RYERSON UNIVERSITY

Evaluating Teaching: Re-visiting the Use of Chemistry Concept Inventories

Noel George, Andrew McWilliams, and Kinjal Naik
Ryerson University, Toronto, Ontario

Expanding the Learning Experience

As educators we are constantly searching for new ways to engage students and provide new learning opportunities.

Some examples of the approaches employed in first year chemistry courses at Ryerson have included:
- Blended Learning Tools (i.e. Solved Problems)
- Concept Mapping
- In-Class Exercises/ Clickers
- Podcasts
- Demonstration Videos
- Online Homework Platforms

How Do We Know They Work?

How do we evaluate our approaches?
- Examine grades/retention rates
- Conduct surveys/collect qualitative data
- Anecdotal Information/gut feelings

Problems with the above?

There is a need:
- To take a more quantitative/scientific approach to our education research.
- For valid and reliable instruments to assess learning gains.
- For 'standardized' instruments for cross-institution comparisons.

Example Instruments

- Force Concept Inventory[1] & Chemistry Concept Inventory [2]
  - Compare the effectiveness of new teaching methods vs. traditional methods

- Potential Advantages:
  1) Identifies the students' strengths/weaknesses
  2) Gives feedback on level of student preparation to both the instructors and students
  3) Quantifies the normalized gain in performance for the class and the individual students
  4) Evaluates the level knowledge gained during a course compared to knowledge retained from previous classes

1. D. Hestenes et al. *The Physics Teacher*, 30(3): 141-158,(1992).
2. Krause at al. 34th ASEE/IEEE, 2004.

Developing a new CCI

Goal:
- Develop a Chemical Concept Inventory that is appropriate for Ryerson and for Ontario Universities (and then other Canadian Universities).

Key Issues:
- Topics should be selected from within the defined curriculum of the Grade 12U classes in Ontario
- Topics must also be covered in first year chemistry classes
- Questions should test knowledge level against commonly held misconceptions
- Multiple questions should evaluate each topic to check for consistency (preferably at different levels of difficulty)

Initial Investigations at Ryerson

Topics	Sub-Categories
Thermochemistry	Heat
(6 questions)	Thermal Conductivity
	Thermal Equilibrium
Equilibrium	Equilibrium Rate
(8 questions)	Equilibrium-Dynamic vs. Static
	Le Chatelier's Principle
Acids and Bases	Equilibrium Constant
(6 questions)	Acid/Base Neutralization
	Acid Strength
	pH

- 20 Multiple Choice Questions

- First year CHY103/CHY113 students

- Two parts
  - Pre-test
  - Post-test

Assessing the Concept Inventory

- Test Validity
- Test Reliability
  - Kuder-Richardson 20 (KR-20)

$$KR - 20 = \left(\frac{k}{k-1} \right) \left(1 - \frac{\sum s_i^2}{s_{total}^2} \right)$$

- Item Acceptability
  - Pass/fail rate
  - Effectiveness of distractors
  - Discrimination Index (item test correlation)

$$r_{it} = \frac{M_c - M_w}{SDt} SDi$$

Test Statistics

	Mean (/20)	Standard Deviation	Kuder-Richardson 20	Number of students
Pre-Test	7.987	2.854	0.496	153
Post-Test	10.590	3.203	0.621	153

Example 1

Q 9. If a reaction has an equilibrium constant that is significantly large (K_C >>1), which of the following statements can be made about the reaction?
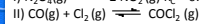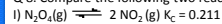
A) The reaction will favor formation of reactants.

B) The reaction will favor formation of products.

C) The reaction will proceed quickly.

D) The reaction will proceed slowly.

E) Both the rate of reaction and extent of reaction can be determined from K_C.

Relative Frequency Data for Question 9
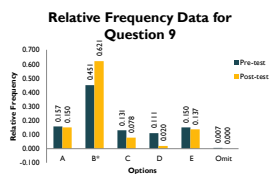
Question 9 Correct Answer: B	Pre-Test	Post-Test
p-value	0.451	0.621
q-value	0.556	0.386
(pq) = s²	0.251	0.239
Discrimination Index	0.257	0.146

Example 2

Q 8. Compare the following two reactions:
I) $N_2O_4(g) \rightleftharpoons 2 NO_2(g)$ K_C = 0.211
II) $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$
K_C = 4.57 x 10⁹

Which of the following statements is correct?

A) Reaction I will proceed faster because K_C is larger.

B) Reaction II will proceed faster because K_C is larger.

C) Reaction I favours the production of products.

D) Reaction II favours the production of products.

E) None of these statements is correct.

Relative Frequency Data for Question 8
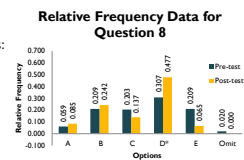
Question 8 Correct Answer: D	Pre-Test	Post-Test
p-value	0.307	0.477
q-value	0.699	0.529
(pq) = s²	0.215	0.253
Discrimination Index	0.360	0.431

Example 3

Q4. A metal ice tray and a plastic ice tray are filled with water and placed in a freezer. Which ice tray will freeze first?

A) They will freeze at the same time because they are in the same freezer at the same temperature.

B) The plastic tray because it has a higher specific heat and attracts heat away from the water.

C) The plastic tray because it insulates the cold into the water.

D) The metal tray because it conducts cold quickly into the water.

**E) The metal tray because it conducts heat quickly away from the water.**

Relative Frequency Data for Question 4
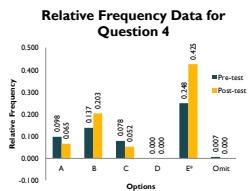
Question 4 Correct Answer: E	Pre-Test	Post-Test
p-value	0.248	0.425
q-value	0.758	0.582
(pq) = s²	0.188	0.204
Discrimination Index	0.326	0.385

Example 4

Q5. In a classroom there are metal chairs and plastic chairs. Students say that the metal chairs feel colder than the plastic ones. Why?

A) Metal naturally has less heat than plastic.

B) Metal quickly conducts cold to your hand.

C) Metal quickly conducts heat away from your hand.

D) Metal attracts and holds cold.

E) Plastic is an insulator and attracts and holds heat.


Relative Frequency Data for Question 5
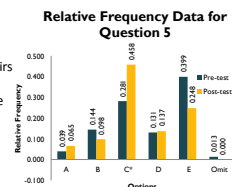
Question 5 Correct Answer: C	Pre-Test	Post-Test
p-value	0.281	0.458
q-value	0.725	0.549
(pq) = s²	0.204	0.251
Discrimination Index	0.461	0.542

Example 5

Q10. Once a system reaches equilibrium:

A) The forward and reverse reactions no longer occur.

B) The forward and reverse reactions continue to occur and alter the concentrations of reactants and products.

C) The forward and reverse reactions occur, but do not alter the concentrations of the reactants or products.

D) Only the forward reaction continues to occur.

E) Only the reverse reaction continues to occur.

Relative Frequency Data for Question 10
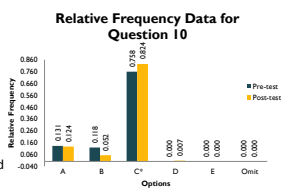
Question 10 Correct Answer: C	Pre-Test	Post-Test
p-value	0.758	0.824
q-value	0.248	0.183
(pq) = s²	0.188	0.151
Discrimination Index	0.326	0.293

Normalized Gain

$$g = \frac{(\text{Post} - \text{test Average Score}) - (\text{Pre} - \text{test Average Score})}{20 - (\text{Pre} - \text{test Average Score})}$$
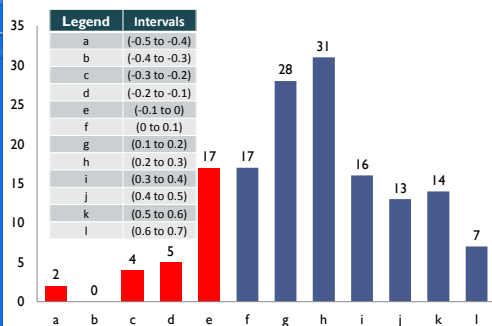
$$g = \frac{(10.590 - 7.987)}{20 - 7.987}$$

$$g = \frac{2.603}{12.013}$$

$$g = 0.217$$

Krause et al. 34th ASEE/IEEE, 2004.

Average Normalized Gain for Students

Legend	Intervals
a	(-0.5 to -0.4)
b	(-0.4 to -0.3)
c	(-0.3 to -0.2)
d	(-0.2 to -0.1)
e	(-0.1 to 0)
f	(0 to 0.1)
g	(0.1 to 0.2)
h	(0.2 to 0.3)
i	(0.3 to 0.4)
j	(0.4 to 0.5)
k	(0.5 to 0.6)
l	(0.6 to 0.7)

Concluding Remarks

- Our results were similar, but not quite as good as the CCI used by Krause et al.
- Used properly, a Chemistry Concept Inventory can be used as an effective tool in evaluating teaching methods/approaches
- CCI's can also provide insight to students regarding their strengths and weaknesses
- For best results, item analysis must be done and questions iteratively refined.

Next Steps?

Acknowledgements

Collaborators:
- Dr. Andrew McWilliams

RYERSON UNIVERSITY

Students:
- Kinjal Naik
- Natalia Mnich

Intrigued?

If you are interested in participating in the development of a Chemistry Concept Inventory designed for Ontario Universities (and other Canadian Institutions), please contact Dr. Noel George (n3george@ryerson.ca) or Dr. Andrew McWilliams (amcwilli@ryerson.ca) for more information