Assessment of Learning in a Liquid-liquid Extraction Experiment and Technical Skill in an Undergraduate Chemistry Laboratory

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Introduction

- Student achievement of Learning goals in a 1st year extraction experiment
- Questions underwent expert and student validation to improve effectiveness and clarity
- Questions pertained to liquid-liquid extraction and melting point analysis
- Pre-quiz 2-5 weeks prior and post-quiz 2 weeks after experiment
  - Normalized learning changes calculated from matched pre-/post-quiz scores

Methodology

Expert validation	• Maintain consensus, confirm correct answers • Input analyzed and presented to Research Team
Instrument revision	• Questions revised and/or developed from prioritized learning goals and expert validation • Split between two versions of quiz
Student validation	• "Think-aloud"[1] interviews improved clarity, functionality and interpretation of questions
Quiz administration	• All students wrote same version of pre/post quiz • Comparison groups: (1) only post-quiz given to assess "pre-test effect", (2) pre/post-quiz written before lab to determine if changes due to actual lab
Lab observations	• Examination of Learning goals that could not be assessed in written format (86% reliability)
Data analysis	• Processing and scoring of quizzes, exclusion of invalid data, single factor ANOVA, (paired) t-test, repeated measures Cohen's d[2], normalized learning change[3]
Technical skill assessment	• Alignment of technical skill expectations between upper-level Chemistry laboratory courses

Participant Demographics and Responses:

Students (1600 total)	1st- year	Female	Male	Canadian Citizen	English as a 1st Language
All of CHEM123	96%	58%	42%	82%	48%
Group 1	96%	61%	39%	83%	50%
Group 2	94%	56%	44%	81%	55%

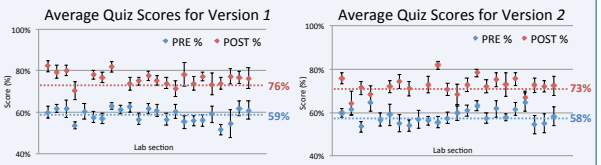
- All data demographically representative of associated lab section

Of the 1207 students assigned to Groups 1 and 2 and comparison groups:

- 938 pre-quizzes and 1122 post-quizzes were completed

✓ 494 valid pre- and post-quiz scores used in analyzing learning gains

Results



A. No significant differences between lab sections of individual weeks, and
B. No significant difference the normal pre-/post-quiz groups, permitting data to be combined

Comparison group (1)

- ANOVA found **no** significant difference ($p > 0.05$) in post-quiz versus those that also did the pre-test, 74.09 ± 2.05% for Version *1*, 72.85 ± 1.79% for Version *2*

★ Prior exposure to questions did not influence post-test scores, so existence of "pre-test effect" not supported

Comparison group (2)

- Paired t-tests found **no** significant difference ($p > 0.05$) in pre-/post-tests scores *before* completing the experiment, 0.006 ± 0.039 for Version *1* and 0.043 ± 0.035 for Version *2*

★ Calculated normalized learning changes are attributed to student performance on the Experiment

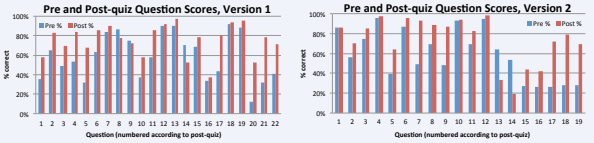
Normalized learning gains

└ a value of +1.0 indicates 100% gain in learning while -1 represents 100% loss in learning ┘

Version *1*	Version *2*
0.412 ± 0.018	**0.345 ± 0.018**

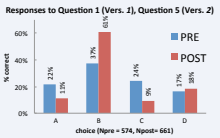
- Learning gains observed in all 40 normal lab sections
- All lab sections experienced large significant improvements to pre-/post-quiz scores ($d > 0.8$ for all groups)

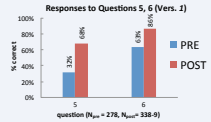
Question Analysis:



*Caffeine is soluble in water (cola) and is **more** soluble in dichloromethane (CH_2Cl_2), an organic solvent. When the water is 'extracted' with CH_2Cl_2, the caffeine moves from the water into CH_2Cl_2, based on solubility. If the extraction technique was performed according to the lab manual, how often can **100%** of the caffeine move **from** the cola **to** CH_2Cl_2?*

a. Always ***b. Never*** *c. Sometimes* *d. Rarely*





A student proposed the following reasons for getting less caffeine from cola X than other students. Which of the following are possible explanations?

*5. T **F** Some of the **cola** layer was spilled after the extraction was completed.*

*6. **T** F Some of the **dichloromethane** layer was spilled after the extraction was completed.*

- Grasp of extraction "effectiveness" improved
- Improved understanding of factors that affect yield, changing "water" to "cola" (Q5) gave pre-test results of 32%, compared to 62% last year

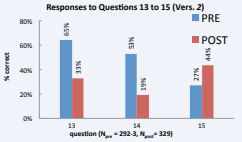
Results

*Which of the following are **generally** true of the layer positions in a liquid-liquid extraction?*

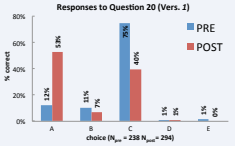
*13. T **F** The water layer is the top layer.*

*14. T **F** The organic liquid is the bottom layer.*

*15. T **F** The liquid that contains more dissolved solids will be the bottom layer.*



- Incorrect responses likely from in-lab experience
- Student realization of density and layer positioning noted (Q12, Vers. *2*)



20 (v.1). Which best describes the change in a sample's melting point when it has impurities?

a. The sample's melting point decreases.

b. The sample's melting point increases.

c. Depending on the impurity, the sample's melting point can increase or decrease.

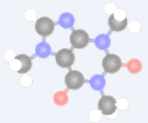
d. The sample's melting point stays the same.

e. The sample's melting point cannot be determined.

- Incorrect association with solution chemistry during validation interviews
- Substantial change during post-test, but choice (c) still prominent

Conclusions

- Third round of question refinement, better optimized to target learning goals of the experiment
- Learning changes were noted in all sections, 41% and 35% of total possible learning on average
- Comparison groups showed no "pre-test effect" evidence and that learning attributed to experimental lab work



Future Work

- Reduce the amount of excluded pre-test data
- Compare results of each question by year
- Cross-reference responses to determine individual learning gains (or losses) by topic
- More in-depth analysis of student demographics needed

References

(1) Leighton, J., In *How to Build a Cognitive Model for Educational Assessments*, Proceedings of the National Council on Measurement in Education (NCME), San Diego, California, April 14-16, 2009.

(2) Advanced ANOVA, Power & Effect Sizes. Effect Sizes (Cohen's d): Repeated measures. http://wilderdom.com/courses/surveyresearch/tutorials/5/ (accessed April 7, 2011).

(3) Marx, J.D., Cummings, K., *Am. J. Phys.* **2007**, *75*, 87-91.

Acknowledgments

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