Development of a Concept Inventory for
Measuring Learning Gains in Analytical Chemistry

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[Context] Analytical Chemistry at UBC

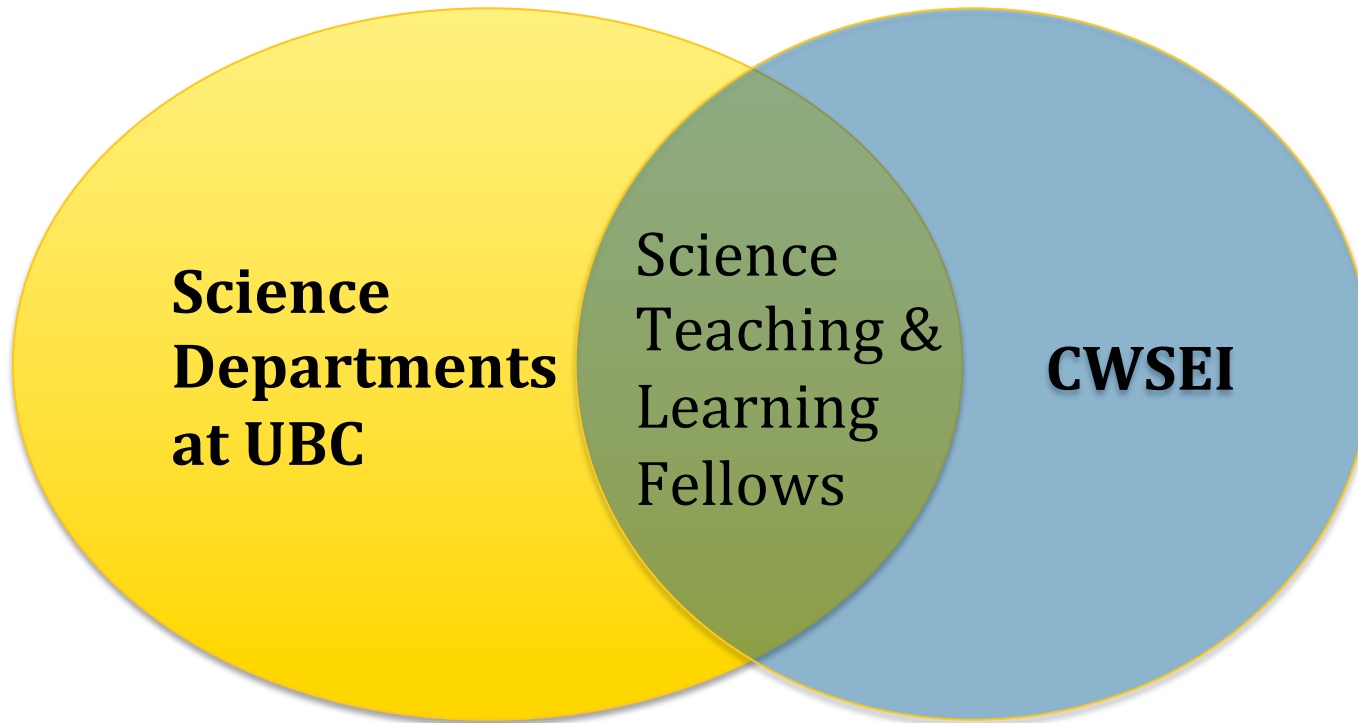| Introduction to Chemical Analysis (CHEM 211)	Instrumental Analytical Chemistry (CHEM 311)

Analytical Concepts
 	
Basic Statistics
 	
Complex Equilibria
  Acid/base, Solubility, Complexation
 	
UV/visible Spectrophotometry
 	
Fundamentals of Potentiometry
 	
Introduction to Chromatography
	Data Domains & Transfer of Information
	
	Molecular Spectroscopy
	  UV/vis, Luminescence, IR, Raman
	
	Atomic spectroscopy
	
	Mass Spectrometry
	
	Electrochemistry
	
	Analytical Separations

LAB	
Offered in fall and winter terms	Offered in winter term only

CWSEI at UBC

Carl Wieman Science Education Initiative (CWSEI)

http://www.cwsei.ubc.ca/

CWSEI at UBC

Carl Wieman Science Education Initiative (CWSEI)

What **should** students learn?

What **instructional approaches** help students learn?

What **are** students learning?
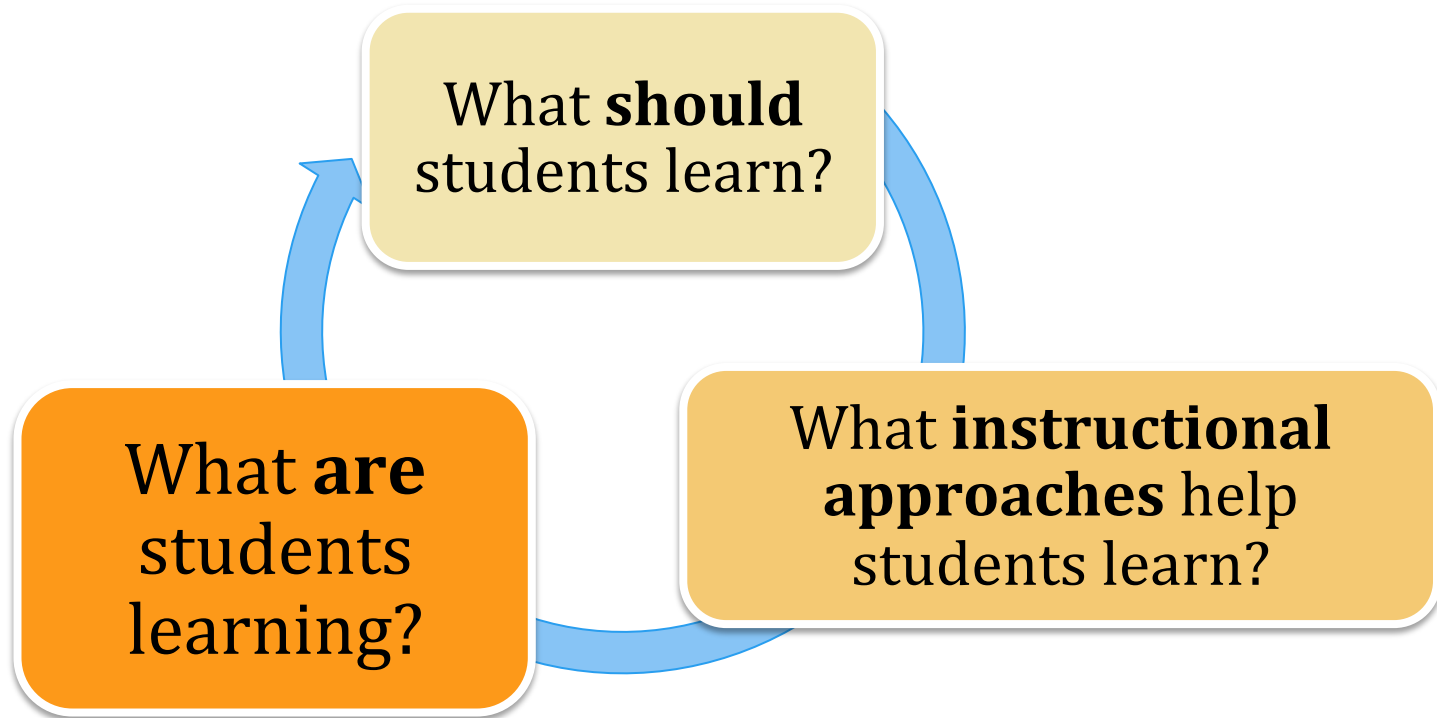
Why use a Concept Inventory?

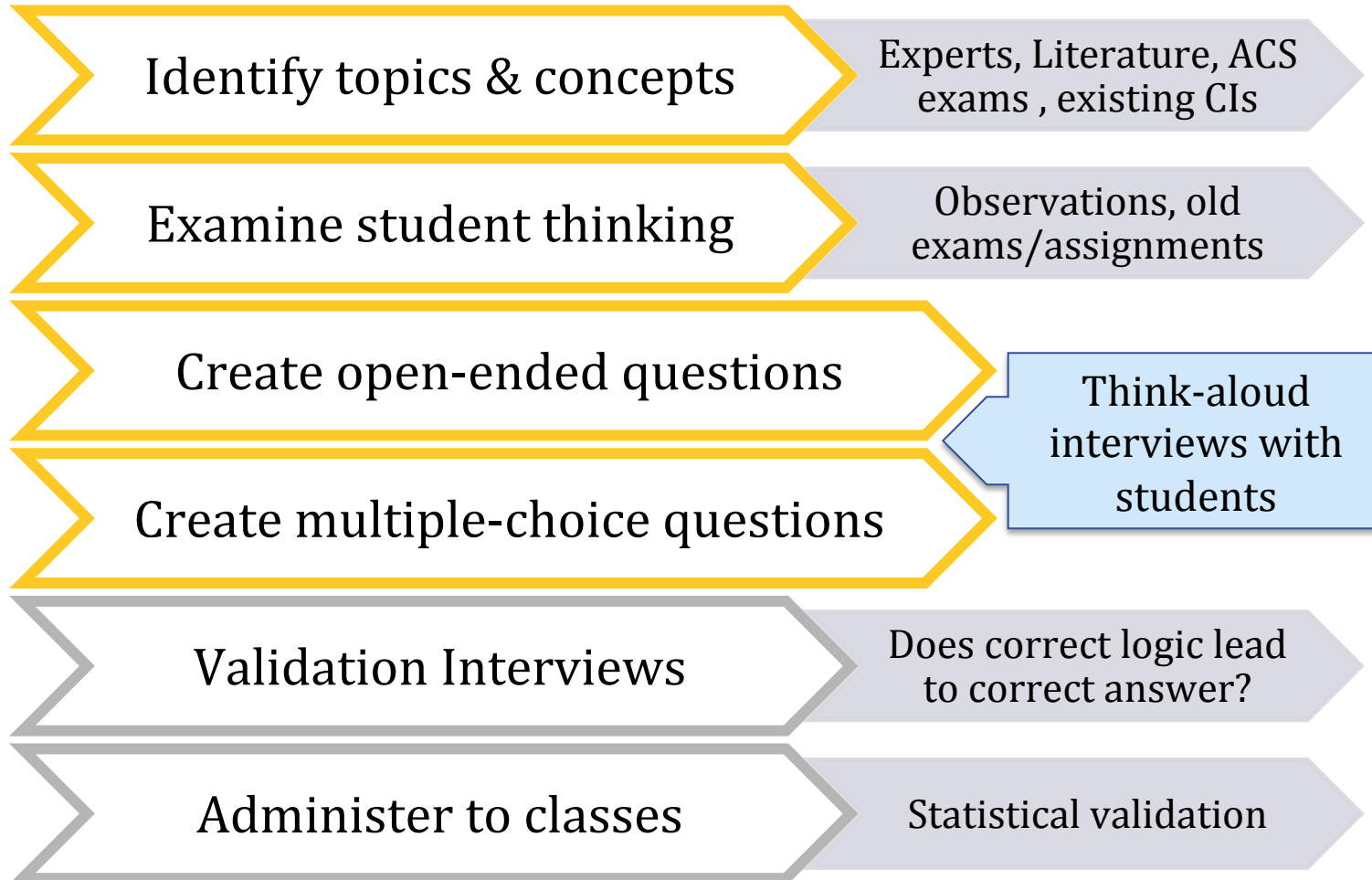|	Course Exam *vs.*	Concept Inventory
Evaluation of:	Students	Course or Learning Activities
Focus on:	Course Learning Goals	Conceptual understanding, Misconceptions
Validated?	No	**Yes**

- Experts agree on correct answers
- Students agree on meaning of question
- Correct answer requires expert-like reasoning

Chemistry Concept Inventories - Example

Assume a beaker of pure water has been boiling for 30 minutes. What is in the bubbles in the boiling water?

	pre-test	post-test
a) Air	47	32
b) Oxygen gas and hydrogen gas	399	360
c) Oxygen	101	93
d) Water vapor	**368**	**435**
e) Heat	12	4

Concept Inventory Development Process

Step	Detail
Identify topics & concepts	Experts, Literature, ACS exams , existing CIs
Examine student thinking	Observations, old exams/assignments
Create open-ended questions	Think-aloud interviews with students
Create multiple-choice questions	
Validation Interviews	Does correct logic lead to correct answer?
Administer to classes	Statistical validation

Adams & Wieman. **Development and Validation of Instruments to Measure Learning of Expert-Like Thinking**. Int J Sci Ed 2011

Current Status of the ACCI

Current version of Analytical Chemistry Concept Inventory (ACCI)

Topic	Questions	Items
Analytical Concepts	4	10
Light & Spectroscopy	6	13
Equilibrium	8	19
Chromatography	4	18
Electrochemistry	5	8

Tested in April, 2014
- 49 students enrolled in CHEM 211

Identify topics & concepts

"What <u>concepts</u> in 2nd year Analytical Chemistry are most important?"

Analytical Concepts
Random vs. systematic
    error
Accuracy, Precision
Calibration
Sensitivity, SNR
Limit of detection

Equilibrium
Mass & charge balance
Titrations curves
Alpha diagrams
K_a, K_b, K_w, K_{sp}, K_f
EDTA complexation
Activity

Electrochemistry
Galvanic cells
Nernst equation
Standard conditions
Potentiometric cells
Ion-selective electrodes

Spectroscopy
Properties of light
Process of Absorption
Energy levels & spectra
Molar absorptivity
Beer's law
Spectrophotometers

Chromatography
Chromatograms
Order of elution
Void time
GC configuration
Partition coefficient
Resolution

Characteristics of a good CI question

Assume a beaker of pure water has been boiling for 30 minutes. What is in the bubbles in the boiling water?

a) Air

b) Oxygen gas and hydrogen gas

c) Oxygen

d) Water vapor

e) Heat

- Multiple choice
- Probes ONE important concept
- Short and clear
- Can be modified to create an *isomorph*

AVOID:

- Focus on memorization
- Calculations

Douglas R. Mulford and William R. Robinson. **An Inventory for Alternate Conceptions among First-Semester General Chemistry Students** J. Chem. Ed., 2002, 79 (6), p 739

Identify topics & concepts

What <u>concepts & skills</u> are most **appropriate** for a Concept Inventory?

- **Interpret** different representations of analytical processes and data
  - Numerical, Symbolic, Graphical (Spectra, Calibrations, Titration curves, Alpha diagrams, …)

- **Relate** measured results to analyte properties, experimental conditions, figures of merit, …

- **Identify** correct relationships, assumptions, requirements, …

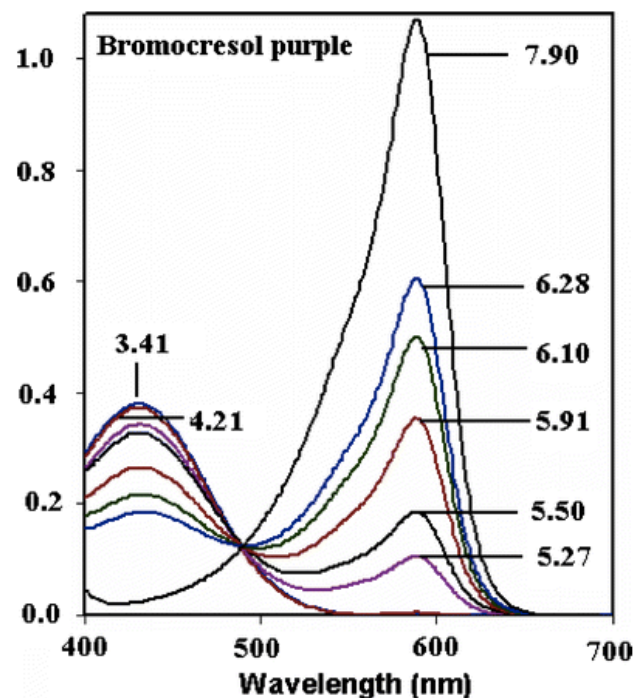- **Predict** the effect of experimental changes on concentrations, performance, retention times, …

Relate measured results to analyte properties

Bromocresol purple is an indicator dye whose wavelength of maximum absorption, λ_{max} , changes from 430 nm at pH = 3.41 to 600 nm at pH = 7.90.

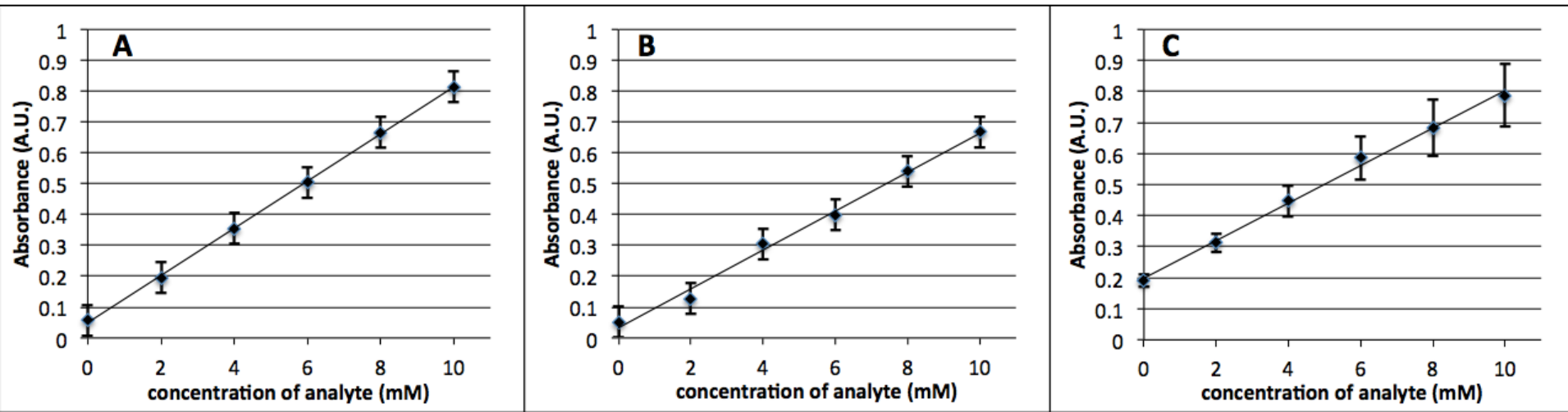**Why does the magnitude of the absorbance increase from A ≈ 0.4 to A ≈ 1.0 as the pH increases?**

a) More photon energy is available to excite each molecule   6

b) Each molecule is more likely to absorb a photon   **19**

c) The energy barrier to excitation is lower   22

d) More photons are required to excite each molecule   1

e) Each photon can excite more molecules   1

Three calibration curves (A, B, C) for three analyses of the same analyte are shown above. Error bars indicate ±1 SD from the mean. *The blank signal is shown on the y-axis and has not been subtracted from the other measured absorbance values.*

Which calibration would be able to detect the lowest concentration of analyte (mM)?

A. 16
B. 26
C. **7**

Predict the effect of changes in experimental conditions

[Previous Question] You add 0.010 mol of lead chloride ($PbCl_2$) to a beaker containing 100 mL of distilled water. After stirring, you observe that only a small amount of the solid has dissolved.

How would the following changes affect the free concentrations of [Pb^{2+}], [Cl^-], and K_{sp} ?

Change	[Pb]$^{2+}$ ⬆	[Pb]$^{2+}$ –	[Pb]$^{2+}$ ⬇	[Cl]$^-$ ⬆	[Cl]$^-$ –	[Cl]$^-$ ⬇
Addition of 1 gram of $NaCl_{(s)}$	15	13	**21**	**31**	4	14
Addition of 1 mmol EDTA	9	9	**31**	**20**	25	3
Addition of 1 gram of $KNO_{3(s)}$	**22**	22	5	**22**	19	8
Heating the solution to 80°C	**35**	10	4	**36**	8	5

Current Status of the ACCI

Current version of Analytical Chemistry Concept Inventory (ACCI)

Topic	Questions	Items	Average score
Analytical Concepts	4	10	66%
Light & Spectroscopy	6	13	65%
Equilibrium	8	19	57%
Chromatography	4	18	61%
Electrochemistry	5	8	54%

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Future directions

Create multiple-choice questions

Validation Interviews — Does correct logic lead to correct answer?

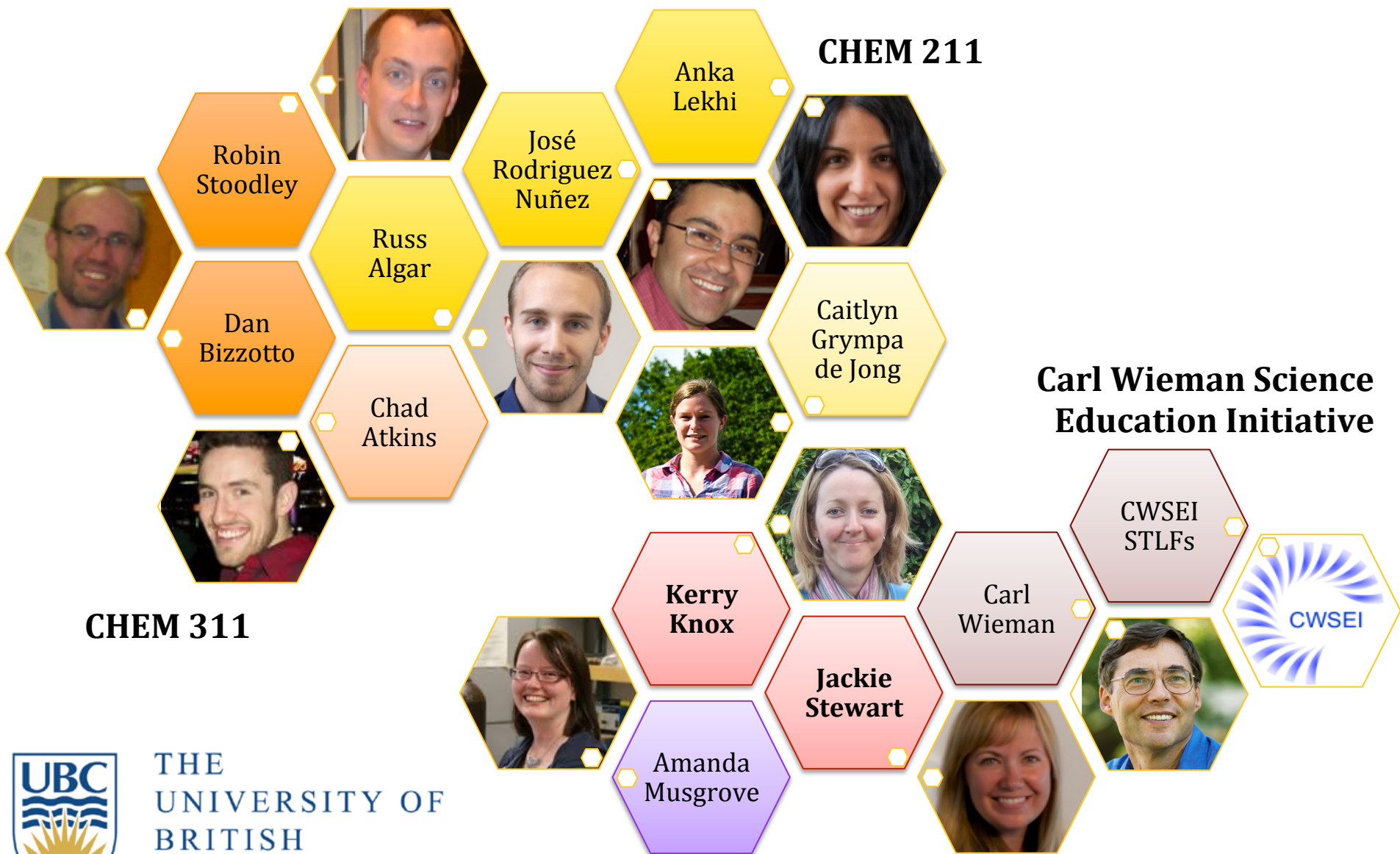Administer to classes — Statistical validation
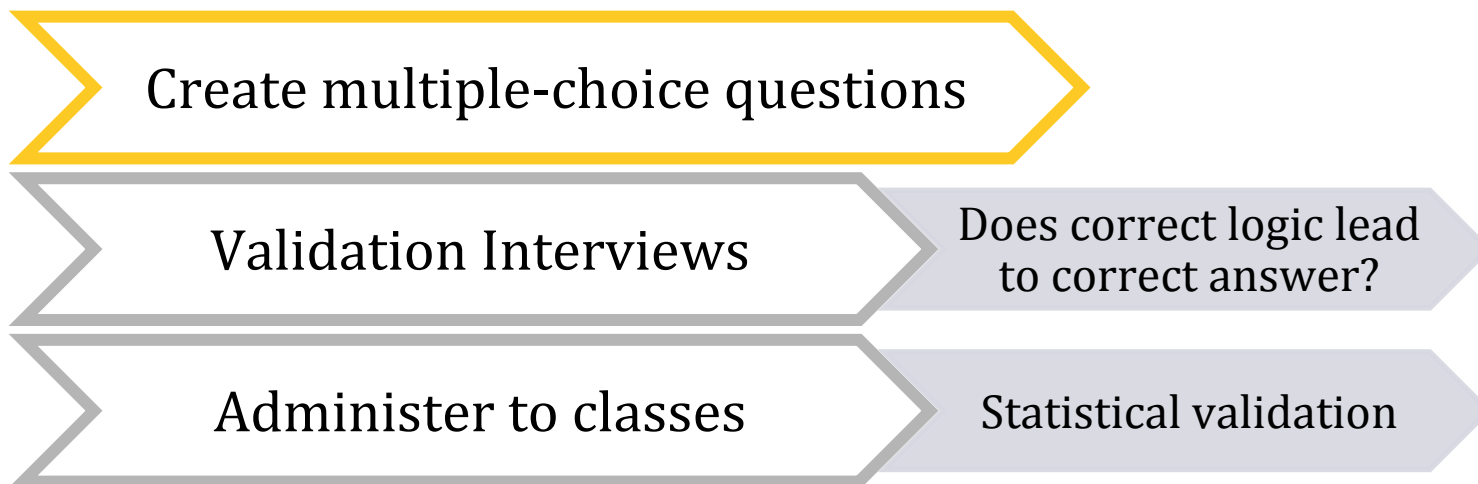
- Expansion to 3rd-year topics

Do you teach or do research in Analytical chemistry?

Your help is needed
- Topics for inclusion
- Experts for validation
- Feedback from potential users

Thank you.

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