Evaluation of Students' Realization of Laboratory Learning Goals Associated with an Acid/Base Buffer Experiment in a Large, Introductory Undergraduate Lab

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Introduction

• This study assesses students' achievement of learning gains & laboratory learning goals (LGs) related to an acid/base buffer experiment in a large (>1,600 students) introductory chemistry course (CHEM 123 at UBC).

• Concern from the Chemistry Faculty over UBC Chemistry students' lab skills development prompted this initiative. The Chemistry Department initiated research, with support from the Carl Wieman Science Education Initiative (CWSEI), to review the chemistry lab program by gauging students' learning gains.

• Multiple-choice/true-false questions were developed to measure students' achievement of laboratory LGs through learning gains before and after their experiment was complete.[1]

Research Design

Assessment LG achievement

An iterative cycle of assessment was used to develop and refine questions to ensure students appropriately understood the meaning of the questions, while making sure that the question still reflected the intended LGs.[2]

• Written Assessment Instruments (i.e. Quizzes)
• Student (Think-Aloud) Validation Interviews
• In-Lab Observations

Quiz Administration and Processing

• PRE quiz: students randomly received either Quiz Version 1 or Quiz Version 2.

• POST quiz: ~1/2 of the students received the same quiz version as in PRE testing, while the others received the opposite quiz version.

• This is to examine whether students will score differently on the POST quiz when they had a different starting point (i.e. different PRE quizzes): the presence of a pre-test effect will be assessed.

Sample Size & Student Demographics

	Sample Size	Response rate	in 1st-Year	Male	Female	Canadian citizen	English is 1st Language
CHEM 123	1692	91.19%	90.54%	41.04%	59.02%	78.18%	44.65%
Group 2	460	91.30%	91.67%	37.39%	62.61%	79.57%	52.66%
Group 3	678	91.15%	92.40%	41.59%	58.41%	74.60%	37.60%

From 1138 students assigned to Groups 2 and 3 in the CHEM 123 lab,

• 1060 responses were collected for the PRE quiz

• 1035 responses were collected for the POST quiz

• 779 valid responses remained and were analyzed for learning gains

Learning gain scores were calculated by a formula that normalized gain scores.[3] Standard error was used to estimate the error associated with calculating average gain scores.

Acknowledgements

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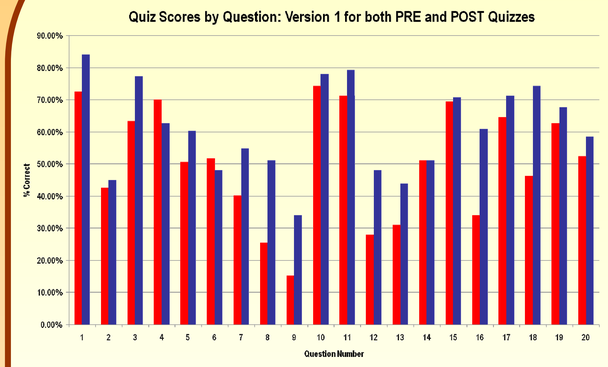
References

1. Rice University - Interdisciplinary Web-Based Teaching Laboratory Materials, http://www.owlnet.rice.edu/~labgroup/assessment/lab_objectives.html (accessed April 20, 2010).
2. Towns, M. H. *Journal of Chemistry Education.* **2010**, *87*, 91-96.
3. Marx, J. D.; Cummings, K. *American Journal of Physics.* **2007**, *75*, 87-91.

Results: Version 1 Quiz Scores



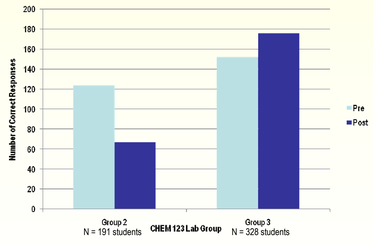
Given the values below:	
Name:	K_a
H_3PO_4(aq)	6.3×10^{-3}
$H_2PO_4^-$(aq)	6.3×10^{-8}
HPO_4^{2-}(aq)	5×10^{-13}

Which of the following is a weak acid?

2. *T* F H_3PO_4(aq)
3. *T* F $H_2PO_4^-$(aq)
4. *T* F HPO_4^{2-}(aq)

Which of the following is a weak base?

5. T *F* H_3PO_4(aq)
6. *T* F $H_2PO_4^-$(aq)
7. *T* F HPO_4^{2-}(aq)

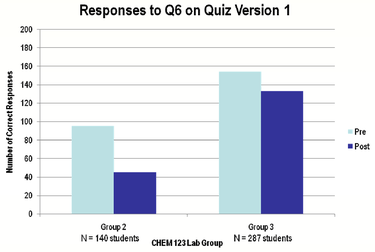


Question 4, Quiz Vers. 1:

• Answer = True, HPO_4^{2-} is a weak acid.

• Group 3 experienced a learning gain while Group 2 did not, resulting in an overall learning "loss."

• Validation interviews provided no explanations towards possible reasons for learning loss.



Question 6, Quiz Vers. 1:

• Answer = True, $H_2PO_4^-$(aq) is a weak base.

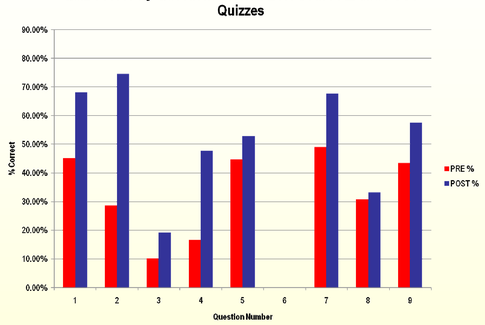
• 1 out of 7 interviewees answered correctly.

• One student explanation involved calculating K_b for $H_2PO_4^-$ using K_w (ionization constant of water) and K_a of the **same compound** (instead of the K_a of H_3PO_4).

• Misconceptions about K_a and K_b could be related to the observed learning loss.

→ Further examination of students' understanding is needed

Results: Version 2 Quiz Scores



Question 3, Quiz Vers. 2:

Answer = "D"; majority of students' answers answered "A"

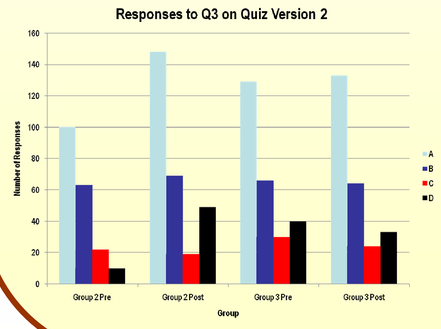
3. When preparing your buffer solutions, what type of glassware will you use?

a. Volumetric glassware, because you need to know your volumes exactly in order to measure pH.

b. Volumetric glassware, because you need to know your volumes exactly in order to calculate the volume of each drop.

c. Non-volumetric glassware because the pH measurements are only approximate.

d. Non-volumetric glassware, because the volumes are only approximate.



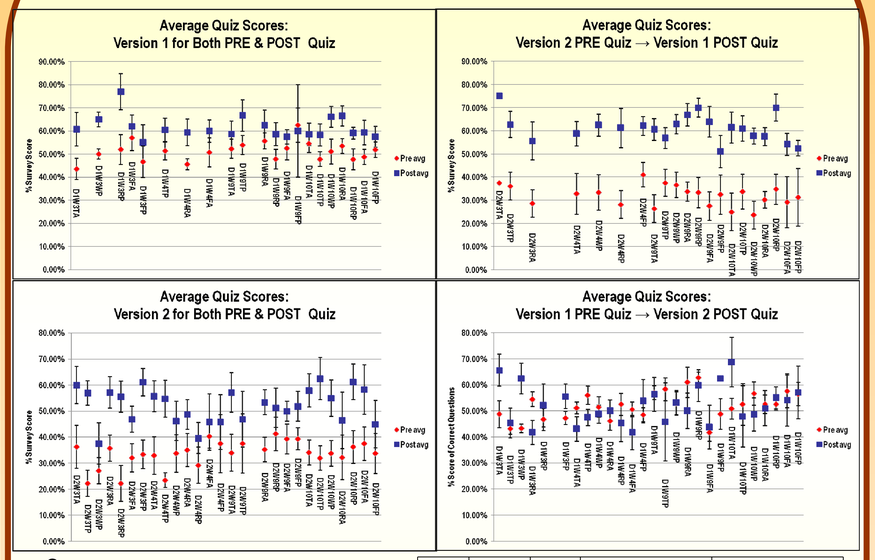
• While volumetric glassware is not necessary to prepare buffer solutions, students use volumetric glassware to dilute the buffer. The purpose is to provide additional practice with volumetric glassware.

• This could be linked to students choosing option "A", and could suggest that students are not critically thinking about the experimental procedure.

• In student validation interviews, 5 out of 7 chose "A".

• Three interviewees had already prepped for this lab but only one recognized that non-volumetric glassware is appropriate.

Results: Pre-test effect



Summary:

PRE/POST Quiz	# of Lab Sections	Avg. Gain Score
Version 1	21	0.2092 ± 0.0229
Version 2	27	0.2316 ± 0.0267

PRE	POST	N	PRE Average	POST Average
1	1	164	(50.91 ± 0.94) %	(61.13 ± 1.16) %
2	1	161	(32.14 ± 1.46) %	(61.06 ± 1.16) %
2	2	235	(33.51 ± 1.21) %	(52.55 ± 1.37) %
1	2	219	(51.83 ± 0.77) %	(51.94 ± 1.28) %

• Student scores appear unaffected by which version of the PRE quiz taken as the POST scores were almost identical, suggesting no pre-test effect in this study.

Conclusion

- The absence of a pre-test effect was confirmed through comparing quiz scores from students who completed the same and different versions of the PRE/POST-experimental quizzes
- Most of the questions from both quiz version 1 and version 2 experienced learning gains regardless of which lab group a student was assigned.
- Most lab sections experienced learning gains with gain scores of 0.2092 and 0.2315 for quiz versions 1 and 2 respectively.

Future Work

- Further analysis of the students' responses will involve cross-referencing the individual answers of each student on both their pre- and post- experiment quizzes
- Comparison of comments from Expert validation interviews (quizzes done by faculty) versus Student validation interviews to see if the interpretation of questions are the same compared to the researchers and to the students.