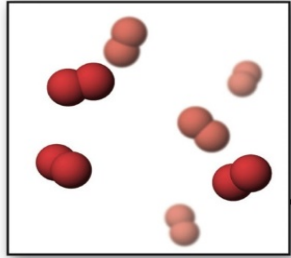


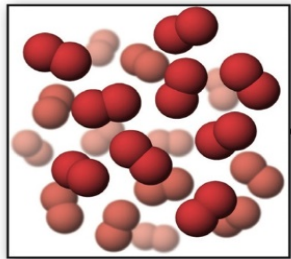
**Solid**



Bromine  
solid and liquid



**Gas**



**Liquid**



Bromine  
gas and liquid

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# Potential Change to a Core Course – Pilot Design, Implementation, Analysis and Research

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# Discussion

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# Overview

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Why a Pilot?

Pilot Design and Implementation

Laboratory Alignment

Analysis of Common Exams

In-Depth analysis - Research



# What Is the Change?

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## **Conventional SC111 (CV)**

1. Basic Concepts
2. Atoms, Molecules and Ions
3. Chemical Reactions
4. Stoichiometry
5. Energy and Chemical Reactions
- 6. The Structure of Atoms**
- 7. Periodic Trends**
- 8. Bonding and Molecular Structure**
- 9. Bonding Theory**

## **Atoms First SC111 (AF)**

1. Basic Concepts
2. Atoms, Molecules and Ions
- 6. The Structure of Atoms**
- 7. Periodic Trends**
- 8. Bonding and Molecular Structure**
- 9. Bonding Theory**
3. Chemical Reactions
4. Stoichiometry
5. Energy and Chemical Reactions

# Why a Pilot?

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Large Change – involves not just lecture change but re-alignment of laboratory program

- Seven weeks of semester that might need new labs

Large Course

- 50 Sections
- 28 Instructors

Support Services impacted

- MGSP
- Academic Center

# Pilot Design and Implementation

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One laboratory room – holds up to 12 sections

Recruited seven instructors to participate – 10 to 11 sections – 200-220 plebes

Completely random registration

Special sections of Supplemental Instruction

Special sections of MGSP with Atoms First specific leaders

# Pilot Design and Implementation

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Same textbook – different order of topics

Same homework system – different due dates for same questions

Commonality to exams

- Six-week exam – same questions for common chapters
- Same final exam

# Discussion

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# Laboratory Design for AF

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Emphasis on Interactions of Light with Matter

- Spectroscopy

Used same atom and ions for multiple experiments (copper and copper(II) ions)

Repeated use of Excel for series of experiments

# Laboratory Design for AF

<b>Atoms First SC111</b>	<b>Experiment Alignment</b>
Weeks 1&2: <b>Ch 1. Basic Concepts</b> <b>Ch 2. Atoms, Molecules and Ions</b>	Expt. 1G: <b>Chemical and Physical Properties</b> – New experiment – measure density of solution and solid – observe reactions of copper metal, zinc metal and brass with acids
Week 3/4: <b>Ch. 6. The Structure of Atoms</b>	Expt. 40B: <b>Light, Energy, and Spectra</b> – Revised experiment - What happens when matter interacts with light.
Week 6: <b>Ch. 9. Bonding Theory</b>	Expt. 7F – <b>Beer’s Law</b> – New experiment – Discovery of Beer’s Law and UV/Vis Spectroscopy – Colored solution of copper(II) ions primarily
Week 7: <b>Ch. 3 – Writing Chemical Reactions</b>	Expt. 7G – <b>Spectroscopy of Ionic Solutions</b> – New experiment – Observe colors of solutions of copper(II), iron(III) and cobalt(II). Observe color changes with chemical reaction.
Week 8: <b>Ch. 4 – Stoichiometry</b>	Expt. 7A – <b>Analysis of Brass</b> – Lightly revised experiment - Analysis an alloy of copper and zinc, using spectroscopy.

# Laboratory Outcome for Atoms First Labs

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Did the experiments work well?

- As well as any experiments in the first or second iteration.

Midshipman Feedback

- Did as well as CV students on lab questions on final exams.
- Course evaluation questions about lab were slightly more positive for AF

# Lecture Assessment

## Did the AF students do as well or better?

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Examine performance on multiple choice exams with validated questions.

- Chemistry has extensive database of questions from previous years.
- Spring final exam is a national standardized exam.

# Final Exam Comparisons

<b>Exam</b>	<b>Atoms First</b>	<b>Conventional</b>
<b>SC111 Final (AY17)</b>	75.4%	75.1%
<b>SC112 Final (AY17)</b>	65.1%	64.1%
<b>ACS portion of SC112 Exam (AY17)</b>	65.3%	64.2%
<b>SC111 Final (AY18)</b>	75.3%	72.4%
<b>SC112 Final (AY18)</b>	60.1%	59.6%
<b>ACS portion of SC112 Exam (AY18)</b>	60.8%	60.2%

Are these statistically significant?

Are there other factors to explain this?

# Are the Differences Significant?

## Wilcoxon Analysis (Mann-Whitney signed ranked analysis)

Item	Conventional	AF Score	Delta	Sign	Abs Value	Rank	Signed-Rank	W	n
1	90.9	90.8	-0.08	-1	0.08	2	-2	321	80
2	41.8	49.3	7.48	1	7.48	75	75	$\sqrt{n*(n+1)*(2n+1)/6}$	
3	53.2	51.2	-1.97	-1	1.97	34	-34	416.9892	
4	45.9	44.4	-1.42	-1	1.42	24	-24		
5	37.0	34.8	-2.22	-1	2.22	41	-41	Z	
6	50.3	47.3	-2.96	-1	2.96	49	-49	0.769	
7	79.5	81.6	2.12	1	2.12	36	36	50.0% con	0
8	40.0	40.6	0.58	1	0.58	7	7	72.6% con	0.6
9	38.9	38.2	-0.76	-1	0.76	12	-12	78.8% con	0.8
10	30.9	30.0	-0.95	-1	0.95	14	-14	84.1% con	1
11	39.2	38.2	-1.00	-1	1.00	16	-16	88.5% con	1.2
12	73.5	79.7	6.18	1	6.18	72	72	93.4% con	1.5
13	48.9	46.9	-2.00	-1	2.00	35	-35	97.5% con	1.96
14	49.6	45.9	-3.69	-1	3.69	55	-55	99% confi	2.326
15	53.2	51.7	-1.48	-1	1.48	28	-28	99.5% con	2.576
16	74.4	70.5	-3.84	-1	3.84	59	-59	99.95% co	3.291

# Statistically Significant?

<b>Exam</b>	<b>Atoms First</b>	<b>Conventional</b>	<b>Statistically significant, CI?</b>
<b>SC111 Final (AY17)</b>	75.36%	75.12%	No
<b>SC112 Final (AY17)</b>	65.10%	64.10%	>95% CI
<b>ACS portion of SC112 Exam (AY17)</b>	65.26%	64.18%	>99% CI
<b>SC111 Final (AY18)</b>	75.28%	72.38%	>99.9% CI
<b>SC112 Final (AY18)</b>	60.1%	59.6%	>75% CI
<b>ACS portion of SC112 Exam (AY18)</b>	60.8%	60.2%	>75% CI

# Did AF students do as well or better?

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Based on common exam performances, the AF students seem to do as well or slightly better than CV.

This is true for SC112 final exam, given 16 weeks later. Mostmids not with same instructor for spring, intermixed with CV students in all sections of SC112



# Discussion

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# Result of the Pilot

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## ADOPTING ATOMS FIRST FOR SC111 in AY2020

- Find a textbook and homework system that support AF.
- Use and/or develop experiments that support AF, especially spectroscopy experiments



# Looking Deeper – Transition to Research

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The exam results are interesting but can we look deeper?

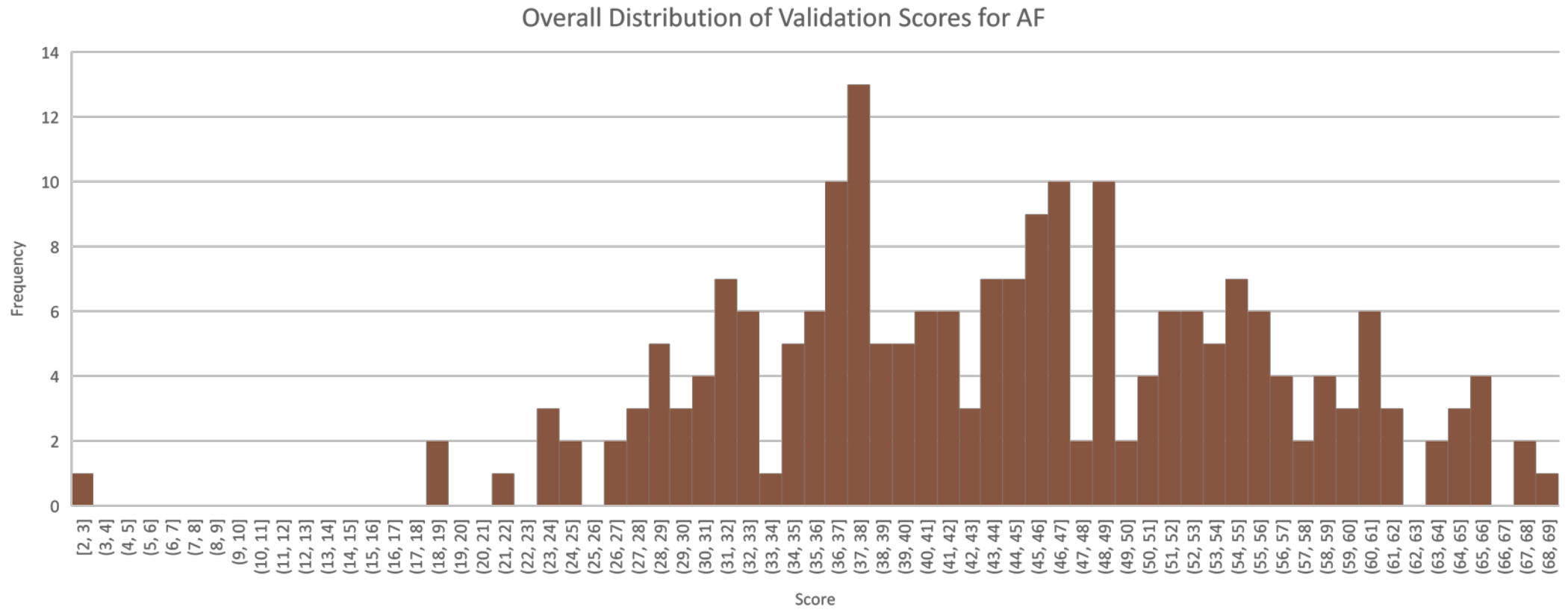
Next portion is Educational Research – SC495/496 Project  
– Midn. 1/c Olivia Bair

What makes this research?

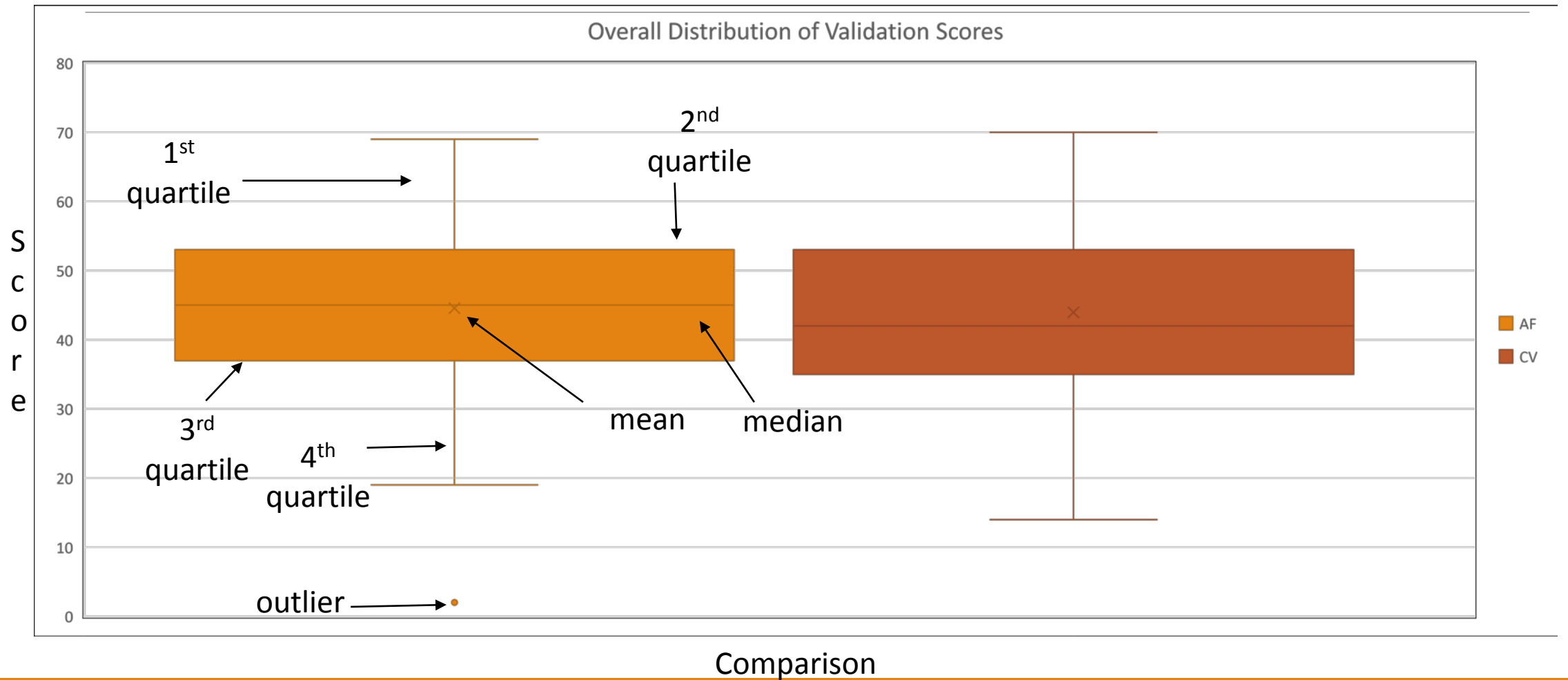
- Internal vs External presentation
- De-identified vs Identified
- HRPP Approval #USNA.2016.0035-CR01-AM02-EP7-A

# Predictors of SC111 Performance (AY18)

## Validation Scores



# Predictors for AY18





# TOST Analysis

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Two One Sided t-Test

Test for equivalence between two groups

# Predictors for AY18

<b>SC111 All</b>	<b>AF Mean (SD)</b>	<b>CV Mean (SD)</b>	<b>Equivalence Interval from TOST</b>	<b>Confidence Interval for Mean Difference</b>	<b>Result of TOST</b>
<b>SAT Verbal</b>	668 (84)	670 (81)	(-16.5, 16.5)	(-10.2, 6.2)	Equivalent
<b>SAT Math</b>	671 (79)	667 (74)	(-15.3, 15.3)	(-3.6, 11.6)	Equivalent
<b>Validation Scores</b>	45 (11)	44 (12)	(-2.3, 2.3)	(-0.1, 2.1)	Equivalent

# Are the Two Groups Equivalent?

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For the entire populations – all AF students and all CV students – the two groups are equivalent.

This means the previous exam analyses for AY2018 groups are valid.





# Predictors from AY18

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Used validation scores to sort by three performance groups

- Top 27% (scores > 51)
- Middle 46% (scores between 36 and 51)
- Bottom 27% (scores < 36)
- Percentages based on all SC111 students

For Consenting SC112 Students (429 CV and 117 AF)

- Kept in same groups
- Distribution of bottom and top groups not well matched

# SC112 6-week Exam Analysis –AY18

Wilcoxon Analysis	AF	CV	Wilcoxon (Z-value)	Analysis
Overall	73.35% (N=202)	72.19% (N=823)	1.244	Significant at the 88.5% CI
Bottom	63.63% (N=32)	65.36% (N=100)	-0.895	No statistical difference
Middle	72.82% (N=93)	71.39% (N=184)	1.271	Significant at the 88.5% CI
Top	81.45% (N=58)	82.23% (N=115)	-0.370	No statistical difference

# SC112 12-week Exam Analysis – AY18

Wilcoxon Analysis	AF	CV	Wilcoxon (Z-value)	Analysis
Overall	68.80% (N=207)	68.20% (N=819)	1.352	Significant at the 88.5% CI
Bottom	60.00% (N=32)	63.00% (N=100)	-1.715	Significant at the 93.4% CI
Middle	67.30% (N=93)	68.00% (N=184)	-0.612	No statistical difference
Top	77.50% (N=58)	77.00% (N=115)	0.464	No statistical difference

# Comparison of AF vs CV by groups for common exams

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For the overall groups, AF performed better on the six-week and twelve-week common exams

For the middle group – AF performed better on the six-week and the two groups were statistically the same on the twelve-week

Top and Bottom groups were not well-matched so interpretation of results is difficult



# Longitudinal Analysis

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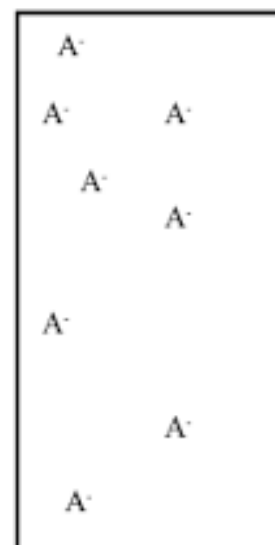
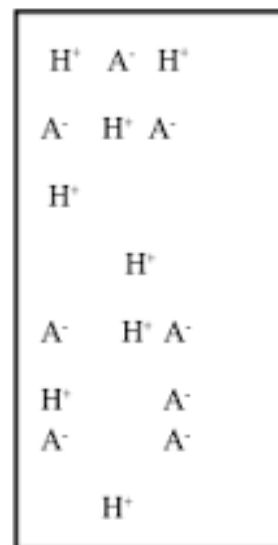
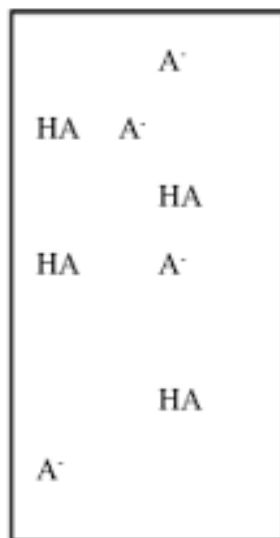
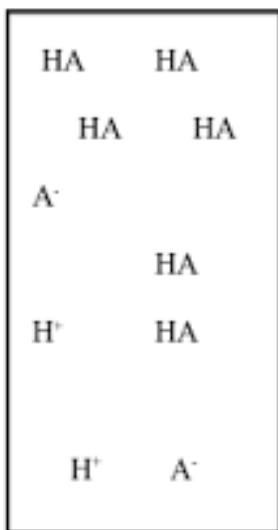
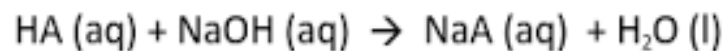
Three questions given to students in the spring (AY17 and AY18) as quiz questions at various points through the semester

Coding for each question established based on AY17

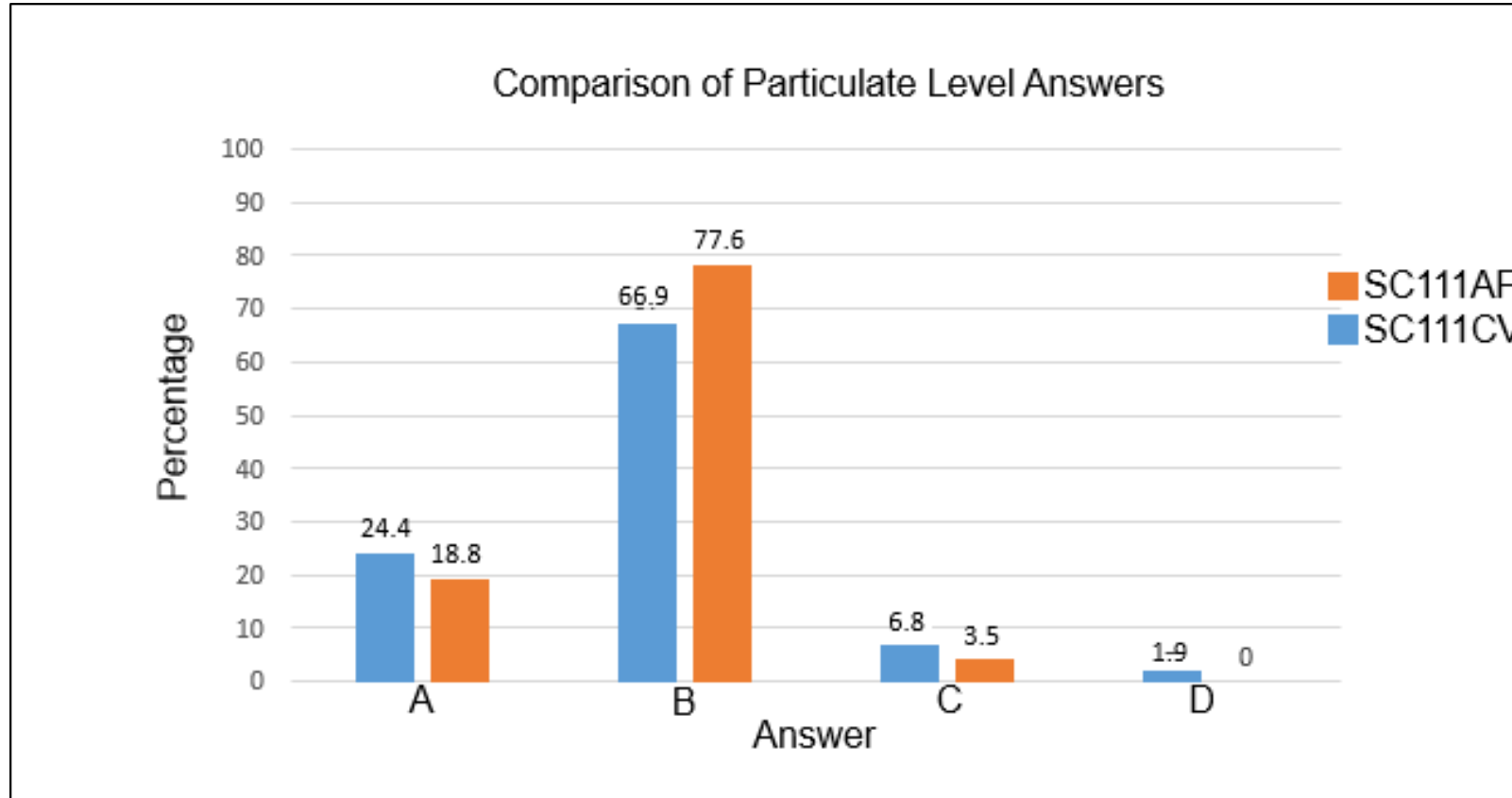
Free response questions given and now ready for analysis

# Multiple Choice Question

1. Which figure illustrates the species at the half-equivalence point when a weak acid, HA, is titrated with NaOH? For clarity, water molecules and Na<sup>+</sup> ions are omitted.



# Analysis of Multiple Choice Question



# Analysis of Multiple Choice Question

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- A Fisher's exact is analogous to a t-test, but for categorical data.
- The statistic compares the performance of two populations on a single question.

Percent Correct (AF/CV)	Fisher's Exact	Conclusion
77.6/66.9 (n=85 /n=266)	p=0.0780	SC111AF did statistically better than SC111CV



# Free Response Question

An aqueous solution is 0.10 molal in sodium sulfate,  $\text{Na}_2\text{SO}_4$ .

What ions, atoms and molecules are present in the solution and what are the concentrations of each? (Fill in the appropriate number of blanks below.)

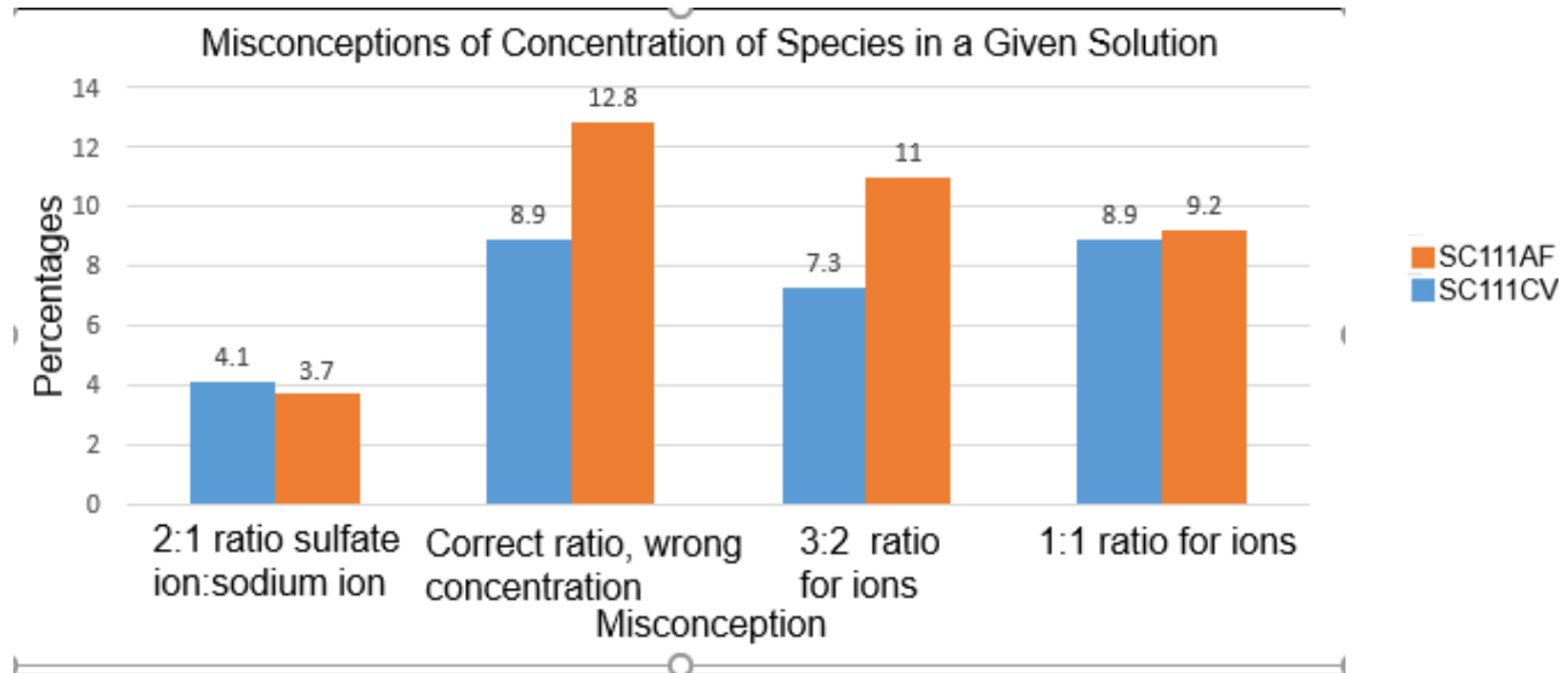
Ion, atom or molecule    $\text{Na}^+$    concentration   0.20 molal  

Ion, atom or molecule    $\text{SO}_4^{2-}$    concentration   0.10 molal  

Ion, atom or molecule    $\text{H}_2\text{O}$    concentration   solvent  

What is the freezing point of this solution? ( $K_{\text{fp}}(\text{H}_2\text{O}) = -1.86 \text{ }^\circ\text{C}/\text{m}$ ,  $\Delta T_{\text{fp}} = i K_{\text{fp}} m$ ). Show your work.

# Analysis of Free Response Question - Coding



# Status of Research Project

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- Have Developed a Method for Analyzing Multiple Choice Questions on Quizzes – Fisher's Exact Test
- Have Developed a Coding Scheme for Analysis of Free Response Questions
- Project will be continued by two SC495/496 students in AY2019 – Midn. 2/c Bianca Roach, Midn 2/c Claire Suess

# Conclusion – Research Analysis

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Research at the deeper level is more time consuming

Multiple choice and free response questions can give us a deeper picture of student learning



# Acknowledgements

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USNA Chemistry Department

Participating instructors

- Atoms First instructors: Maria Schroeder, Melonie Teichert, Christine Copper, Virginia Smith, LCDR Robert Russell, CDR Julie Spencer, CAPT Rob Calhoun, Deb Dillner
- SC112 instructors who
  - allowed us to recruit their students and
  - photocopied student work

SC111/SC112 Students

IRB board and HRPP office



# Methodology

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Data involves students

Randomly assigned

Consent

- HRPP Approval #USNA.2016.0035-CR01-AM02-EP7-A

N values of population

- AY17: 774 CV, 238 AF
- AY18: 852 CV, 212 AF

Data sources

- Exams, coursework