Assessing Student Learning in Chemical Engineering Laboratory Courses: A Multi-Dimensional Approach

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Motivation

- Rose-Hulman Capstone Laboratory Sequence:
  - CHE411: Chemical Engineering Laboratory I (Spring Y3)
  - CHE412: Chemical Engineering Laboratory II (Fall Y4)
  - CHE413: Chemical Engineering Laboratory III (Winter Y4)
- Lab curriculum revisions are planned to streamline content and improve student learning and engagement in laboratory
- Desire a means to measure how students' **technical skills**, **writing skills**, and **general interest and engagement** change as a result of the proposed laboratory changes

Multi-dimensional Approach

- Areas of assessment throughout the 3-course sequence before making changes to the course structure
  - **Student Knowledge** before and after each laboratory course
  - **Student Skills** before and after each laboratory course
  - **Student Attitudes** in the laboratory
- Use of both self-assessment and direct assessment tools

Assessment Method	Type of Assessment	Outcomes of Assessment	Validated Instruments
Student Self-Assessment	Self-Assessment	Self-reported knowledge, skills, attitudes	URSSA [1] MUSIC [2]
Laboratory Skills Test	Direct Assessment	Student laboratory knowledge and skills	n/a
Writing Assessment	Direct Assessment	Written communication skills	VALUE Rubric [3]

1) Student Self-Assessment

Purpose: To gauge student attitudes about their own knowledge and abilities that pertain to the laboratory, as well as gauge student attitudes about the course.

Method: The Student Self-Assessment is comprised of two validated assessment instruments:

- **Undergraduate Research Student Self-Assessment (URSSA) [1]**
  - Designed for students to self-assess their confidence and abilities in a laboratory research setting
  - Some questions added to improve relevance to laboratory class
- **MUSIC Model of Motivation [2]**
  - Designed to assess student motivation and engagement in a course

Evaluation administered in-class via Moodle pre- and post-Lab II.

Sample Questions: From modified URSSA

Presently I can...

	not applicable	not at all	just a little	somewhat	a lot	a great deal
write technical reports or papers that I am comfortable giving to my employer.	○	○	○	○	○	○
make effective oral presentations.	○	○	○	○	○	○
defend an argument when asked questions.	○	○	○	○	○	○
explain engineering concepts to non-engineers.	○	○	○	○	○	○
prepare a scientific poster.	○	○	○	○	○	○
keep a detailed lab notebook.	○	○	○	○	○	○
conduct observations in the lab or field.	○	○	○	○	○	○

Preliminary Results: Results shown are pre- and post-Laboratory II course

	PRE		POST			
	M	*SD*	*M*	*SD*	*Sig*	*D*
Formulate an experimental objective that can be answered with data.	3.70	0.64	4.33	0.54	***	1.06
Figure out the next step in a lab experiment.	3.52	0.64	4.11	0.59	***	0.96
Identify limitations of experimental methods and designs.	3.47	0.66	4.03	0.70	***	0.82
Explain the chemical engineering principles within a lab project.	3.67	0.75	4.21	0.67	***	0.76
Relate experimental data to theoretical phenomena.	3.70	0.74	4.08	0.62	***	0.56

Subset of results from URSSA survey reporting student self-assessment of knowledge and skills related to their laboratory experience. Mean (*M*), standard deviation (*SD*), *p*-value, and effect size (*D*) are given. *N*=66. This subset includes most significant shifts observed.

*Students experienced greatest shift in **how to formulate an experimental objective**, and **how to figure out the next step**.*

	PRE		POST			
	M	*SD*	*M*	*SD*	*Sig*	*D*
EMpowerment	4.34	0.88	4.58	1.05	*	0.3
Usefulness	4.80	0.81	4.68	1.03		-0.1
Success	4.99	0.62	4.79	0.73		-0.3
Interest	4.28	0.80	4.38	1.02		0.1

Results of MUSIC Inventory reporting self-assessment of student attitudes related to their laboratory experience. Mean (*M*), standard deviation (*SD*), *p*-value, and effect size (*D*) are given. *N*=66.

*Students experienced greatest shift in sense of **empowerment**.*

2) Laboratory Skills Test

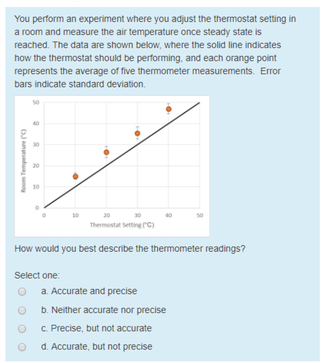
Purpose: To gauge student understanding of laboratory concepts and skills

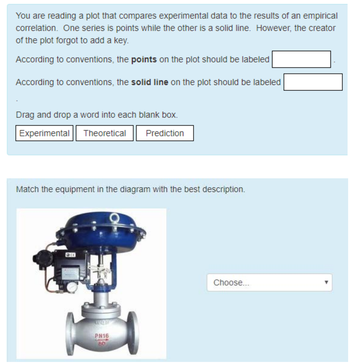
Method: The Laboratory Skills Test was developed by preparing multiple-choice and short-answer questions related to the following topics, which were generated by Rose-Hulman Chemical Engineering faculty:

Laboratory Safety	Data Acquisition	Data Analysis
Connecting Theory & Experiment	Troubleshooting Equipment & Data	Knowledge of Equipment
Team Management	Application of Concepts	Communication

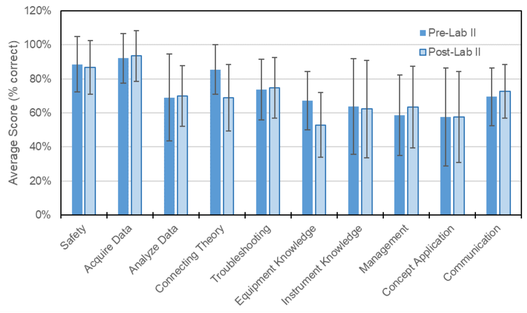
Test administered in-class via Moodle pre- and post-Lab II. Test participation was required, but not counted as a grade item.

Sample Questions:





Preliminary Results:



Average student score for each category of the Skills Test administered before and after the Lab II course. Error bars represent standard deviation of 66 scores (pre-test) and 65 scores (post-test).

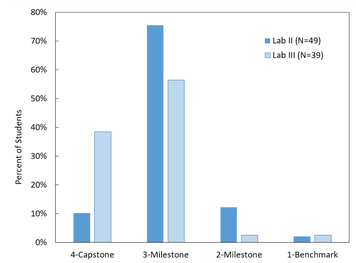
*Observed drops in average scores may be attributed **to inequivalent question format and complexity.***

3) Writing Assessment

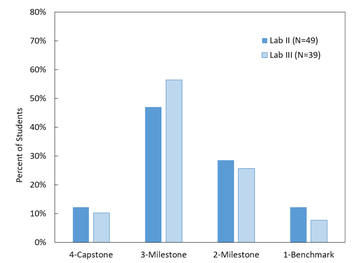
Purpose: To gauge student written communication skills in the context of technical laboratory reports.

Method: The **Written Communication VALUE Rubric [3]** assessed the context, content development, conventions, sources, and writing mechanics of the first draft of student laboratory reports in Lab II and Lab III. Assessment was completed by four non-ChemE Rose-Hulman faculty with periodic checks for inter-rater reliability as part of RosEvaluation.

Preliminary Results:



Content Development



Control of Syntax & Mechanics

Subset of results showing the distribution of evaluator rankings using the Written Communication VALUE Rubric for two of the five categories. A ranking of 4 represents the highest ("Capstone") skill level.

*On average, **moderate positive shifts in written communication skills** were observed for **Content Development** and **Control of Syntax & Mechanics**.*

Future Work

- Deeper analysis of Student Self-Assessment and qualitative responses on Skills Test
- Improvement and validation of Laboratory Skills Test
- Identifying future uses for instruments
- Assessment during AY 2018-2019 as laboratory changes are made

References & Acknowledgements

[1] A.B. Hunter, T.J. Weston, S.L. Laursen, and H. Thiry, "URSSA: Evaluating Student Gains from Undergraduate Research in the Sciences," *Council on Undergraduate Research,* vol. 29, no. 3, 2009, pp. 15-19.
[2] B.D. Jones, "Motivating Students to Engage in Learning: The MUSIC Model of Academic Motivation," *International Journal of Teaching and Learning in Higher Education*, vol. 21, 2009, pp. 272–285.
[3] T. Rhodes, "Assessing Outcomes and Improving Achievement: Tips and Tools for Using the Rubrics." *Association of American Colleges and Universities*, 2009.

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