiality
Your study data will be handled as confidentially as possible. If results of this study are published or presented, individual names and other personally identifiable information will not be used.

To minimize the risks to confidentiality, we will assign you a unique participant ID number that will be used to replace identifying information, such as your name, in your data. Your data (video included) will be stored in a locked cabinet in our lab or electronically in password-protected files. The list that links participant numbers to identity will be kept in a locked cabinet separate from study data.

When the research is completed, we may save the study data for use in future research done by ourselves or by others. We will retain these records for up to 6 years after the study is over. The same measures described above will be taken to protect confidentiality of this study data.

Compensation
One bonus point will be awarded for the completion of each survey. If you do not wish to participate but would still like to receive these bonus points, you may complete the alternate assignment outlined in the invitation e-mail.

Rights
Participation in research is completely voluntary.

You have the right to decline to participate or to withdraw at any point in this study without penalty or loss of benefits to which you are otherwise entitled; your standing in the class or school will in no way be affected by your decision.

Questions
If you have any questions or concerns about this study, you may contact Laura Armstrong at armstronglaura@berkeley.edu.

If you have any questions or concerns about your rights and treatment as a research subject, you may contact the office of UC Berkeley's Committee for the Protection of Human Subjects, at 510-642-7461 or subjects@berkeley.edu.

1. If you agree to take part in the research, please indicate what you agree to, using the buttons below. Mark all that apply.

- [ ] I agree to have my survey responses and course materials collected.
- [ ] I agree to be contacted to participate in individual interviews, if chosen by the research team.

2. If you are willing to be contacted for participation in interviews, please include the email address that is best to use to contact you.

Chem 1AL Fall 2016 - Survey 1

CHEMISTRY UNDERSTANDING

3. Presently, how much do you understand each of the following concepts?

	not at all	a little	somewhat	a good deal	a great deal
Relationships between physical properties and molecular structures	○	○	○	○	○
Functional groups as a way of categorizing molecular structures	○	○	○	○	○
Intermolecular interactions	○	○	○	○	○
Types of bonding (non-polar covalent, polar covalent, ionic)	○	○	○	○	○
Reaction equilibrium	○	○	○	○	○
Acid and base reactivity	○	○	○	○	○
Beer's law	○	○	○	○	○
Absorption of light by molecules	○	○	○	○	○
Reaction kinetics and mechanisms	○	○	○	○	○
Chromatography	○	○	○	○	○
Electrochemistry	○	○	○	○	○
Spectroscopy	○	○	○	○	○

4. Presently, how familiar are you with the following techniques?

	not at all	a little	somewhat	a good deal	a great deal
Titration using a pH probe	○	○	○	○	○
Calorimetry	○	○	○	○	○
Serial dilutions	○	○	○	○	○
Thin layer chromatography (TLC)	○	○	○	○	○
UV/Vis spectroscopy	○	○	○	○	○
Error analysis	○	○	○	○	○
Calibration curves	○	○	○	○	○
Quantitative measurement: using volumetric glassware and balances	○	○	○	○	○

5. Please indicate your level of agreement with the following statement: I know what the term Green Chemistry means.

- ◯ Strongly disagree
- ◯ Somewhat disagree
- ◯ Somewhat agree
- ◯ Strongly agree

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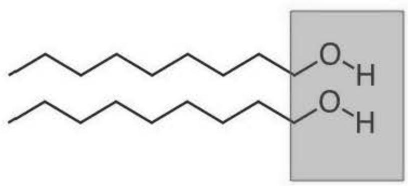
Chem 1AL Fall 2016 - Survey 1

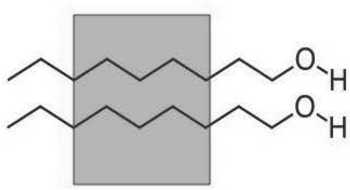
CONCEPT MEASUREMENT

Please do your best to answer the following questions honestly. If you do not know the answer or how to attempt the problem, please do not guess; mark "I don't know."



6. Indicate which of the following intermolecular interactions is occurring in the area shaded in the diagram above.

- ◯ Ionic interactions
- ◯ Hydrogen bonding interactions
- ◯ London dispersion interactions (induced dipole-induced dipole interactions)
- ◯ I don't know.



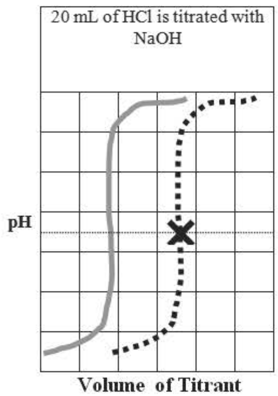
7. Indicate which of the following intermolecular interactions is occurring in the area shaded in the diagram above.

- ◯ Ionic interactions
- ◯ Hydrogen bonding interactions
- ◯ London dispersion interactions (induced dipole-induced dipole interactions)
- ◯ I don't know.

5

For the next question consider the following information:

In lab you see two titration curves representing two different titrations. Both titrations used 20 mL of HCl and were titrated with NaOH. Titration 1 is represented by the solid line, and Titration 2 is represented by the dotted line.

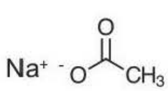


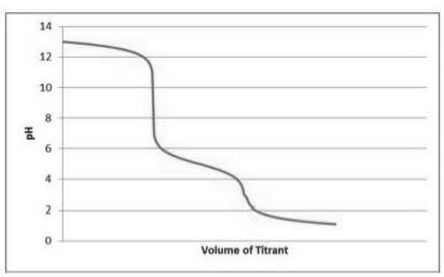
8. How can you best explain the difference between the two titrations, given the curves in the graph above?

- A. The concentration of HCl in Titration 2 is greater than the concentration of HCl in Titration 1.
- B. The concentration of HCl in Titration 1 is greater than the concentration of HCl in Titration 2.
- C. The moles of NaOH used in Titration 2 is greater than the amount of NaOH used in Titration 1.
- D. The moles of NaOH used in Titration 1 is greater than the amount of NaOH used in Titration 2.
- Either answers A or D are correct.
- Either answers B or C are correct.
- I don't know.

For the next question consider the following information:

In lab you use hydrochloric acid (HCl) to titrate a mixture of sodium hydroxide (NaOH) and sodium acetate ($NaC_2H_3O_2$). You measure the pH during the titration, and the titration curve shown below is the result.

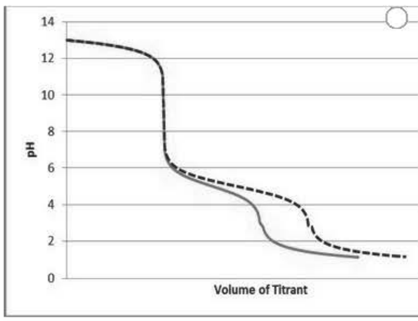

sodium acetate

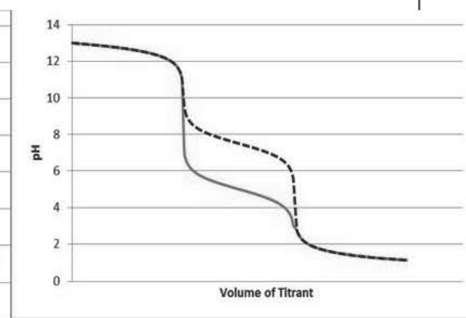


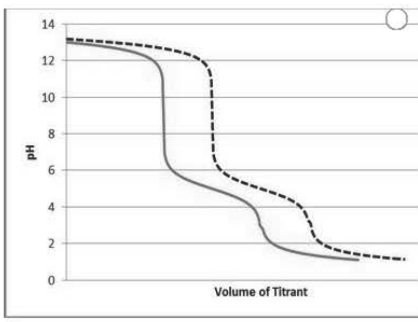
Your lab partner has a different sample, one with a greater amount of NaOH and the same amount of $NaC_2H_3O_2$.

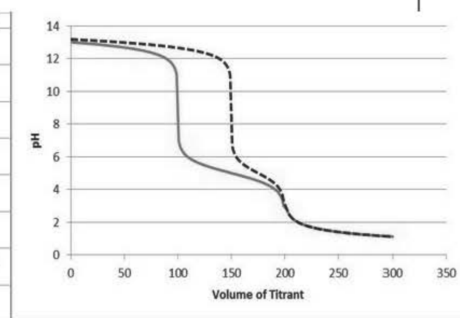
— Your data
--- Your lab partner's data

9. What would the titration curve for this sample look like compared to yours?

◯ 

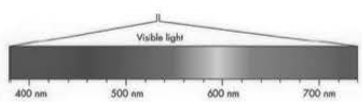
◯ 

◯ 

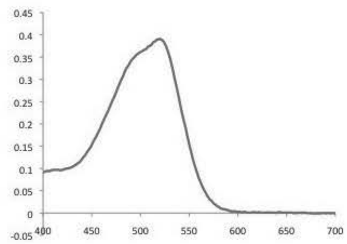
◯ 

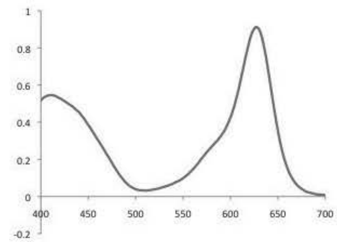
◯ I don't know.

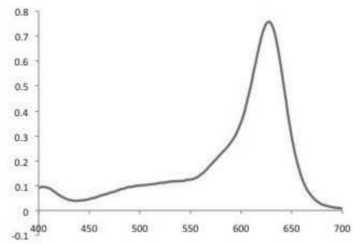
For the next question, refer to the spectrum provided below:



10. Which absorbance spectrum (absorbance versus wavelength in nm) would correspond to a green solution?

◯ 

◯ 

◯ 

◯ I don't know.

11. Heat is given off when hydrogen burns in air according to the equation:

$$2H_2 + O_2 \rightarrow 2H_2O$$

Which of the following is responsible for the heat?

◯ A. Breaking bonds between hydrogen atoms gives off energy.

◯ B. Breaking bonds between oxygen atoms gives off energy.

◯ C. Forming bonds between hydrogen and oxygen atoms gives off energy.

◯ Both answers A and B are correct.

◯ Answers A, B, and C are correct.

◯ I don't know.

Chem 1AL Fall 2016 - Survey 1

ATTITUDE TOWARD CHEMISTRY

For the following questions please complete the statement "Chemistry is..." by marking a number on the scale from 1 to 7, where "1" and "7" represent the extreme viewpoints of the topic. For example, in answering the first question under "Chemistry is...", a "1" represents "easy" and a "7" represents "hard."

12. Chemistry is...

	1	2	3	4	5	6	7
(1) easy...hard (7)	○	○	○	○	○	○	○
(1) complicated...simple (7)	○	○	○	○	○	○	○
(1) confusing...clear (7)	○	○	○	○	○	○	○
(1) comfortable...uncomfortable (7)	○	○	○	○	○	○	○
(1) satisfying...frustrating (7)	○	○	○	○	○	○	○
(1) challenging...not challenging (7)	○	○	○	○	○	○	○
(1) pleasant...unpleasant (7)	○	○	○	○	○	○	○
(1) chaotic...organized (7)	○	○	○	○	○	○	○

For the following questions please complete the statement "Chemistry research..." by marking a number on the scale from 1 to 7, where "1" and "7" represent the extreme viewpoints of the topic. For example, in answering the first question under "Chemistry research...", a "1" represents "harms people" and a "7" represents "helps people."

13. Chemistry research...

	1	2	3	4	5	6	7
(1) harms people...helps people (7)	○	○	○	○	○	○	○
(1) decreases quality of life...improves quality of life (7)	○	○	○	○	○	○	○
(1) creates problems...solves problems(7)	○	○	○	○	○	○	○
(1) causes society to decline...advances society (7)	○	○	○	○	○	○	○

14. How do you rank your confidence for each of the following?

	none	a little	some	a good deal	a great deal
Confidence that you understand the material in this course	◯	◯	◯	◯	◯
Confidence that you can do chemistry	◯	◯	◯	◯	◯
Confidence in designing or changing an experiment to test a hypothesis	◯	◯	◯	◯	◯
Enthusiasm for chemistry	◯	◯	◯	◯	◯

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SCIENCE IN PRACTICE

15. Please select your level of confidence in performing the following activities.

	no confidence	a little confidence	some confidence	good confidence	great confidence
Performing a literature search to find relevant background information	◯	◯	◯	◯	◯
Forming a hypothesis	◯	◯	◯	◯	◯
Developing an experiment to test a hypothesis	◯	◯	◯	◯	◯
Collecting and analyzing data to determine the results of an experiment	◯	◯	◯	◯	◯
Using results to support or refute a hypothesis	◯	◯	◯	◯	◯

For the next two questions, please refer to the scenario described below:

You are walking around the UC Berkeley campus and notice that the south side of campus seems to have more squirrels than the north side of campus. You are curious what might be the **cause** of such an imbalance.

16. Think of **one** possible reason for an imbalance in the squirrel populations. Write the corresponding hypothesis.

17. Next, in 5-7 sentences, explain how you would design one or more experiments to test your hypothesis.

SCIENCE IN PRACTICE

For the next question use the following chart which appeared in a scientific article about the effects of pesticides on tadpoles in their natural environment:

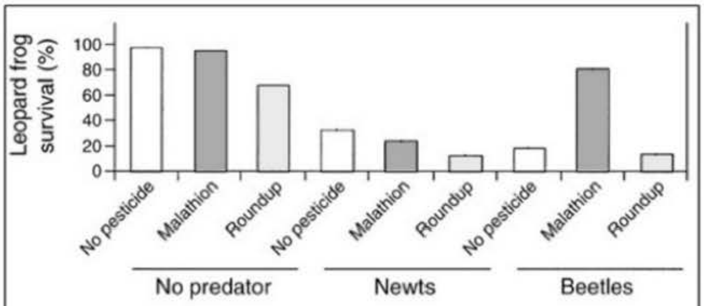

Fig. 2. Total survival of Leopard frog tadpoles living in ponds with 2 pesticides added (Malathion and Roundup) and 2 tadpole predators present (newts and beetles).

(modified from Relyea, R.A., N.M. Schoeppner, J.T. Hoverman. 2005. Pesticides and amphibians: the importance of community context. Ecological Applications 15: 1125-1134.)

18. When beetles were introduced as predators to the Leopard frog tadpoles, and the pesticide Malathion was added, the results were unusual. Please construct a scientific argument that explains the results using all the available data.

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DEMOGRAPHICS/BACKGROUND INFORMATION

19. Which science courses have you taken in the past? (check all that apply)

- ☐ Integrated Science
- ☐ Environmental Science
- ☐ Earth Science
- ☐ Biology
- ☐ Honors Biology
- ☐ AP Biology
- ☐ IB (International Baccalaureate) Biology
- ☐ Chemistry
- ☐ Honors Chemistry
- ☐ AP Chemistry
- ☐ IB (International Baccalaureate) Chemistry
- ☐ Physics
- ☐ Honors Physics
- ☐ AP Physics
- ☐ IB (International Baccalaureate) Physics
- ☐ Chemistry at a community college, 4 year college, or different university
- ☐ Chemistry at UC Berkeley

Other (please specify)

20. How many SEMESTERS of chemistry have you completed previously, in high school and college together?

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ more than 4
- ○ I have never taken chemistry.

13

21. In the most recent chemistry course you took, indicate how often you did laboratory work (investigations involving the use of chemicals, including household chemicals, other lab equipment, and/or measurements).

- Never
- Once or twice a semester
- Once a month
- Twice a month
- Once a week
- More than once a week

22. In your most recent chemistry course, which of the following did you do?

- Did not do labs
- Only followed a given procedure
- Sometimes designed a procedure or scientific experiment

23. In your most recent chemistry course, indicate the average size of groups you were in during laboratory experiments.

- Did not do labs
- Worked alone
- Pairs
- Groups of 3
- Groups of 4
- Groups of 5 or more

24. Rank how useful the laboratory experiments in your most recent chemistry course were in helping you learn chemistry.

- Not at all useful
- Not very useful
- Useful
- Very useful

25. What do you expect to gain from this introductory chemistry laboratory experience?

26. Did you transfer to UC Berkeley from another college or university?

- No
- Yes

27. Are you an international student?

- ◯ No
- ◯ Yes

28. What is your intended major?

- ◯ Bioengineering
- ◯ Chemical Biology
- ◯ Chemical Engineering
- ◯ Chemistry
- ◯ Civil Engineering
- ◯ Computer Science
- ◯ Environmental/Natural Science
- ◯ Humanities
- ◯ Life Science/Biology
- ◯ Mathematics
- ◯ Mechanical Engineering
- ◯ Nutrition Science
- ◯ Other Engineering
- ◯ Physical Science
- ◯ Public Health
- ◯ Social Science
- ◯ Undeclared

Other (please specify)

29. Which of the following best describes your socio-economic class when you were growing up?

- ◯ Wealthy
- ◯ Upper-middle or professional-middle
- ◯ Middle-class
- ◯ Working-class
- ◯ Low-income or poor
- ◯ Decline to state

30. What is the highest level of education completed by your father?

- ◯ Did not complete high school
- ◯ High school degree
- ◯ Some college
- ◯ Two-year degree
- ◯ Four-year degree
- ◯ Some graduate school
- ◯ Graduate degree
- ◯ Not sure

31. What is the highest level of education completed by your mother?

- ◯ Did not complete high school
- ◯ High school degree
- ◯ Some college
- ◯ Two-year degree
- ◯ Four-year degree
- ◯ Some graduate school
- ◯ Graduate degree
- ◯ Not sure

32. What is your ethnic category? (mark all that apply)

- ☐ American Indian/Alaska Native
- ☐ Chinese/Chinese American
- ☐ Indian/Indian American
- ☐ Pakistani/Pakistani American
- ☐ Japanese/Japanese-American
- ☐ Korean/Korean-American
- ☐ Filipino/Filipino-American
- ☐ Pacific Islander
- ☐ South East Asian
- ☐ Other Asian
- ☐ African-American/Black
- ☐ Mexican/Mexican American/Chicano
- ☐ Spanish-American/Latino/Latina
- ☐ Middle Eastern
- ☐ White
- ☐ Decline to state

Other (please specify)

33. What is your gender?

- ○ Male
- ○ Female
- ○ Female to male transgender
- ○ Male to female transgender
- ○ Not sure
- ○ Decline to state
- ○ Other (please specify)

34. Is English your first language?

- ○ Yes, English is my first language
- ○ No, English is NOT my first language

35. How fluently do you speak and/or write English?

- ○ Very fluently
- ○ Somewhat fluently
- ○ Not very fluently

36. What audience were you writing to while answering the free response survey questions?

- ◯ Scientist (Instructor, GSI, etc.)
- ◯ Fellow science students
- ◯ Non-scientist (friend, parent, etc.)
- ◯ Other (please specify)

Chem 1AL Fall 2016 - Survey 1

COURSE ENROLLMENT

* 37. We appreciate your feedback and ask for your student ID to verify your enrollment in the course. Before this data is reported, your student ID will be removed. Thank you for your participation.

Appendix III: Factor Analysis

Factor analysis was used to explore the underlying structure of the survey used to measure student learning gains and attitudes towards chemistry for the general chemistry laboratories. The scree plot (Figure II.A) and eigenvalues (Table II.A) for each factor suggested a cutoff of six factors. These six factors were then retained and I then used varimax rotation and a factor loading threshold of 0.3 to assess loading and cross loading for each variable (Tables II. B and II.C).

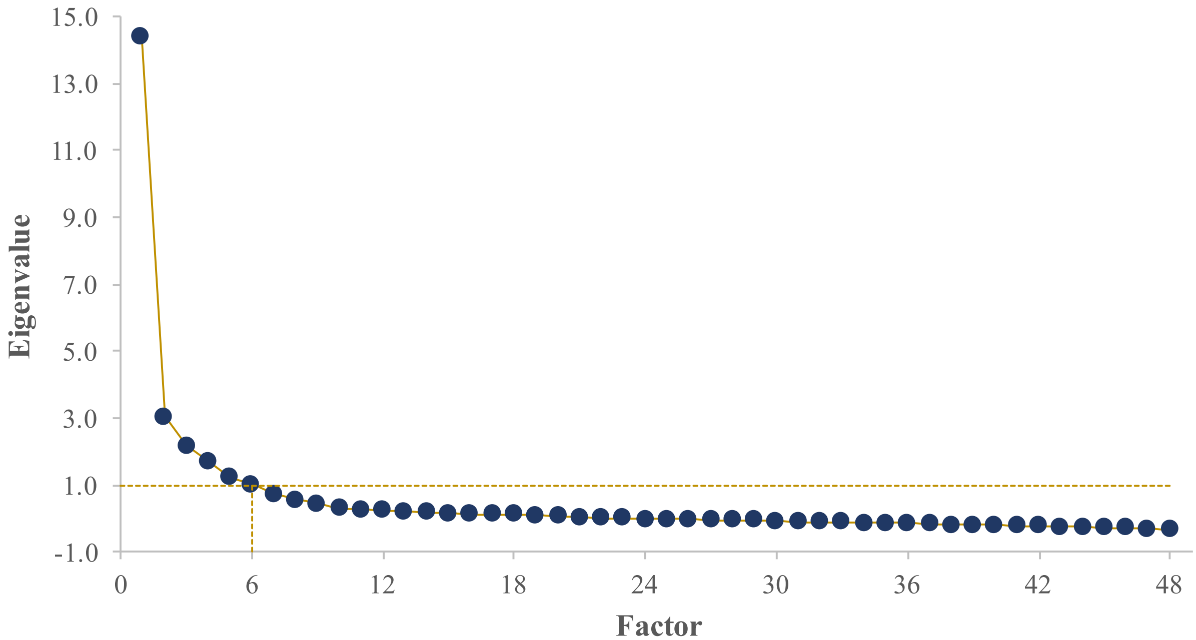

Figure II. A: *Scree plot showing cutoff at eigenvalue = 1 (corresponding to factor 6)*

Table II. A: *Eigenvalue for each factor. Factors with an eigenvalue above 1 are shaded green.*

Factor	Eigenvalue	Factor	Eigenvalue	Factor	Eigenvalue
1	14.36	17	0.13	33	-0.11
2	3.03	18	0.12	34	-0.13
3	2.19	19	0.09	35	-0.14
4	1.71	20	0.07	36	-0.14
5	1.22	21	0.05	37	-0.15
6	1.04	22	0.02	38	-0.18
7	0.73	23	0.02	39	-0.19
8	0.55	24	0.00	40	-0.19
9	0.44	25	-0.02	41	-0.21
10	0.31	26	-0.02	42	-0.22
11	0.27	27	-0.03	43	-0.23
12	0.25	28	-0.04	44	-0.25
13	0.22	29	-0.05	45	-0.27
14	0.19	30	-0.08	46	-0.29
15	0.17	31	-0.10	47	-0.30
16	0.14	32	-0.10	48	-0.32

Table II.B: *Factor loading and rotation sum of squared loadings for each survey question used for exploratory factor analysis. Light green shading indicates a factor loading of 0.3 – 0.399, medium green shading indicates a factor loading of 0.4 – 0.499, and dark green shading indicates a factor loading of 0.5 and greater.*

Survey Question	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Rotation Sum of Squared Loadings
Concept - Relationships between physical properties and molecular structures	0.531	0.337	0.241	0.132	0.116	0.118	0.498
Concept - Functional groups as a way of categorizing molecular structures	0.532	0.308	0.201	0.098	0.046	0.102	0.441
Concept - Intermolecular interactions	0.707	0.328	0.219	0.105	0.070	0.134	0.689
Concept - Types of bonding (non-polar covalent, polar covalent, ionic)	0.665	0.193	0.240	0.129	0.096	0.114	0.576
Concept - Reaction equilibrium	0.598	0.273	0.134	0.185	0.030	0.155	0.510
Concept - Acid and base reactivity	0.566	0.306	0.190	0.175	0.051	0.122	0.497
Concept - Beer's law	0.219	0.582	0.156	-0.016	-0.090	0.038	0.420
Concept - Absorption of light by molecules	0.385	0.435	0.154	0.181	0.039	0.140	0.415
Concept - Reaction kinetics and mechanisms	0.496	0.430	0.198	0.177	0.044	0.099	0.514
Concept - Chromatography	0.332	0.602	0.127	0.156	-0.025	0.093	0.522
Concept - Electrochemistry	0.457	0.582	0.271	0.058	-0.028	0.050	0.628
Concept - Spectroscopy	0.324	0.674	0.179	0.156	-0.022	0.092	0.625
Technique - Titration using a pH probe	0.557	0.440	0.130	0.173	-0.025	-0.024	0.552
Technique - Calorimetry	0.439	0.546	0.183	0.143	0.040	0.031	0.547
Technique - Serial dilutions	0.411	0.505	0.131	0.121	0.000	0.013	0.456
Technique - Thin layer chromatography (TLC)	0.172	0.653	0.009	0.185	-0.062	0.108	0.506
Technique - UV/Vis spectroscopy	0.088	0.776	0.035	0.154	-0.034	0.090	0.645
Technique - Error analysis	0.426	0.361	0.065	0.279	0.115	0.037	0.409
Technique - Calibration curves	0.296	0.680	0.115	0.110	0.027	-0.016	0.577
Technique - Quantitative measurement: using volumetric glassware and balances	0.525	0.267	0.072	0.274	0.078	-0.046	0.436
In your own words, green chemistry means…	0.197	0.192	0.072	0.249	0.067	-0.013	0.148
Indicate which of the following intermolecular interactions is occurring in the area shaded in the diagram above.	0.467	0.181	0.198	0.044	-0.054	0.036	0.296
Indicate which of the following intermolecular interactions is occurring in the area shaded in the diagram above.	0.478	0.241	0.228	-0.006	-0.059	0.078	0.349
How can you best explain the difference between the two titrations, given the curves in the graph above?	0.469	0.115	0.103	0.083	-0.090	-0.033	0.259

Survey Question	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Rotation Sum of Squared Loadings
What would the titration curve for this sample look like compared to yours?	0.350	0.145	0.137	0.091	-0.040	0.013	0.172
Which absorbance spectrum (absorbance versus wavelength in nm) would correspond to a green solution?	0.394	0.023	0.043	0.055	-0.002	0.106	0.172
Heat is given off when hydrogen burns in air according to the equation. Which of the following is responsible for the heat?	0.423	0.051	0.029	0.034	-0.081	0.087	0.198
Chemistry is... - (1) easy...hard (7)	0.309	0.137	0.525	0.101	-0.016	0.233	0.454
Chemistry is... - (1) complicated...simple (7)	0.137	0.111	0.235	0.126	0.004	0.703	0.596
Chemistry is... - (1) confusing...clear (7)	0.246	0.121	0.476	0.153	0.016	0.620	0.709
Chemistry is... - (1) comfortable...uncomfortable (7)	0.293	0.115	0.644	0.084	-0.065	0.110	0.536
Chemistry is... - (1) satisfying...frustrating (7)	0.160	0.104	0.760	0.113	-0.034	0.039	0.629
Chemistry is... - (1) challenging...not challenging (7)	0.150	0.091	0.084	0.013	0.019	0.619	0.422
Chemistry is... - (1) pleasant...unpleasant (7)	0.153	0.105	0.756	0.090	0.092	0.032	0.623
Chemistry is... - (1) chaotic...organized (7)	0.122	-0.005	0.372	0.159	0.065	0.108	0.195
Chemistry research... - (1) harms people...helps people (7)	-0.044	-0.045	0.064	0.055	0.715	-0.026	0.522
Chemistry research... - (1) decreases quality of life...improves quality of life (7)	0.004	-0.075	0.047	0.064	0.740	-0.019	0.560
Chemistry research... - (1) creates problems...solves problems (7)	-0.001	0.065	0.041	0.069	0.612	0.058	0.389
Chemistry research... - (1) causes society to decline...advances society (7)	-0.011	-0.039	-0.012	0.105	0.651	0.012	0.437
Rank Confidence - Confidence that you understand the material in this course	0.383	0.270	0.534	0.261	0.044	0.147	0.596
Rank Confidence - Confidence that you can do chemistry	0.245	0.225	0.566	0.339	0.068	0.183	0.583
Rank Confidence - Confidence in designing or changing an experiment to test a hypothesis	0.149	0.269	0.376	0.599	0.028	0.153	0.619
Rank Confidence - Enthusiasm for chemistry	0.099	0.209	0.623	0.216	0.114	0.038	0.503
Level of Confidence. - Performing a literature search to find relevant background information	0.028	0.129	0.089	0.616	0.034	0.003	0.406
Level of Confidence. - Forming a hypothesis	0.110	0.097	0.135	0.782	0.050	0.072	0.658
Level of Confidence. - Developing an experiment to test a hypothesis	0.143	0.183	0.161	0.754	0.043	0.051	0.653
Level of Confidence. - Collecting and analyzing data to determine the results of an experiment	0.279	0.094	0.199	0.733	0.110	0.081	0.682
Level of Confidence. - Using results to support or refute a hypothesis	0.221	0.078	0.161	0.778	0.173	0.037	0.717

Table II.C: *Number of factors (with a loading above 0.3) associated with each survey question. For questions that had multiple loadings above 0.3 the main factor had the highest loading value and the secondary factor had the second highest loading value. No questions had more than two loading factors above 0.3.*

Survey Question	Number of Factors	Main Factor	Secondary Factor
Concept - Types of bonding (non-polar covalent, polar covalent, ionic)	1	Factor1	N/A
Concept - Reaction equilibrium	1	Factor1	N/A
Technique - Quantitative measurement: using volumetric glassware and balances	1	Factor1	N/A
Indicate which of the following intermolecular interactions is occurring in the area shaded in the diagram above.	1	Factor1	N/A
Indicate which of the following intermolecular interactions is occurring in the area shaded in the diagram above.	1	Factor1	N/A
How can you best explain the difference between the two titrations, given the curves in the graph above?	1	Factor1	N/A
What would the titration curve for this sample look like compared to yours?	1	Factor1	N/A
Which absorbance spectrum (absorbance versus wavelength in nm) would correspond to a green solution?	1	Factor1	N/A
Heat is given off when hydrogen burns in air according to the equation. Which of the following is responsible for the heat?	1	Factor1	N/A
Concept - Relationships between physical properties and molecular structures	2	Factor1	Factor2
Concept - Functional groups as a way of categorizing molecular structures	2	Factor1	Factor2
Concept - Intermolecular interactions	2	Factor1	Factor2
Concept - Acid and base reactivity	2	Factor1	Factor2
Concept - Reaction kinetics and mechanisms	2	Factor1	Factor2
Technique - Titration using a pH probe	2	Factor1	Factor2
Technique - Error analysis	2	Factor1	Factor2
Concept - Beer's law	1	Factor2	N/A
Technique - Thin layer chromatography (TLC)	1	Factor2	N/A
Technique - UV/Vis spectroscopy	1	Factor2	N/A
Technique - Calibration curves	1	Factor2	N/A
Concept - Absorption of light by molecules	2	Factor2	Factor1
Concept - Chromatography	2	Factor2	Factor1
Concept - Electrochemistry	2	Factor2	Factor1
Concept - Spectroscopy	2	Factor2	Factor1
Technique - Calorimetry	2	Factor2	Factor1
Technique - Serial dilutions	2	Factor2	Factor1

Survey Question	Number of Factors	Main Factor	Secondary Factor
Chemistry is... - (1) comfortable...uncomfortable (7)	1	Factor3	N/A
Chemistry is... - (1) satisfying...frustrating (7)	1	Factor3	N/A
Chemistry is... - (1) pleasant...unpleasant (7)	1	Factor3	N/A
Chemistry is... - (1) chaotic...organized (7)	1	Factor3	N/A
Rank Confidence - Enthusiasm for chemistry	1	Factor3	N/A
Chemistry is... - (1) easy...hard (7)	2	Factor3	Factor4
Rank Confidence - Confidence that you understand the material in this course	2	Factor3	Factor1
Rank Confidence - Confidence that you can do chemistry	2	Factor3	Factor1
Level of Confidence. - Forming a hypothesis	1	Factor4	N/A
Level of Confidence. - Developing an experiment to test a hypothesis	1	Factor4	N/A
Level of Confidence. - Collecting and analyzing data to determine the results of an experiment	1	Factor4	N/A
Level of Confidence. - Using results to support or refute a hypothesis	1	Factor4	N/A
Rank Confidence - Confidence in designing or changing an experiment to test a hypothesis	2	Factor4	Factor3
Chemistry research... - (1) harms people...helps people (7)	1	Factor5	N/A
Chemistry research... - (1) decreases quality of life...improves quality of life (7)	1	Factor5	N/A
Chemistry research... - (1) creates problems...solves problems (7)	1	Factor5	N/A
Chemistry research... - (1) causes society to decline...advances society (7)	1	Factor5	N/A
Chemistry is... - (1) complicated...simple (7)	1	Factor6	N/A
Chemistry is... - (1) challenging...not challenging (7)	1	Factor6	N/A
Chemistry is... - (1) confusing...clear (7)	2	Factor6	Factor3
In your own words, green chemistry means…	0	N/A	N/A

Appendix III: Logic Model

The logic model for the general chemistry laboratory curriculum development, implementation, and outcomes was created with input from several of the primary stakeholders including the lab development team and Director of Undergraduate Research for the College of Chemistry. A draft logic model was construct from my own knowledge of the program and from reading the Dow Foundation grant proposal and was then edited with input from the primary stakeholders.

Figure III.A shows the most current version of the logic model for the curriculum. Since this curriculum has been developed and implemented over five years it has gone through three phases: creation, implementation, and assessment/dissemination. In the first phase, support and funding was obtained for the curriculum redesign and then the new curriculum was designed and developed. In the second phase, the new curriculum was implemented in the laboratory courses and iteratively refined. In the third and current phase, the curriculum implantation and outcomes are being evaluated and the curriculum is being disseminated to other institutions and colleagues.

The logic model shows the outcomes and impacts for the curriculum organized around four main categories: students, GSIs, department, and assessment/dissemination. Student outcomes and impacts are the most immediately recognizable goals of the curriculum implementation. However, the designers of this curriculum also hope to have an impact on GSI teaching practices after they interact with this curriculum. They also aim for this curriculum to influence how the College of Chemistry views undergraduate education – namely that there will be more support for introducing undergraduate students to green chemistry and teaching students authentic science practices.

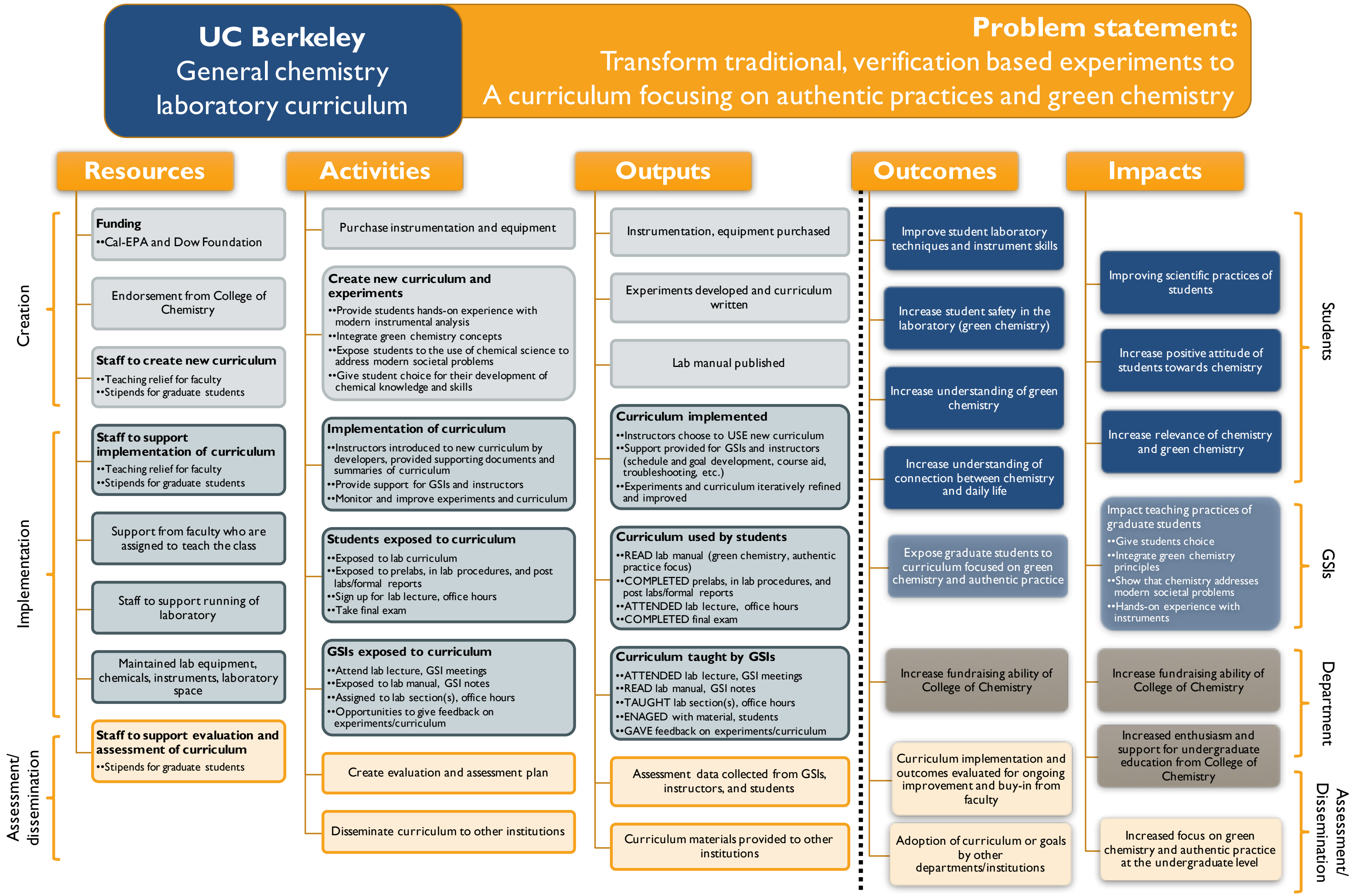

Figure III.A: *Logic model for the redesigned general chemistry laboratory curriculum at UC Berkeley*