Developing the 300-level Integrated laboratory in Chemistry

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Outline

- Upper Year Lab offerings:
  - How does it work?
  - Blurring the barriers between chemistry sub-disciplines
  - Pedagogical strategy for designing interdisciplinary chemistry experiment
- Goals for the 300-level Chemistry laboratories
  - Leading towards a real-world experience.
- Achieving these goals
  - Chemistry Laboratory Scheduling System (CLaSS)
  - Assessments re-visited
- What students learned

Chemistry sub-disciplines

- Different from other sciences
  - Sub-disciplines have been taught as individual packages

- Traditionally
  - Inorganic – About Metals
  - Organic – About C, H, O, N
  - Analytical – About accurate measurements
  - Physical – About spectroscopy/ quantum mechanics

- Today's research – barriers have been blurring
  - so the method of teaching these sub-disciplines also needs to be changed.

Background – old *vs.* new delivery system

Old delivery system

- Laboratory experience - small component of the lecture course.
- Sub-discipline specific laboratory instructor, space and grades.
- All experiments offered during each laboratory session and students cycle through each experiment station over the term.

New delivery system

- Separated the laboratory component from the lecture course.
- Merged all the sub-disciplines into ONE third year laboratory course – Third Year Integrated Laboratory course.
- Lab course taken by chemistry majors and other general science students – increase in enrolment.
- All instructors work together and present unified orientation, learning goals and grades for the stand-alone lab course.
- Introduced interdisciplinary experiments.

Progression through four years of UBC chemistry labs / themes in each of the four years

Year	1st	2nd	3rd	4th (lab course specifically)
Theme	While becoming familiar with the process of scientific research, become proficient in basic laboratory techniques, safe practices, and record keeping. -------	Building upon the fundamental techniques from 121/123, become proficient in new, discipline-specific methods. ---------- mention something like “in many cases reinforce / gain hands-on experience of the concepts from second-year courses”?	**Expand the student’s knowledge base of instrumentation and techniques; use critical thinking to analyze data, and scientific writing style to present results; start to see the connections between the traditional sub-disciplines of chemical research and scholarship.** ----------	Independently devise a hypothesis; plan and execute an experiment to test the hypothesis, then report the results in a peer-reviewed journal format. ----------

Does this experiment move students toward these ways of expert thinking? Yes (Y), No (N), not applicable (NA)

Experiments

Cognitive tasks		X-1	X-2	X-3	X-5	X-4	X-6	X-7	X-8
Establishing research goal	a	N	N	Y	N	N	N	N	Y
	b	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	N
Defining criteria for suitable evidence	a	Y	Y	Y	N	Y	N	y	N
	b	Y	Y	Y	N	Y	Y	N	N
	c	N	N	N	N	N	N	N	N
Determining feasibility of experiment	a	N	N	N	N	N	N	N	N
	b	N	N	Y	N	N	N	N	N
Experimental design	a	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	N
	d	N	N	N	N	Y	N	N	N
Construction and testing of apparatus	a	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	N
	d	N	N	N	N	N	N	N	N
	e	N	N	NA	N	N	N	N	N
	f	N	N	N	N	N	N	N	N
	g	Y	Y	NA	Y	Y	Y	Y	Y
Analyzing data	a	N	N	Y	Y	Y	y	y	Y
	b	Y	Y	Y	NA	Y	N	N	Y
	c	Y	Y	N	NA	Y	N	N	Y
Evaluating results	a	Y	Y	Y	N	Y	Y	Y	Y
	b	N	N	Y	N	N	N	N	Y
Analyzing implications if novel	a	N	N	N	N	N	y	y	N
Presenting the work	a	Y	Y	N	N	Y	Y	Y	N
	b	Y	Y	Y	N	Y	Y	Y	N

Cognitive tasks		A-3	A-4	A-6	A-8	A-9	A-11	A-12	A-13	A-14	A-16
Establishing research goal	a	N	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	N	N	N
Defining criteria for suitable evidence	a	y	y	y	y	y	y	y	y	y	y
	b	N	N	Y	Y	Y	N	Y	N	Y	N
	c	N	N	N	N	N	N	N	N	N	N
Determining feasibility of experiment	a	N	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N	N
Experimental design	a	N	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	N	N	N
	d	N	N	N	N	N	N	N	N	N	N
Construction and testing of apparatus	a	N	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N	N
	c	N	N	y	y	N	N	N	N	N	N
	d	N	N	N	N	N	N	N	N	N	N
	e	N	N	N	N	N	N	N	N	N	N
	f	N	N	N	N	N	N	N	N	N	N
	g	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Analyzing data	a	y	y	y	y	y	y	y	y	y	y
	b	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	c	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Evaluating results	a	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	b	N	N	N	N	N	N	N	N	N	N
Analyzing implications if novel	a	y	y	y	y	y	y	y	y	y	y
Presenting the work	a	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	b	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Cognitive tasks		I-2	I-3	I-6	I-7	I-10	I-11	I-12	I-13	I-14
Establishing research goal	a	Y	Y	Y	Y	Y	Y	Y	Y	Y
	b	N	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	N	N
Defining criteria for suitable evidence	a	Y	Y	Y	Y	Y	Y	Y	Y	Y
	b	Y	Y	Y	Y	Y	Y	Y	Y	Y
	c	N	N	N	N	N	N	N	N	N
Determining feasibility of experiment	a	N	N	N	N	N	N	N	N	N
	b	Y	Y	Y	Y	Y	Y	Y	Y	Y
Experimental design	a	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	Y	N	N	N
	d	N	N	N	N	N	N	N	N	N
Construction and testing of apparatus	a	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	N	N
	d	N	N	N	N	N	N	N	N	N
	e	NA	NA	NA	NA	NA	NA	NA	NA	NA
	f	N	N	N	N	N	N	N	N	N
	g	NA	NA	NA	NA	NA	NA	NA	NA	NA
Analyzing data	a	Y	Y	Y	Y	Y	Y	Y	Y	Y
	b	Y	Y	Y	Y	Y	Y	Y	Y	Y
	c	N	N	N	N	N	N	N	N	N
Evaluating results	a	Y	Y	Y	Y	Y	Y	Y	Y	Y
	b	Y	Y	Y	Y	Y	Y	Y	Y	Y
Analyzing implications if novel	a	N	N	N	N	N	N	N	N	N
Presenting the work	a	N	N	N	N	N	N	N	N	N
	b	Y	Y	Y	Y	Y	Y	Y	Y	Y

Cognitive tasks		O-1	O-2	O-3	O-4	O-5	O-6	O-7C	O-7D	O-9	O-10A	O-10A	O-11	O-12A	O-12B	O-12C
Establishing research goal	a	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Defining criteria for suitable evidence	a	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
Determining feasibility of experiment	a	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Experimental design	a	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	d	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Construction and testing of apparatus	a	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
	d	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
	e	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
	f	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
	g	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
Analyzing data	a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	b	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	c	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Evaluating results	a	NA	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	b	NA	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
Analyzing implications if novel	a	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N
Presenting the work	a	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	b	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

Cognitive tasks		P-1	P-2	P-4	P-5	P-6	P-7	P-8	P-10	P-12	P-13	P-15	P-16	P-18	P-19
Establishing research goal	a	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Defining criteria for suitable evidence	a	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	b	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	c	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Determining feasibility of experiment	a	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Experimental design	a	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	d	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Construction and testing of apparatus	a	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	b	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	c	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	d	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	e	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	f	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	g	Y	N	Y	Y	N	N	N	N	N	N	N	N	N	N
Analyzing data	a	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N
	b	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	c	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Evaluating results	a	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	b	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Analyzing implications if novel	a	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Presenting the work	a	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	b	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

C. E. Wieman, “Cognitive tasks involved in carrying out experimental research”

Conceptual learning objectives of the “new” course

- Become proficient in a range of modern techniques.
- Develop awareness of the interdependence of the traditional sub-disciplines of chemistry.
- Become comfortable in an interdisciplinary research environment.
- Apply critical thinking in the laboratory.
- Recognize whether results and conclusions "make sense".

Interdisciplinary experiments

- Goals:
  - Develop awareness of the interdependence of the traditional sub-disciplines of chemistry.
  - Give the students a more "research-like" experience while extending their knowledge across sub-disciplines.

- Upper year lab courses:
  - Segregated discipline specific experiments with cook-book recipes and some advanced level analysis.

- New interdisciplinary experiments/ projects
  - Merge two or more disciplines in chemistry under the umbrella of one experiment.

Course management

- Context
  - Need to manage this integrated course with ~300 students, ~60 experiments, 5 lab rooms and 5 instructors.
  - Need rotating, flexible schedules as students need to attempt a minimum number of experiments in each discipline per term.

- Met the challenge by:
  - Flexible daily schedules – rotating through different labs
  - Rotations through different experiment stations in a given lab
  - Designing a scheduling software *in-house*

Assessments

- In-lab MARKS
  - Technique marks
    - Generalized Rubric for TAs for any sub-discipline.
    - Congruent marking throughout the course.
- Out of lab MARKS
  - Traditionally – written reports worth 70-75% marks for a given experiment.
  - Now marks are distributed amongst diversified ways of assessment
    - Pre-labs
    - Report marks
      - Written lab reports – long and short
      - ORAL reports!!!
        - » One-on-one discussion
        - » Report wrapper
    - Final exam marks
      - Mandatory experiments for chemists

Technique Rubric

(Please contact the course development team if you are interested in this item; contact info on final slide.)

Assessments

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Assessment – Oral Reports

- What?
  - One-on-one discussion about the execution and data analysis with the instructor.
- How?
  - Given a week to make an appointment.
  - Given a rough guideline to study
  - Generalized feedback form returned to student with comments to make improvements in the future.
  - Report Wrapper – a chance to reflect on the feedback.
- Goal
  - Facilities oral communication
  - Immediate feedback about experiment related concepts
  - Effective learning experience with shorter time investment

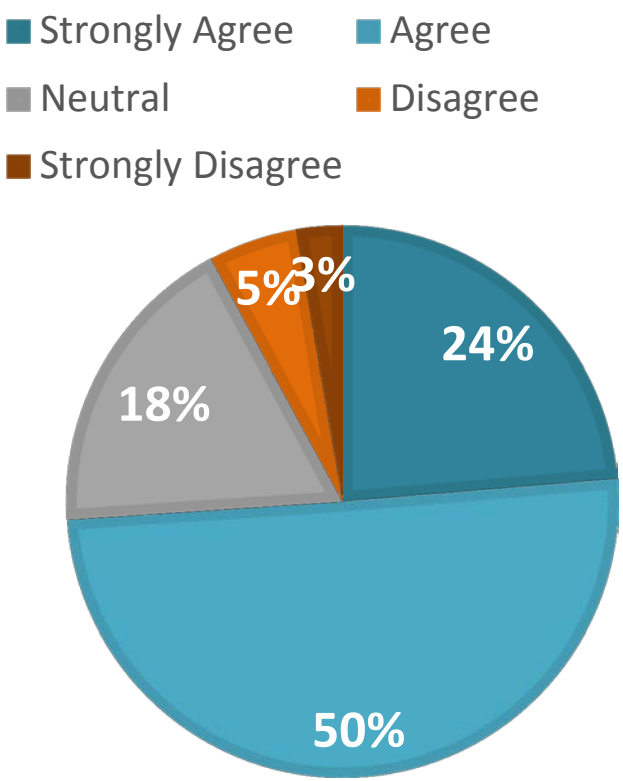
Students' opinion

- *"Had to focus more on the concepts of the experiment as opposed to the analysis of data and "blindly" following a report format to fulfill all the criteria for the creation of a lab report"*
- *"Had to practice talking"*
- *"Ensured that I really understood the concepts of the experiment as I knew I was going to have to explain them under pressure"*

Integrated Course and Interdisciplinary Experiments

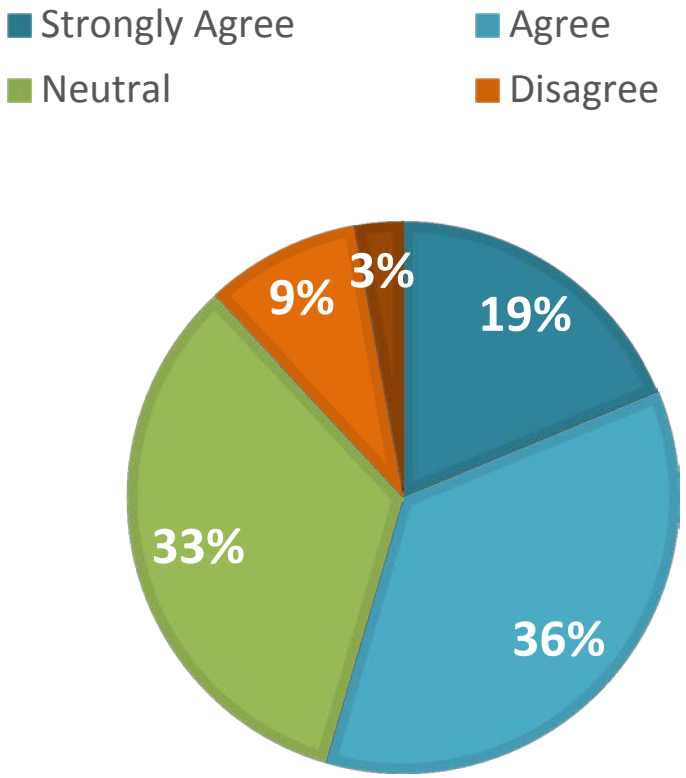
I LIKE THE WAY THAT THE THIRD-YEAR LABORATORY COURSE (CHEM 3XX) OFFERS EXPERIMENTS FROM SEVERAL SUB-DISCIPLINES OF CHEMISTRY WITHIN ONE COURSE, RATHER THAN KEEPING THEM SEPARATE

(STUDENT RESPONSES FROM 2014/2015 – 2015/2016)



I LIKE HAVING THE OPPORTUNITY TO CARRY OUT INTEGRATED EXPERIMENTS (EXPERIMENTS LABELLED STARTING "X-")

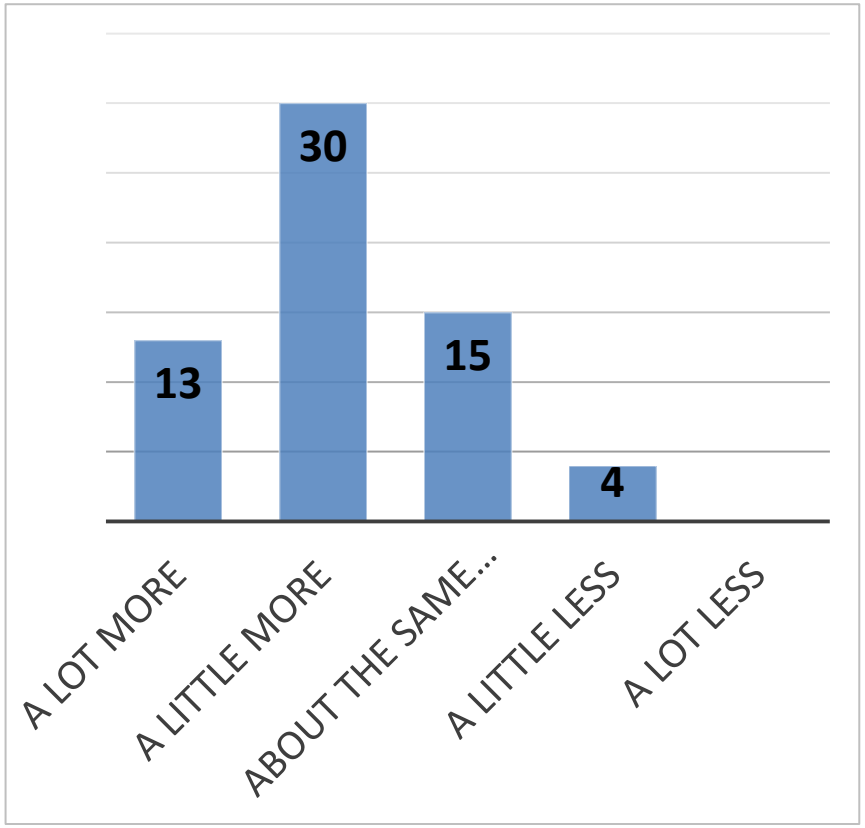
(STUDENT RESPONSES FROM 2014/2015 – 2015/2016), CHEM MAJORS ONLY



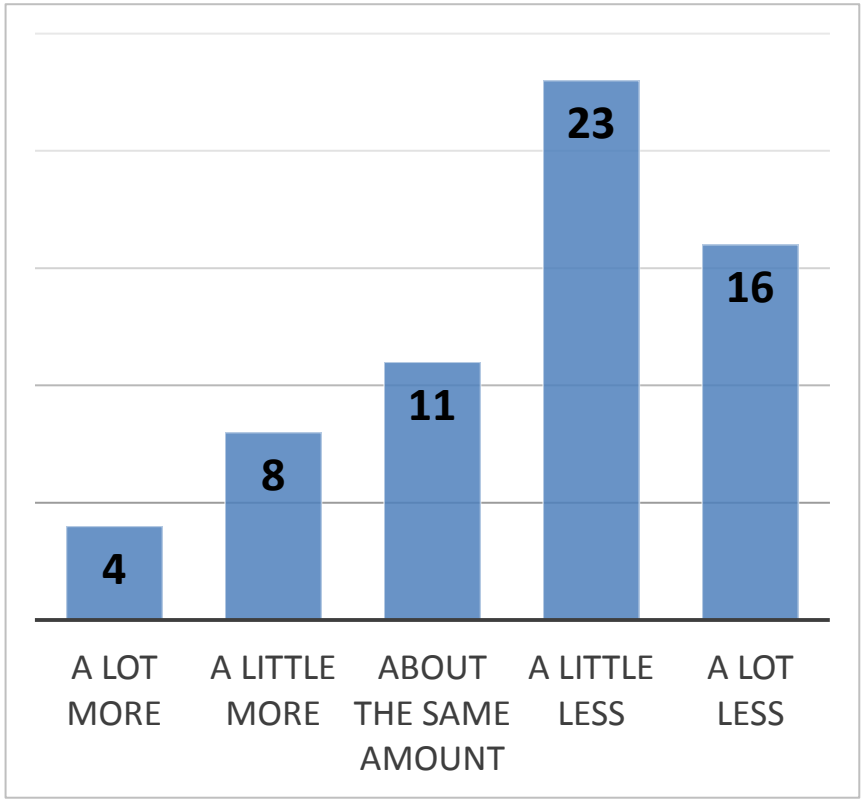
Learning Experience from ORAL Reports

2015/2016 End of Term Student Survey

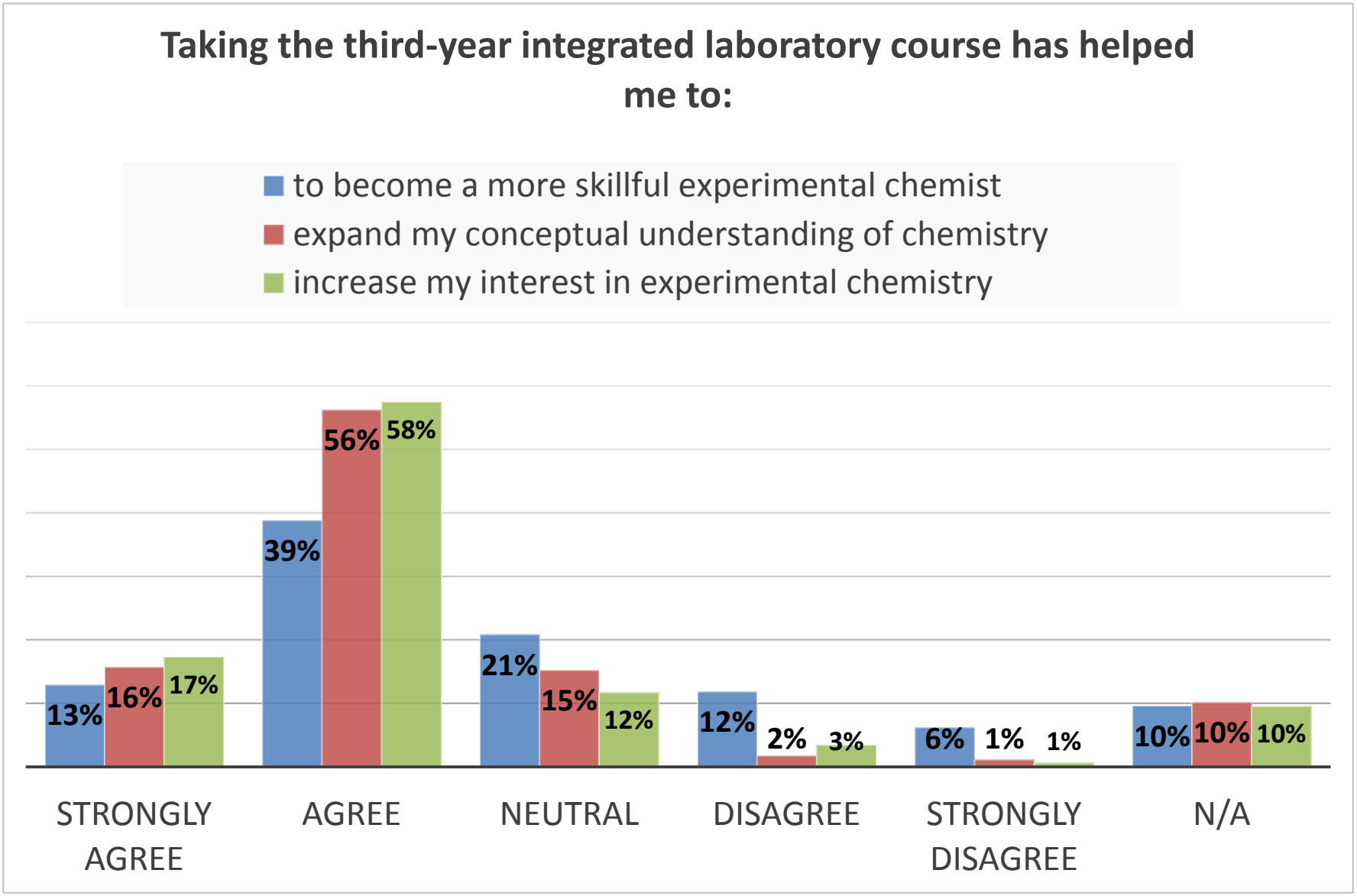
INDICATE WHICH OF THE FOLLOWING OPTIONS BEST DESCRIBES HOW MUCH YOU LEARNED FROM PREPARING FOR AND PARTICIPATING IN AN ORAL LAB. REPORT MEETING.
I LEARNED _____ THAN I WOULD HAVE DONE FROM PREPARING A WRITTEN LAB REPORT



INDICATE WHICH OF THE FOLLOWING OPTIONS BEST DESCRIBES HOW MUCH TIME YOU SPENT PREPARING FOR AN ORAL LAB REPORT MEETING.
I SPENT _____ TIME THAN I WOULD HAVE DONE PREPARING A WRITTEN LAB REPORT



2012/2013 Student Survey



Real world skills

- Think outside the box
  - Extending students' thought process so that they can think about an experiment beyond the details provided in a lab manual.
- Thinking independently in a collaborative setting
  - As employees, the students will end up working in diverse environments and it will be beneficial if they have been exposed to some real world scenarios.
- Problem-solving/ trouble-shooting skills
- Critical thinking

Ongoing efforts…

- Detailed pre-labs – online and in the lab
- Preparing background concept based documents
- Analyzing final exam results
- Designing a multi-week interdisciplinary experiment involving all four sub-disciplines
- Further enhancing inquiry based learning

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