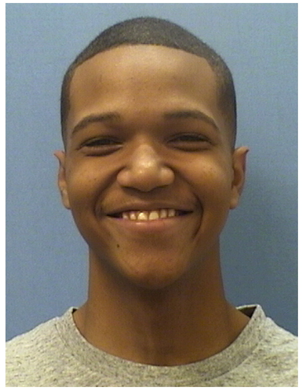





High Structure Active Learning:

Changing the Face(s) of Undergraduate Science Education




High Structure Active Learning

What is it?

Why should we care?

Does it work?

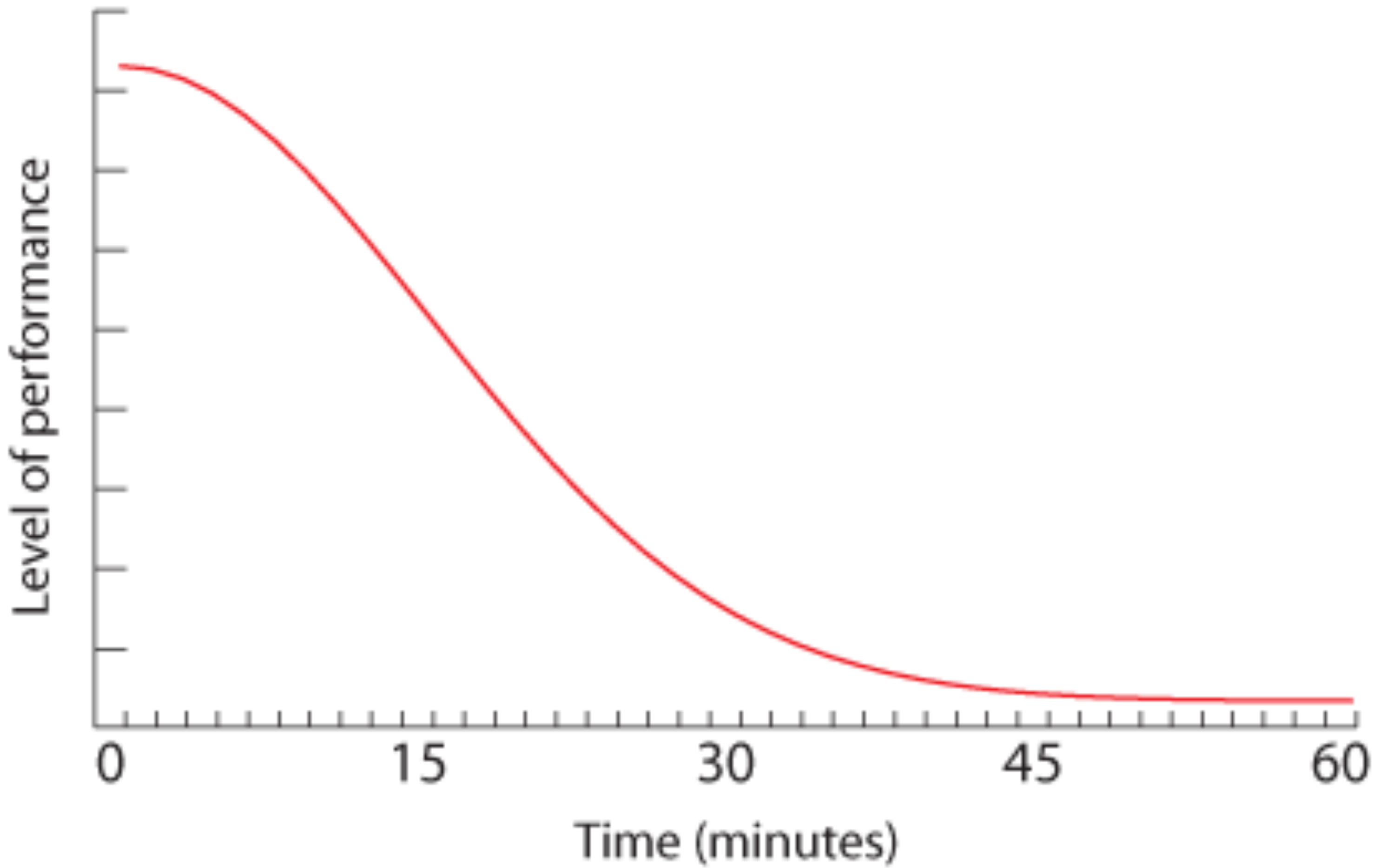
What is high-structure active learning?

Let's start with what it is not……

TRADITIONAL LOW STRUCTURE CLASS

1. Students not held accountable for available pre-class readings or videos.
2. Students listen to a lecture and take notes. Only a few students ask questions and participate.
3. Students review on their own, not held accountable for any review assignments.

Attention Span During a Lecture

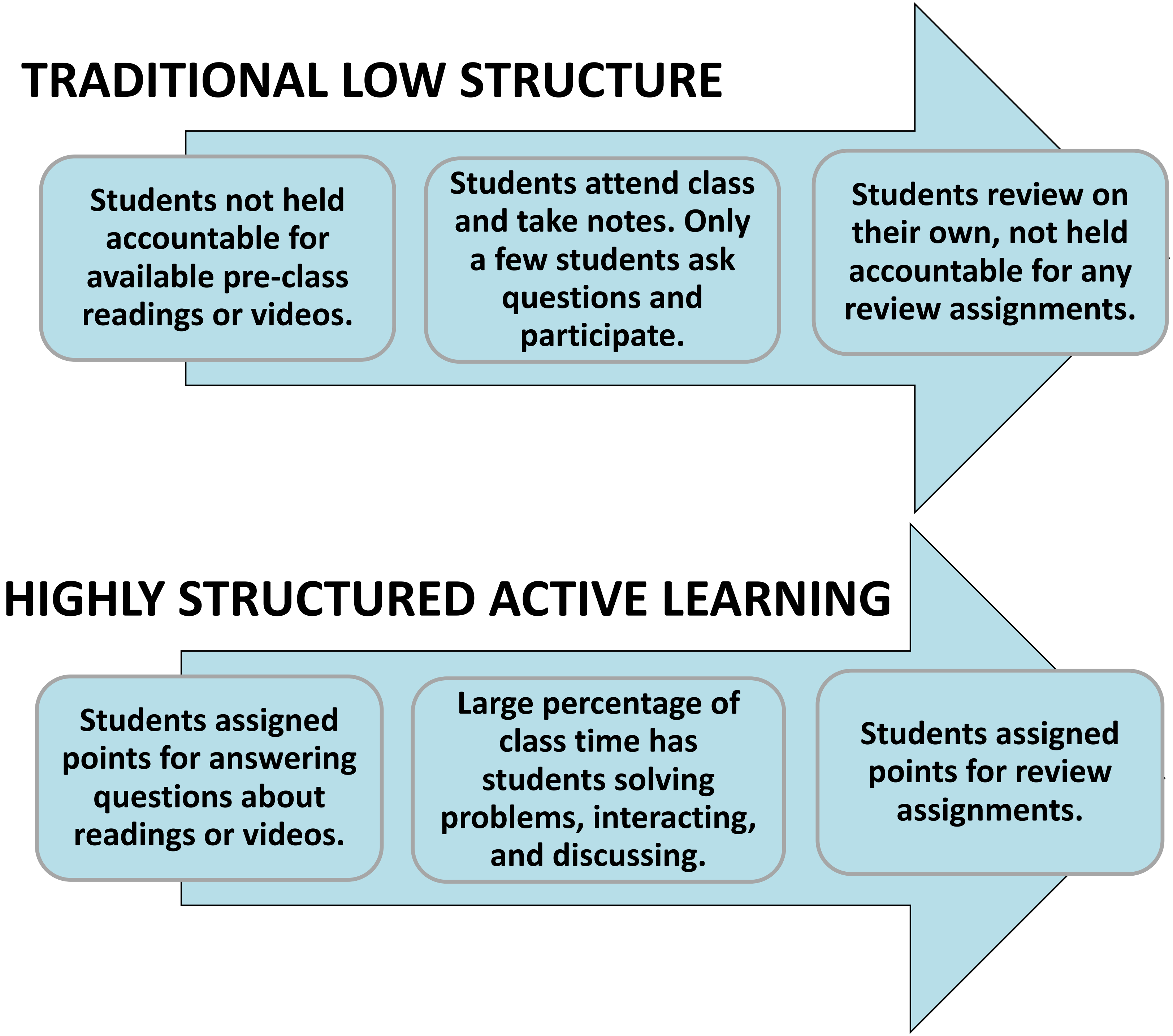


https://flexiblelearning.auckland.ac.nz/teaching-large-classes/2.html

The Lecture

- *"Lecturing is that process by which the contents of the note-book of the professor are transferred to the note-book of the student without passing through the brains of either."*

- *Edwin Slossen*


TRADITIONAL LOW STRUCTURE
Students not held accountable for available pre-class readings or videos.
Students attend class and take notes. Only a few students ask questions and participate.
Students review on their own, not held accountable for any review assignments.
HIGHLY STRUCTURED ACTIVE LEARNING
Students assigned points for answering questions about readings or videos.
Large percentage of class time has students solving problems, interacting, and discussing.
Students assigned points for review assignments.

Changing Activities Improves Retention

Why Use Highly Structured Active Learning?

- A variety of studies show that human attention wanes quickly during lectures.

- Active learning methods improve attention and retention of the content.

- High-structure classes increase achievement for all students, yet ***benefit underrepresented groups even more.***

Active Learning

Examples

- Peer Instruction
- Flipped classroom
- Workshops
- Group problem solving
- Tutorials
- Guided reading questions
- Questions using classroom response systems
- Think-pair-share
- Studio classroom

High Structure Active Learning

- **Active Learning:** Responsibility for learning rests on the learner
- **Student/Learner-Centered Pedagogies**: Students spend class time performing learning activities rather than taking notes
- **High Structure Classes:** Classes designed with psychology of learning in mind.
  - Attention span: 10-15 minutes → switch tasks every 10-15 minutes
  - Best learning from repetitive exposure → spaced practice
  - Students acquire information before class (guided reading or videos) and perform learning activities in class.
  - Higher-order thinking skills developed ***in***, rather than ***out of*** class

Why Use Highly Structured Active Learning?

Increased Course Structure Improves Performance in Introductory Biology

Scott Freeman, David Haak, Mary Pat Wenderoth
CBE—Life Sciences Education **2011**, *10*, 175–186.

"When we controlled for variation in student ability, failure rates were lower in a moderately structured course design and were dramatically lower in a highly structured course design. This result supports the hypothesis that active-learning exercises can make students more skilled learners and help bridge the gap between poorly prepared students and their better-prepared peers."

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Failure rates across quarters						
	Low structure	Moderate structure			High structure	
	Spring 2002	Spring 2003	Spring 2005	Fall 2005	Fall 2007	Fall 2009
% students <1.5	18.2	15.8	10.9	11.7	7.4	6.3
n	324	333	330	333	336	653

High Structure Active Learning

What is it?

Why should we care?

Does it work?

THE WHITE HOUSE
WASHINGTON

In 2012, the President's Council of Advisors on Science and Technology stated:

*"Economic forecasts point to a need for producing, over the next decade, approximately **1 million more** college graduates in STEM fields than expected under current assumptions."*

Nationally, what percent of students who enter college intending to major in a STEM field actually graduate with a STEM degree?

underrepresented minority
^

Nationally, what percent of students who enter college intending to major in a STEM field actually graduate with a STEM degree?

Women and underrepresented minorities make up about what % of U.S. college students?

What % of STEM graduates are women and underrepresented minority students?

Nationally, about 40% of students who enter college intending to major in a STEM field graduate with a STEM degree.

underrepresented minority

Nationally, about 15% of ^ students who enter college intending to major in a STEM field graduate with a STEM degree.

Women and underrepresented minorities make up about 70% of U.S. college students.

Only 45% of STEM graduates are women and underrepresented minority students.

Why Do Students Leave STEM?

- Poor performance and negative experiences in gateway or introductory math and science courses that are uninspiring.

- Feeling isolated in STEM fields (lacking peers, role models and/or mentors.)

- They find a subject that interests them more

STEM Attrition: College Students' Path Into and Out of STEM Fields. Statistical Analysis Report. U.S. Department of Education. Nov. 2013.

High Structure Active Learning

What is it?

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Does it work?

Meta Analysis of Active Learning Studies

Meta analysis of 225 studies that compared exams scores or failure rates between ***traditional lecture*** vs. ***active learning***

Under active learning:
Exam scores increased by an average of 0.47 SD about 6%

Students were 1.5 times more likely to fail in a standard lecture course

Freeman, Scott; *et. al.* *PNAS* **2014**, *111*, 8410-8415

Does the Teacher Matter?

- Two classes of Electricity and Magnetism (Intro Physics II)
- One week of class on electromagnetic waves, photons, etc.
- ***Control section:*** Experienced instructor with strong teaching evaluations who had been teaching the course the entire semester.
- ***Experimental section:*** Novice instructors with no large classroom experience, but training in active learning methods.

Deslauriers, L., Schelew, E., Wieman, C. *Science* **2011**, *332*, 862.

Deslauriers, L., Schelew, E., Wieman, C. *Science* **2011**, *332*, 862.

Control Section

Before Class:

reading assignment

In class:

lecture

example problems

demonstrations

1-2 clicker questions as **summative assessment**

↑ ***evaluates the discussion***

Experimental Section

Before Class:

reading assignment

quiz on reading

In class:

No formal lecture

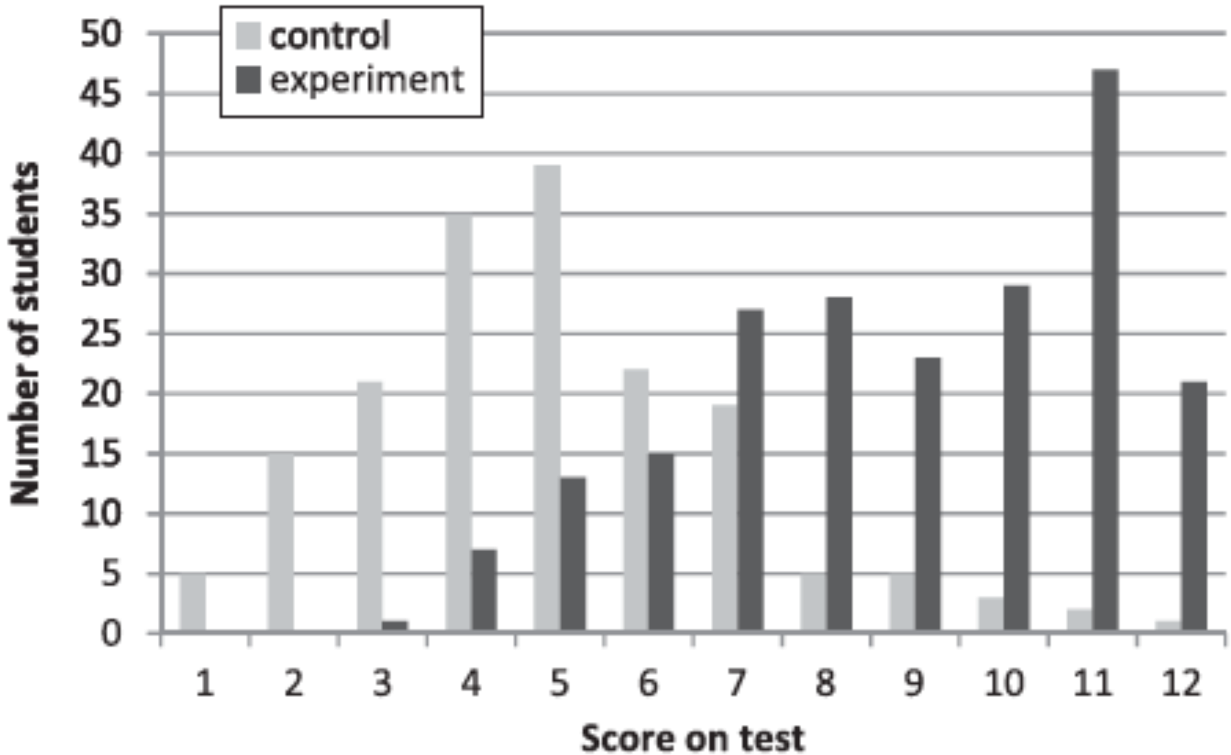
~ 3 clicker questions as **formative assessment** ← ***guides the discussion***

targeted instructor feedback related to questions

1-2 small group learning tasks

targeted instructor feedback

Novice vs. Experienced Instructors



Experienced Instructor + Traditional Lecture = Light Bars
Inexperienced Instructor + Active Learning = Dark Bars

Deslauriers, L., Schelew, E., Wieman, C. *Science* **2011**, *332*, 862.

High Structure Active Learning

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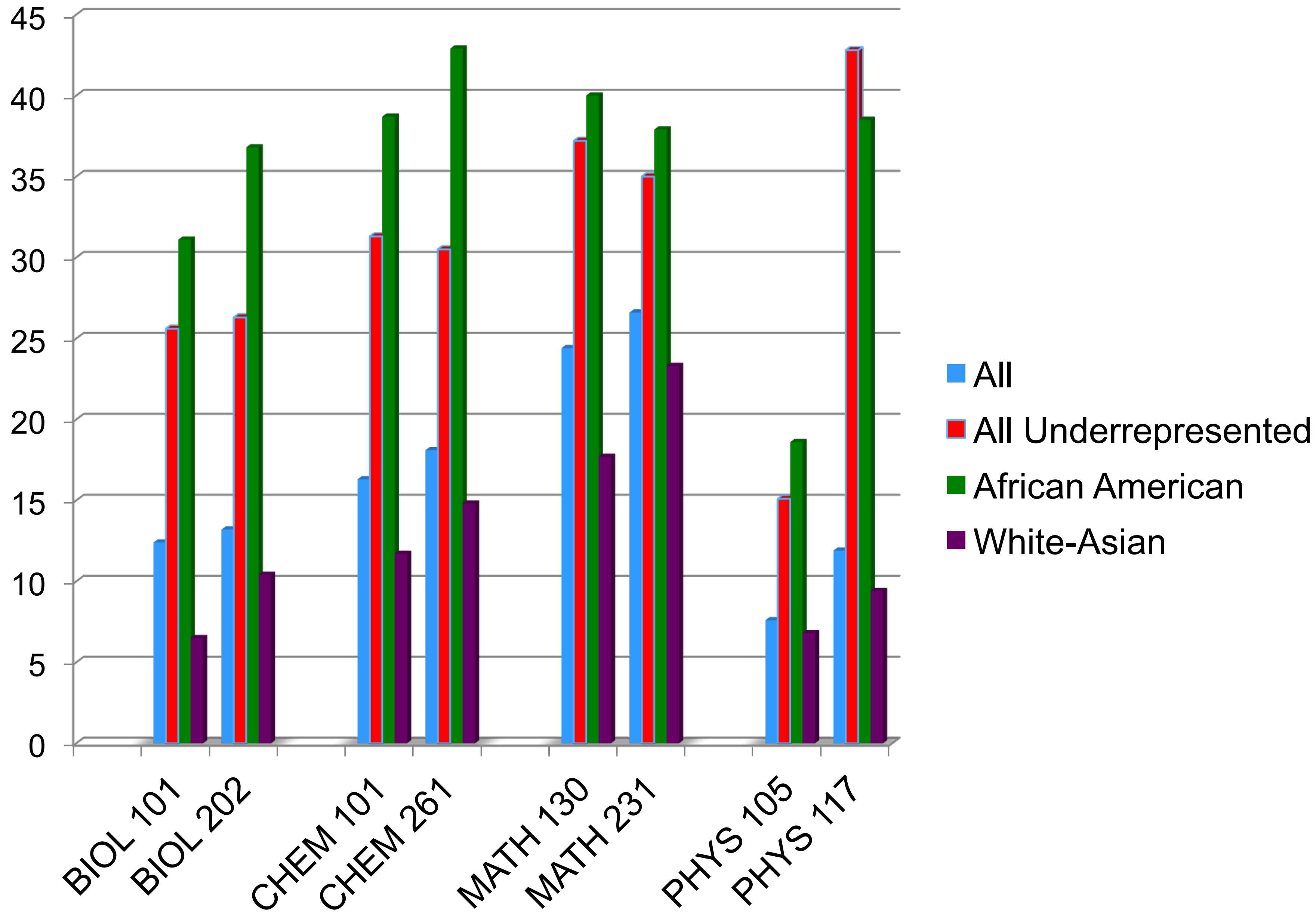
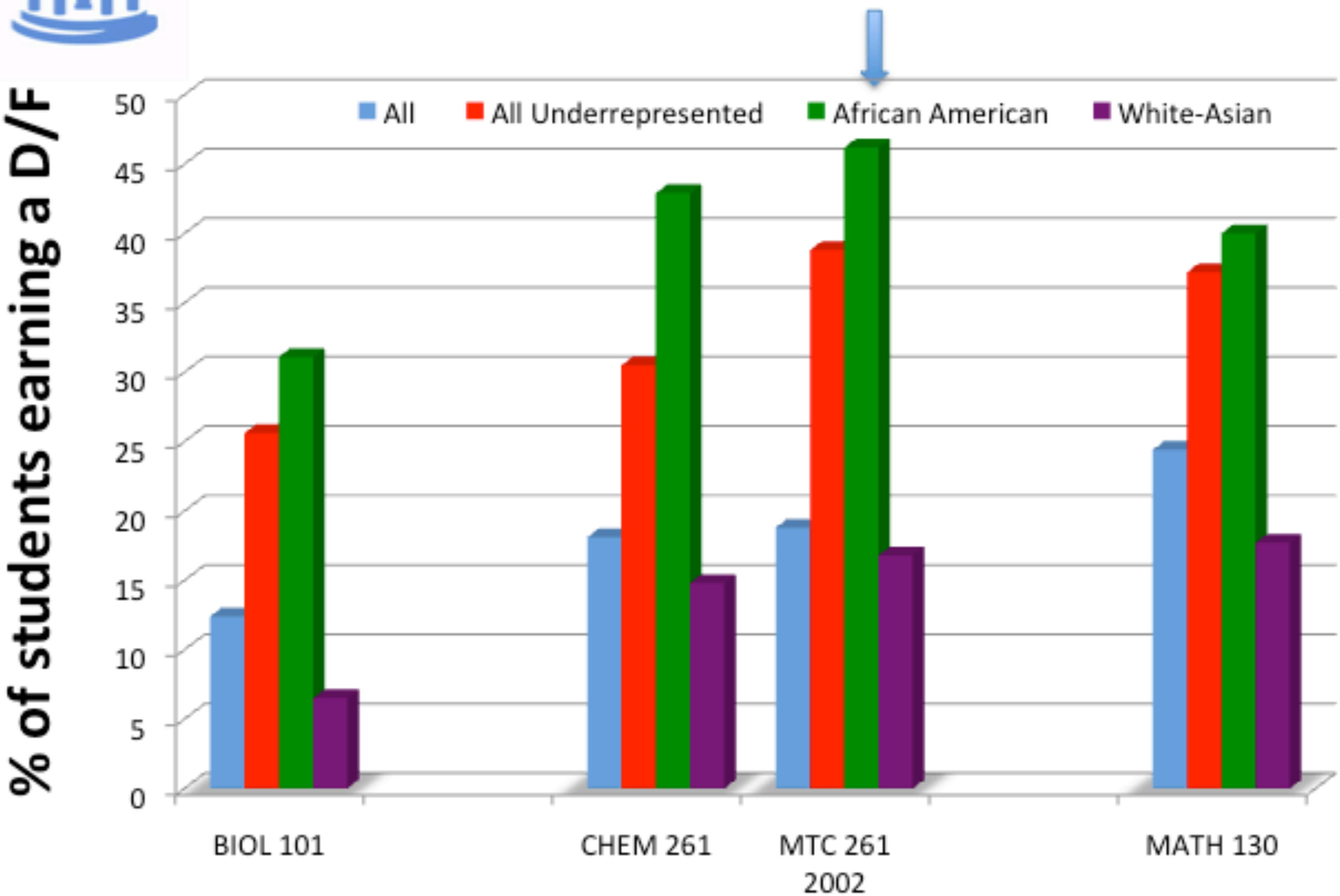
Motivation: 2007-08 Disaggregated D/F Rates

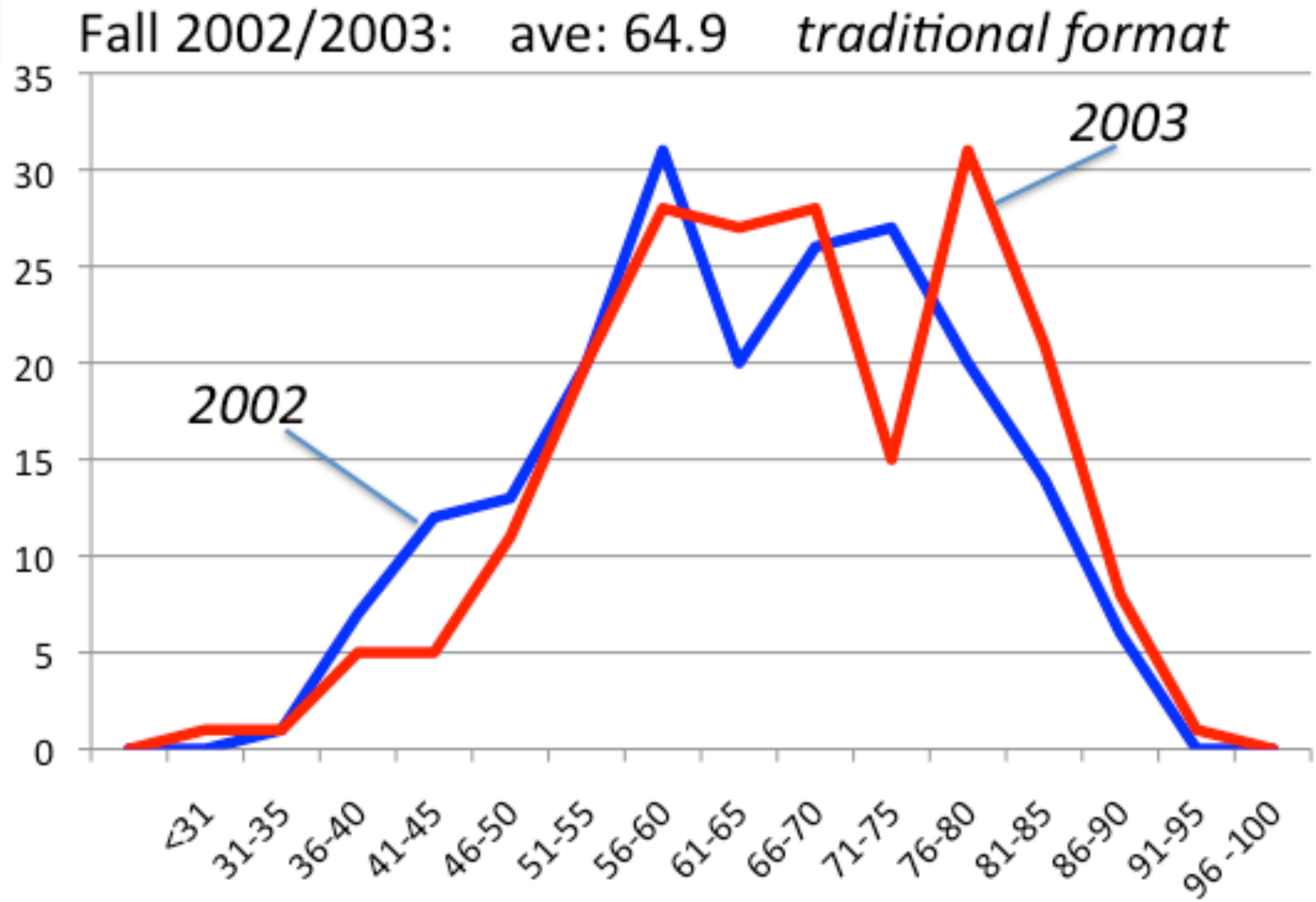


D/F rates in Introductory STEM courses at UNC: 2007-2008



3 years earlier…….

CHEM 261 Final Exam Distribution 2002/2003



Traditional format:

- Lecturing

I have no evidence of learning and no accountability. Students don't do "optional".

High Structure, Active Learning format:

Pre class *Practice*

During class *Practice*

After class *Practice*

Chemistry 261: Organic Chemistry I

Traditional: Rock on rock (chalk on blackboard) or powerpoints and lecture

High Structure, Active Learning format:

- Before Class:

- Class management site with many resources
- Clearly defined learning objectives
- Pre-class reading/video assignment
- Pre-class problem assignments online

Chemistry 261: Organic Chemistry I

High Structure, Active Learning format:

- During Class

- Socratic lecturing (explaining)
- Formative clicker questions during class
- In class problem solving activities
- Undergraduate mentors (in class)

Chemistry 261: Organic Chemistry I

High Structure, Active Learning format:

- After Class

- Daily class problem assignments
- Weekly online homework assignments
- Practice exams, problem sets
- Coordinated content, schedule, and help sessions for three sections

Post-Exam 1 strategy session on metacognition

- Post-Exam 1 strategy session on metacognition
- ***Ave: Exam 1: 71.2; Exam 2: 76.3***
- ***30 students attended session***
    - ***exam 1: 57.5;***
    - ***exam 2: 73.8;***
    - ***average increase/decrease: +16.3 pts***
- ***64 students did not attend session***
    - ***exam 1: 58.3; exam 2: 65.3;***
    - ***average increase/decrease: +7 pts***

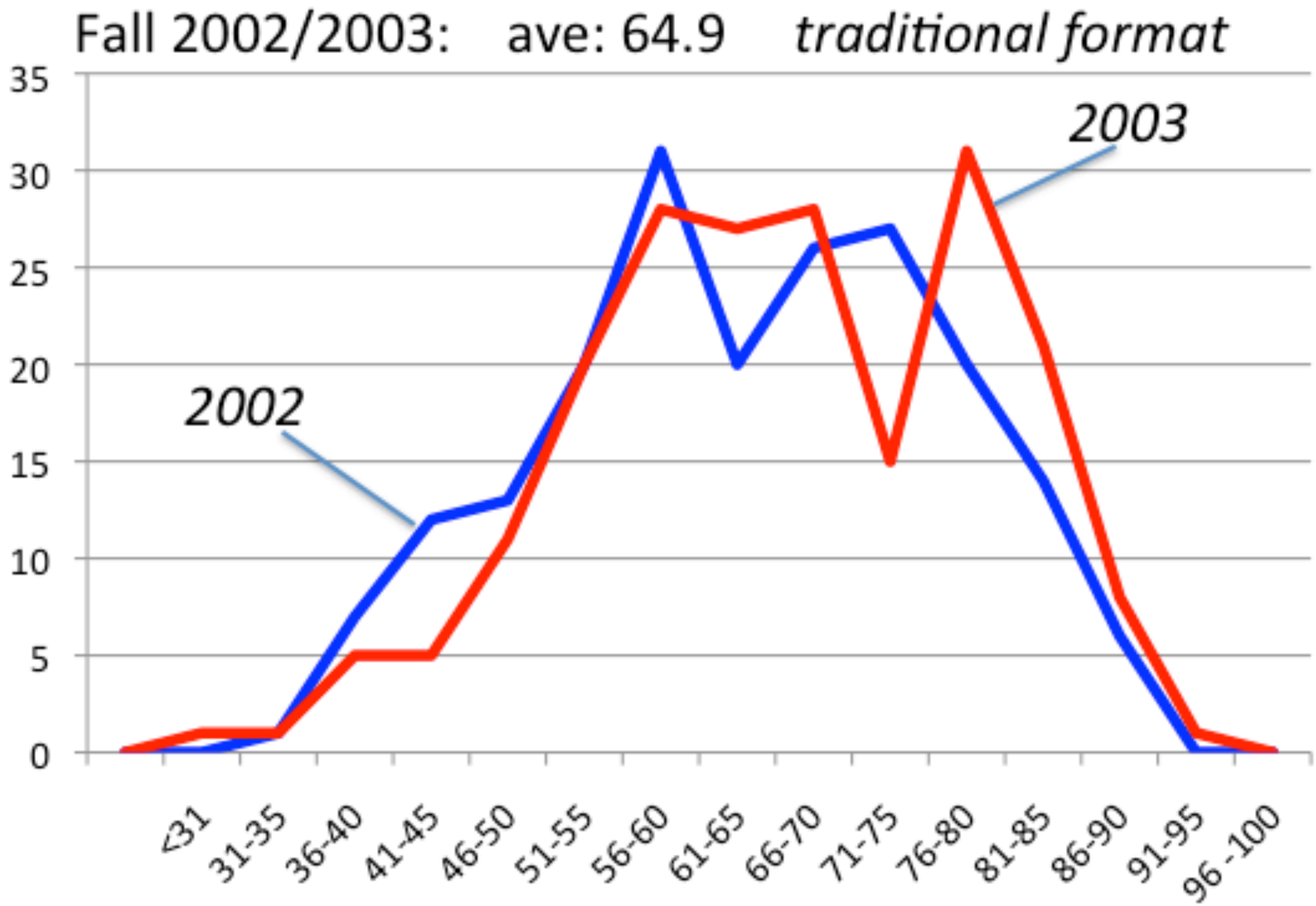
Cook, E.; Kennedy, E.; McGuire, S. *J. Chem. Ed.* ***2013***, 961-967.

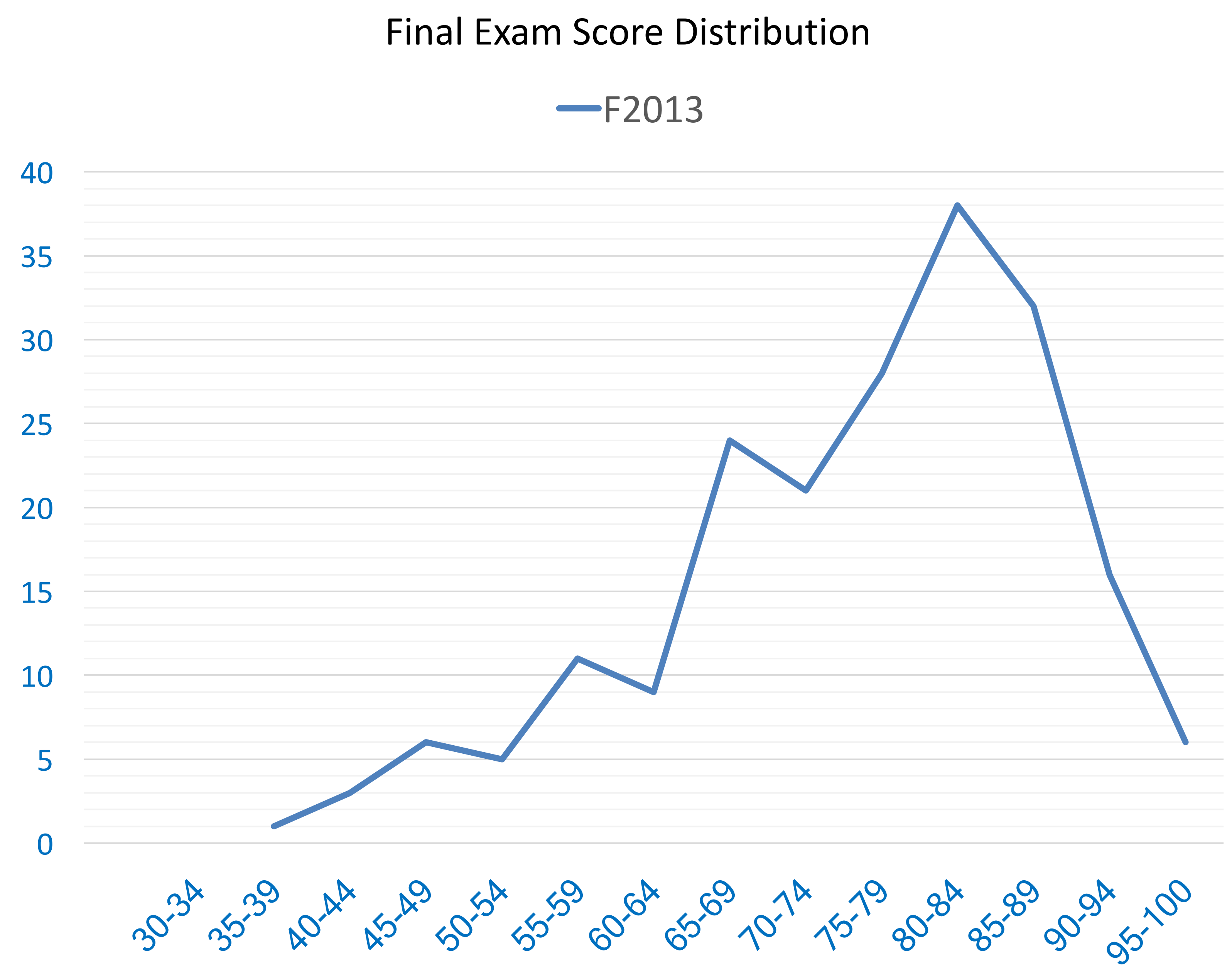
Summary Statistics for Student Outcomes in Organic Chemistry

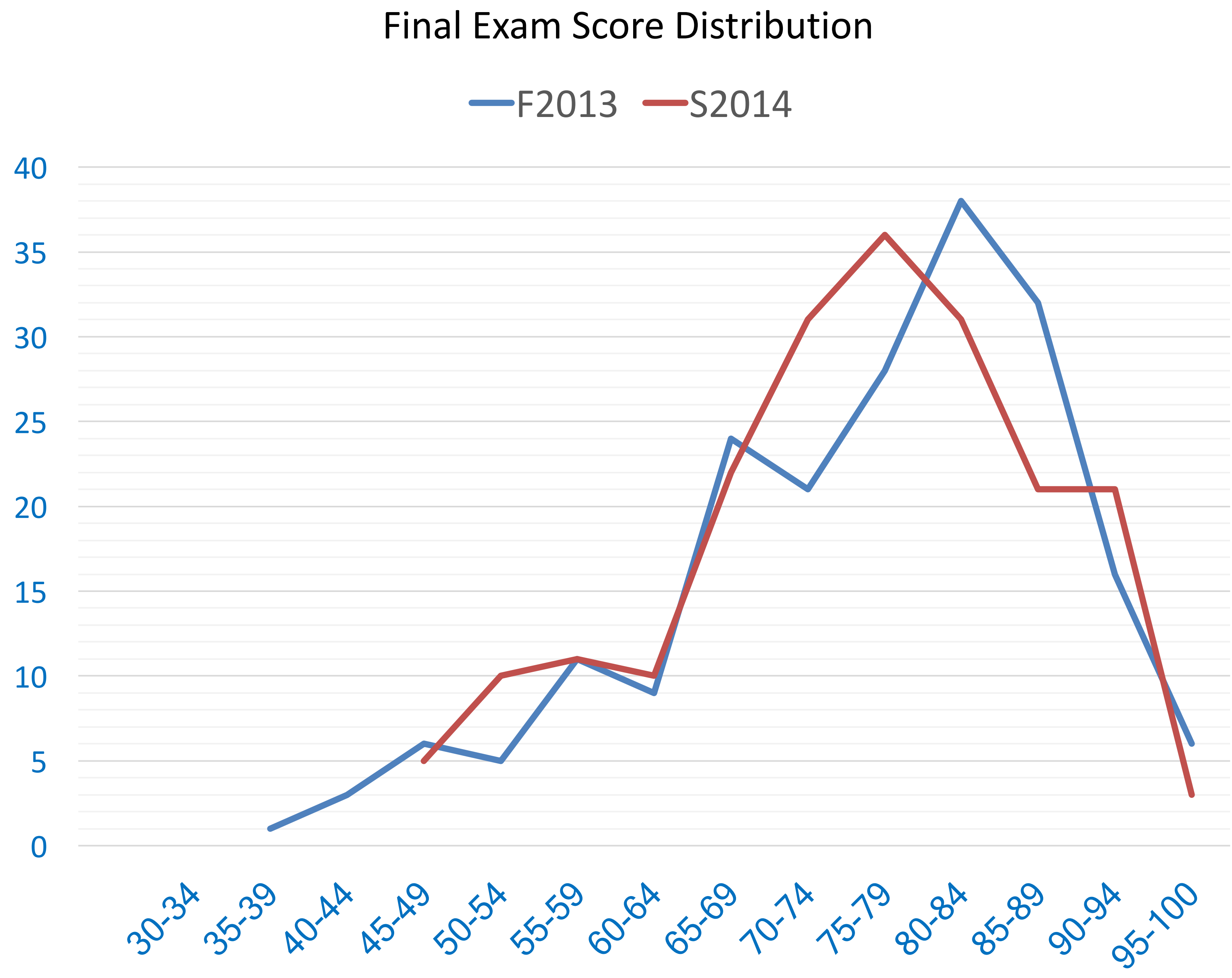
	Mean	Standard Deviation	Minimum	Maximum
Variable Comparison Group, N = 371 2002-2003				
Total points earned	204	37	73	288
Final grade	2.34	1.16	1	4
Final exam scores	64.52	13.08	29	92
SAT quantitative	652	65	440	800
SAT verbal	618	76	390	800
Treatment Group, N = 395 2013-2014				
Total points earned	229	36	73	288
Final grade	2.51	1.08	1	4
Final exam scores	74.66	12.82	33	98
SAT quantitative	670	69	350	800
SAT verbal	637	76	350	800

Crimmins, M. T.; Midkiff, B. *J. Chem. Ed.* **2017**, 429-438

CHEM 261 Final Exam Distribution 2002/2003




Final Exam Score Distribution
F2013
40
35
30
25
20
15
10
5
0
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
90-94
95-100



Final Exam Score Distribution
F2013
S2014
40
35
30
25
20
15
10
5
0
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
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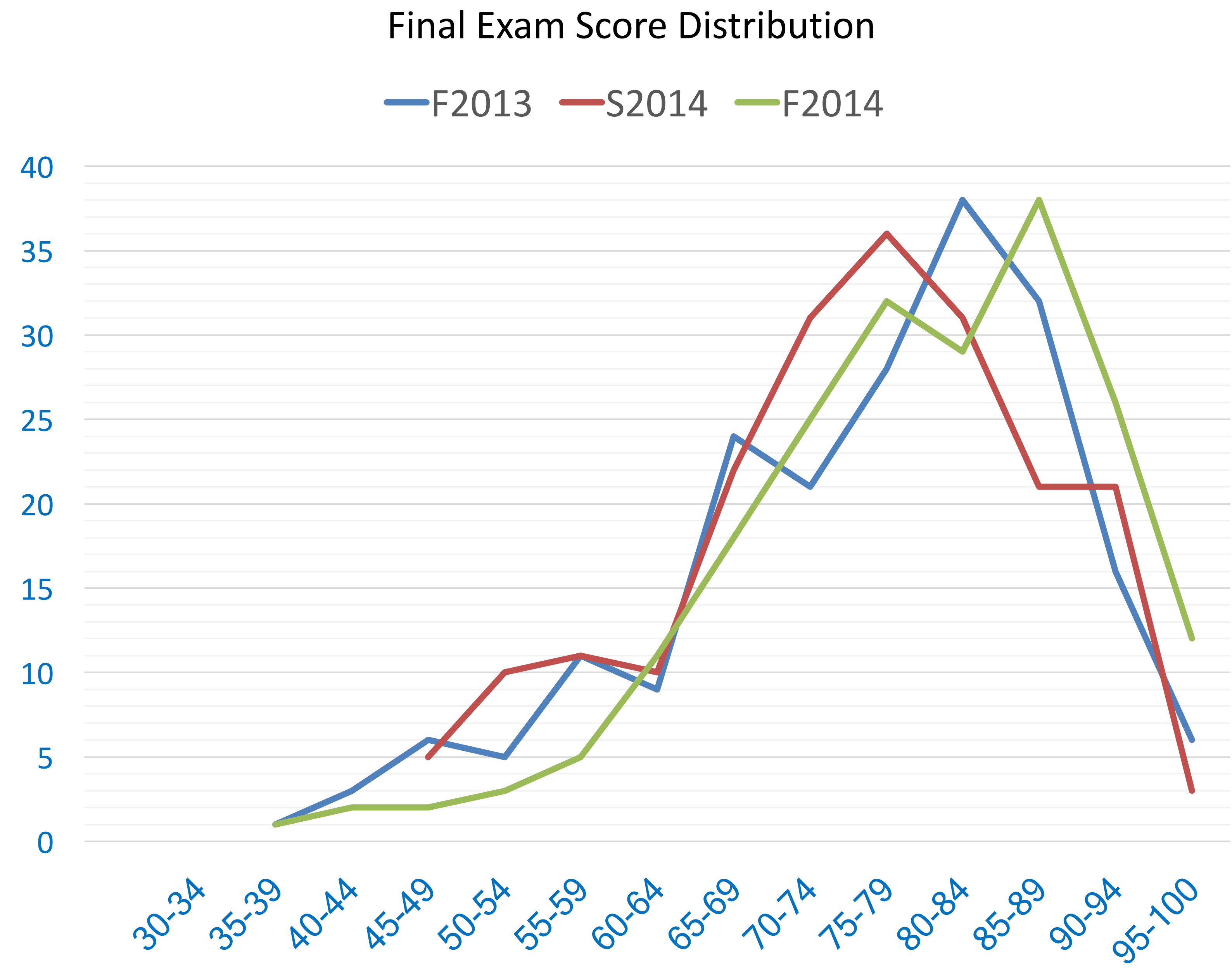
85-89
90-94
95-100



Final Exam Score Distribution
F2013
S2014
F2014
40
35
30
25
20
15
10
5
0
30-34
35-39
40-44
45-49
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55-59
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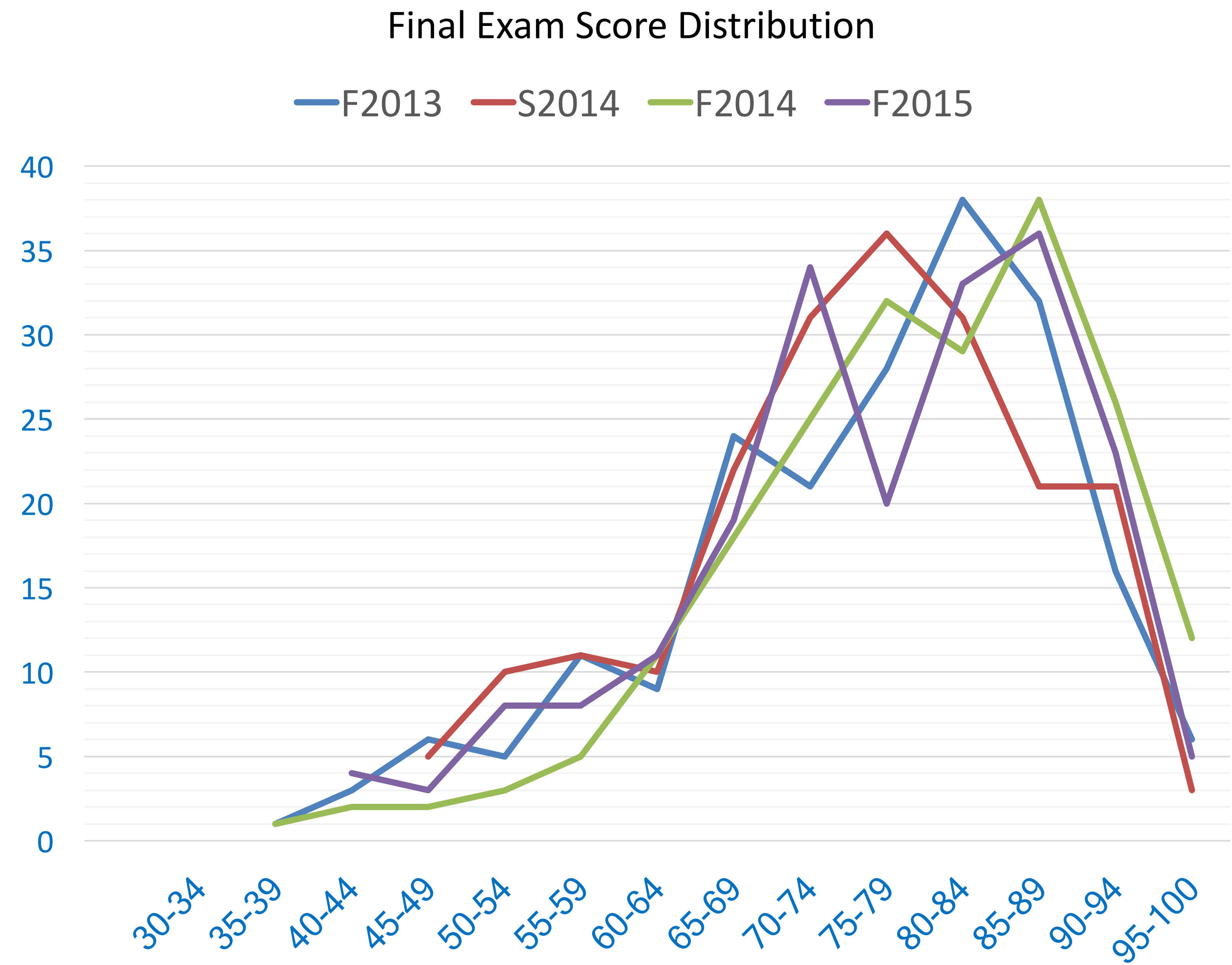
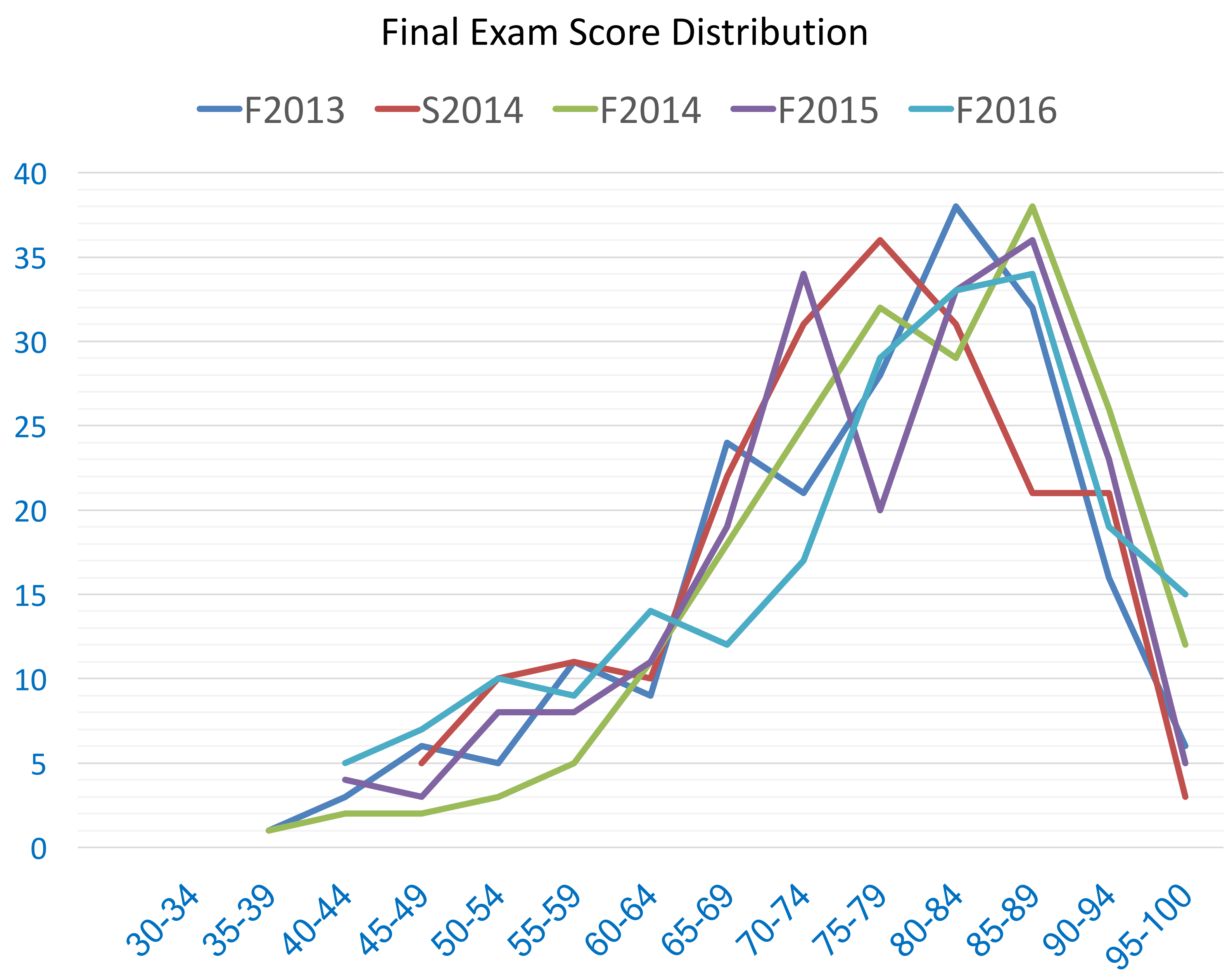
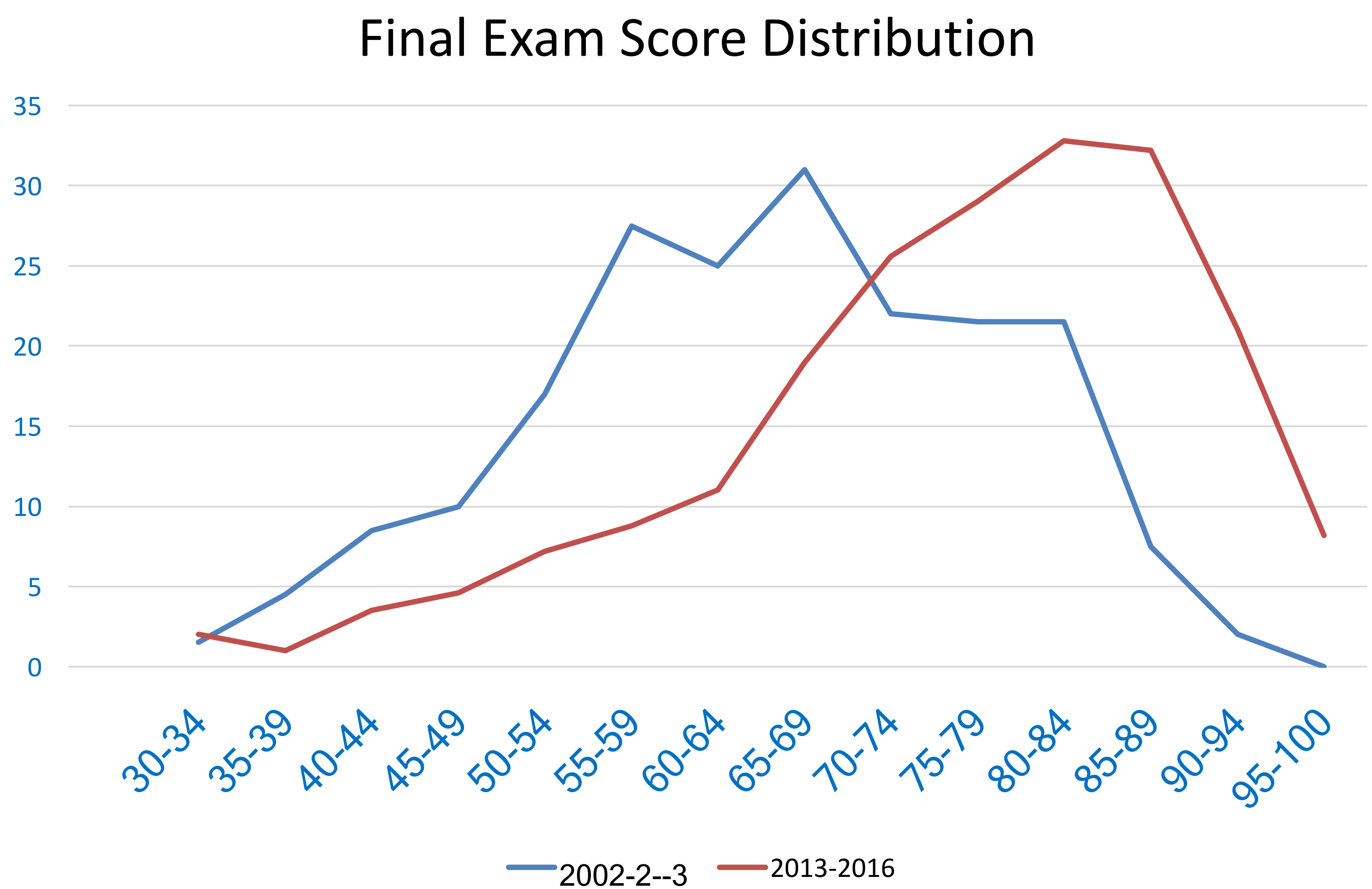
85-89
90-94
95-100



Final Exam Score Distribution
F2013
S2014
F2014
F2015
40
35
30
25
20
15
10
5
0
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
90-94
95-100



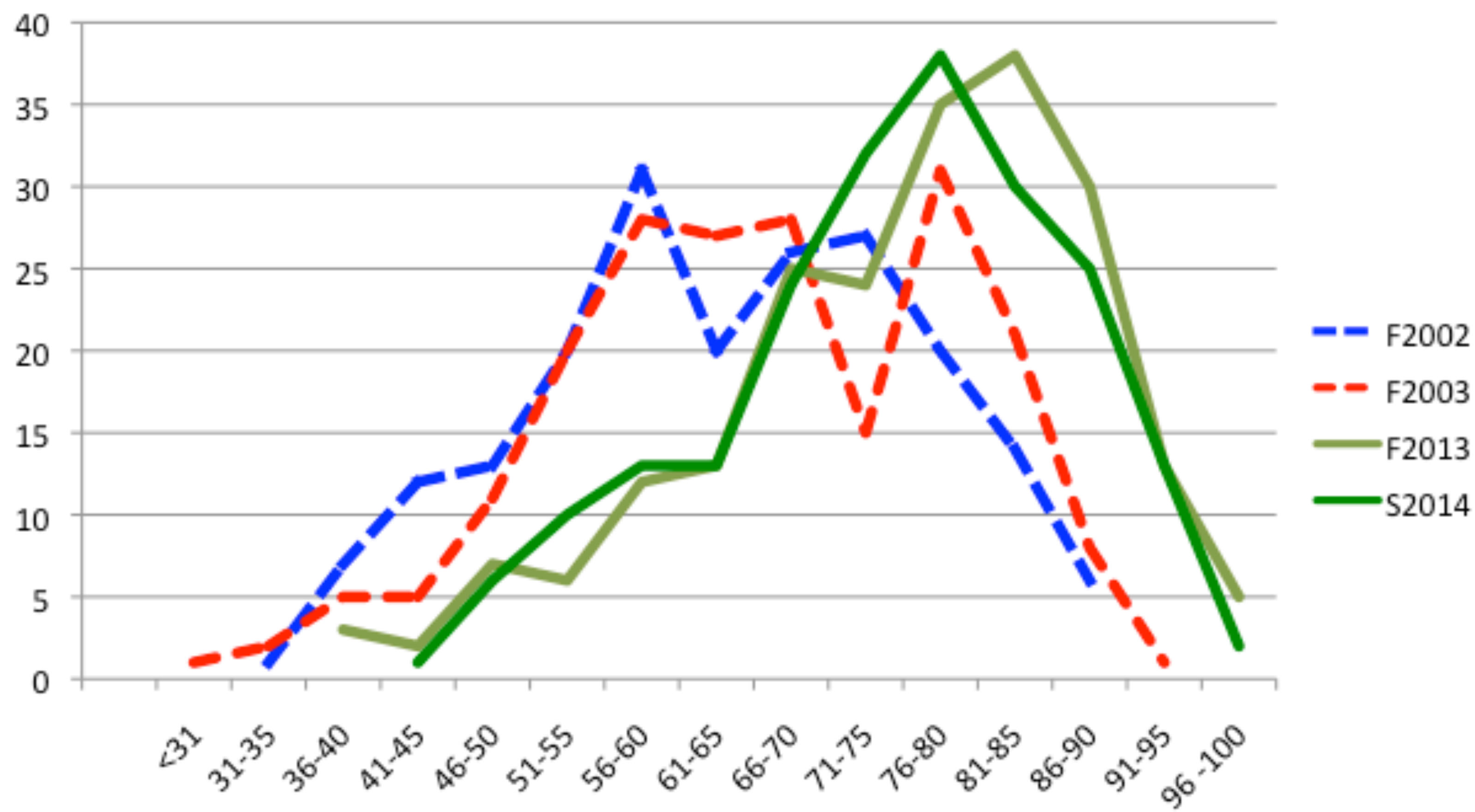
Final Exam Score Distribution
F2013
S2014
F2014
F2015
F2016
40
35
30
25
20
15
10
5
0
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
90-94
95-100



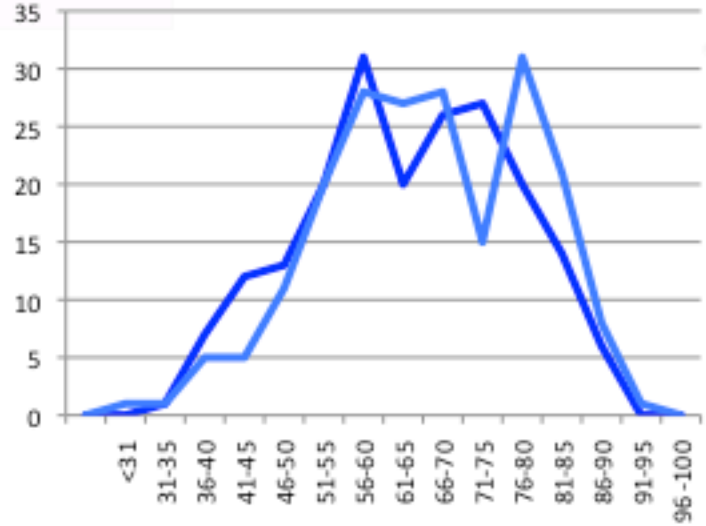
Final Exam Score Distribution
35
30
25
20
15
10
5
0
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
90-94
95-100
2002-2--3
2013-2016

CHEM 261 Final Exam Distribution 2013/2014

Fall 2013/Spring 2014: ave: 74.9 *reformed format*

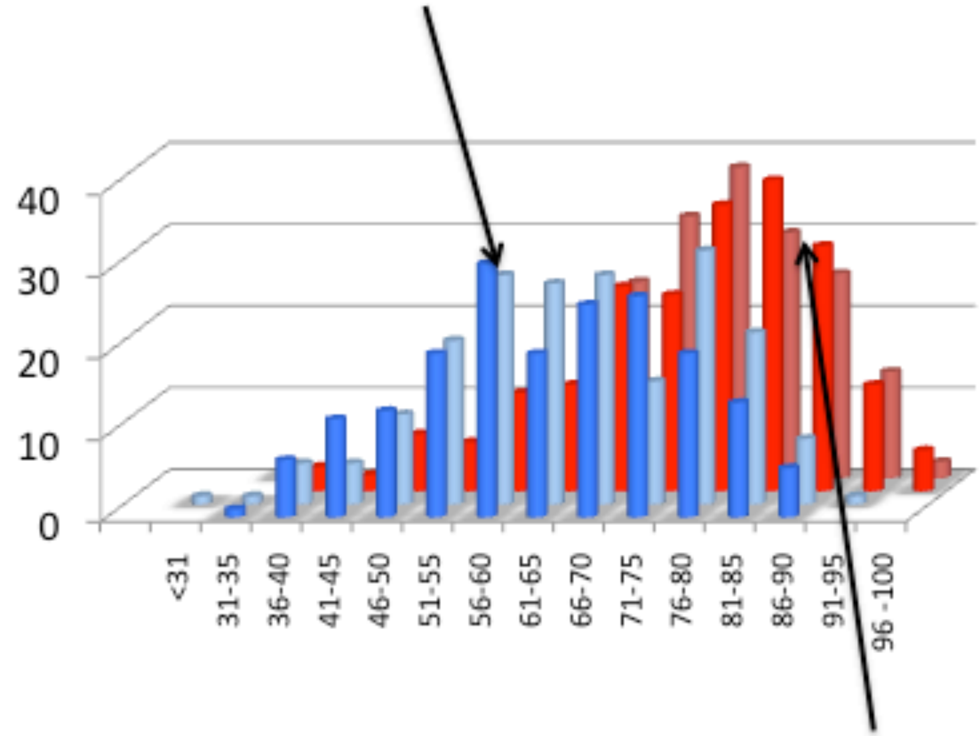


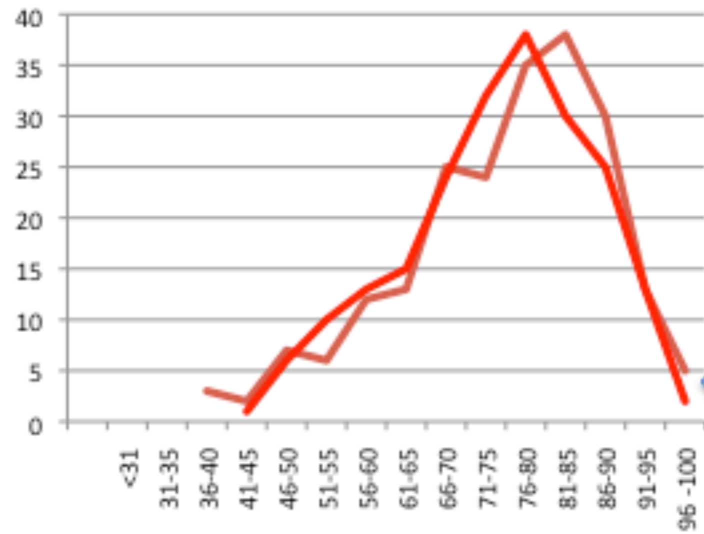
CHEM 261 Final Exam Distribution



Fall 2002: ave: 64.9 *traditional*

Fall 2003:





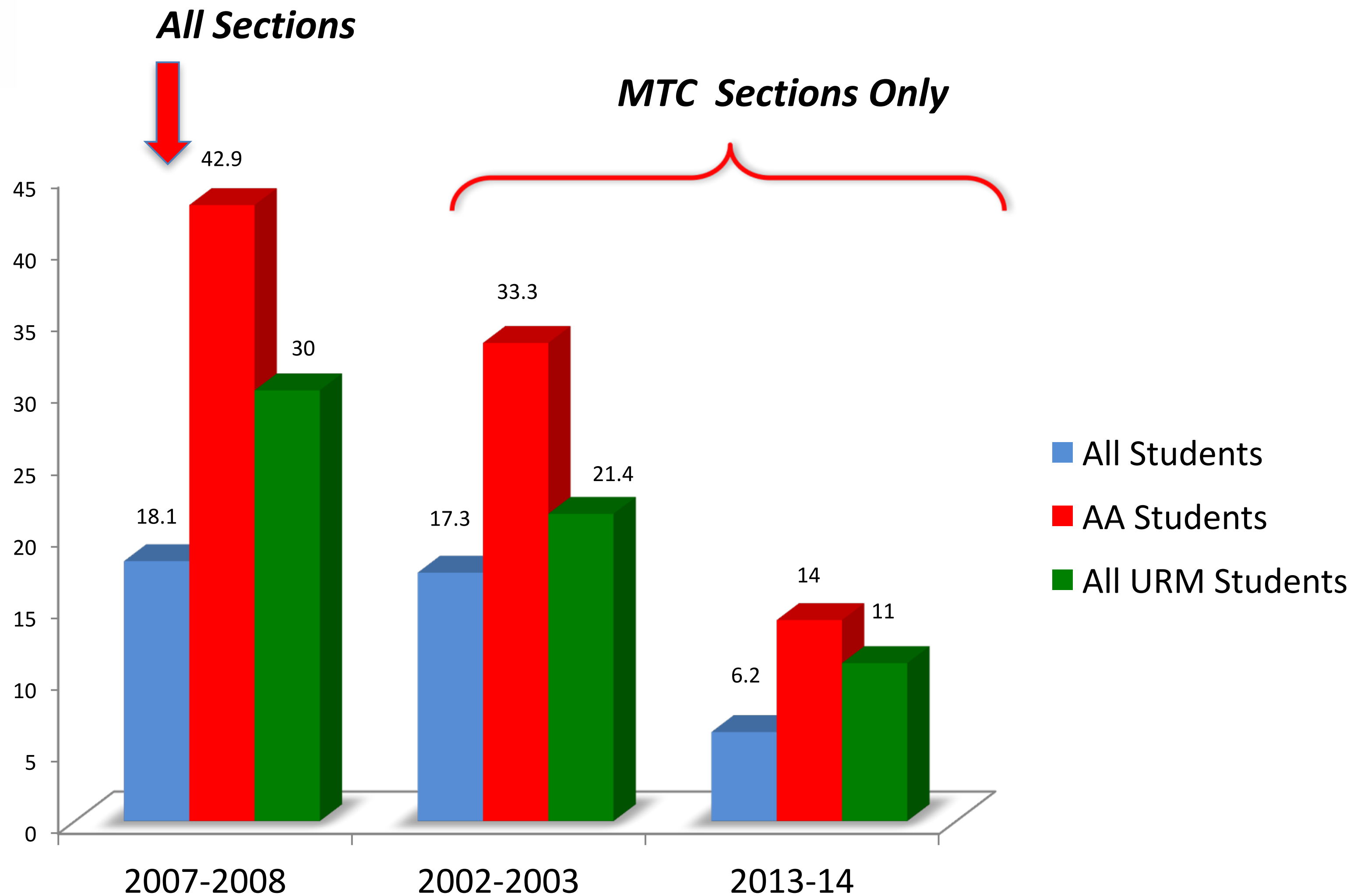
Fall 2013: ave: 74.9 *reformed*

Spring 2014:

CHEM 261 Final Exam Averages

• Fall 2002	63.7	Traditional format
• Fall 2003	66.1	
• Fall 2013	75.5	High Structure format
• Spring 2014	74.5	
• FALL 2014	78.6	
• Fall 2015	76.5	
• Fall 2016	76.3	

CHEM 261 D/F Rates %



Quantile Regression Analysis for Students' Final Exam Grades (N = 765)

Variable	25th percentile	50th percentile	75th percentile
Effect on Treatment Group	11.78 pts	10.49 pts	8.59 pts
Standard deviation	(1.57)	(1.17)	(1.35)
Confidence interval	8.71-14.85	8.20-12.78	5.94-11.23

$p < 0.01$

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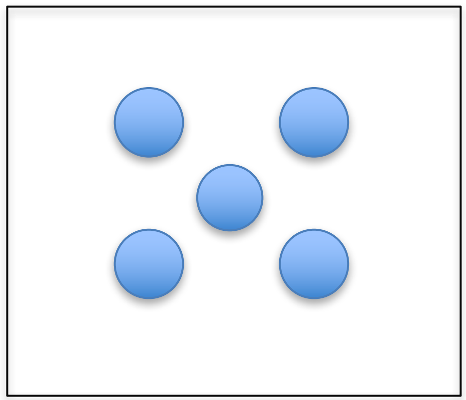
Thermal expansion

When metals heat up, they expand.

COLD

HOT

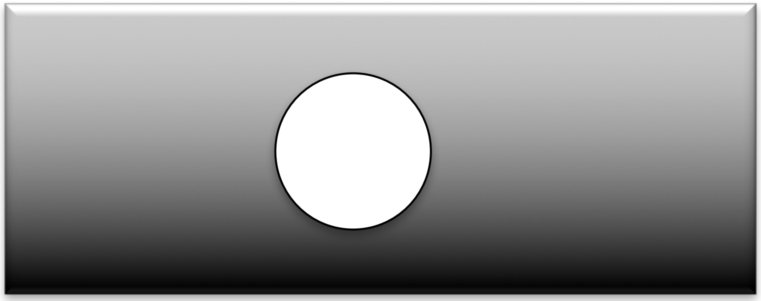


Conceptual questions test understanding, <u>not</u> memorization skills.

When metals heat up, they expand.

Consider a metal plate with a circular hole in it. If you heat the plate uniformly, what happens to the hole?

A. It decreases
B. It stays the same
C. It increases



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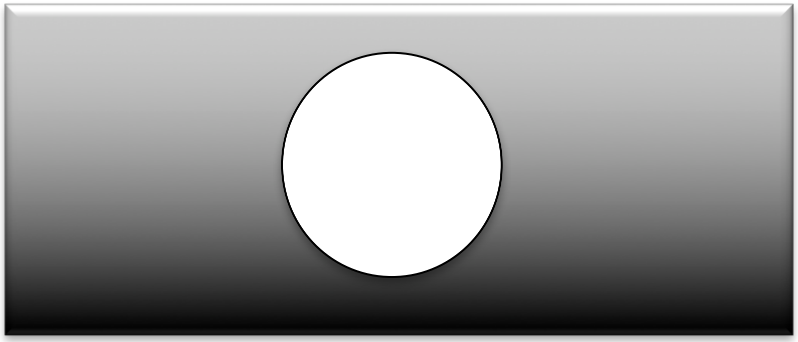
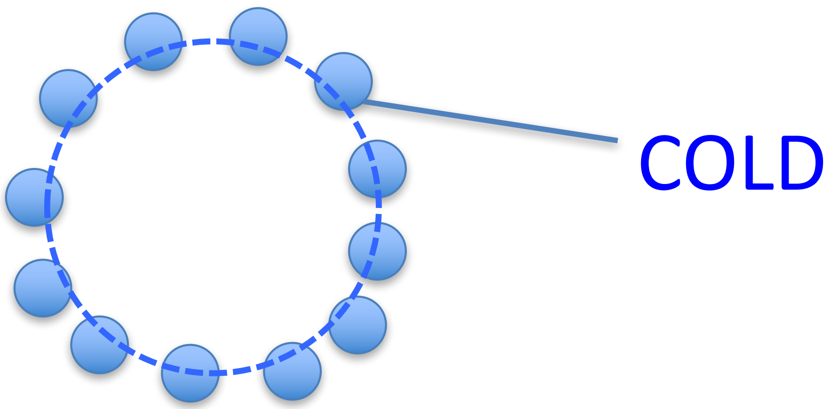
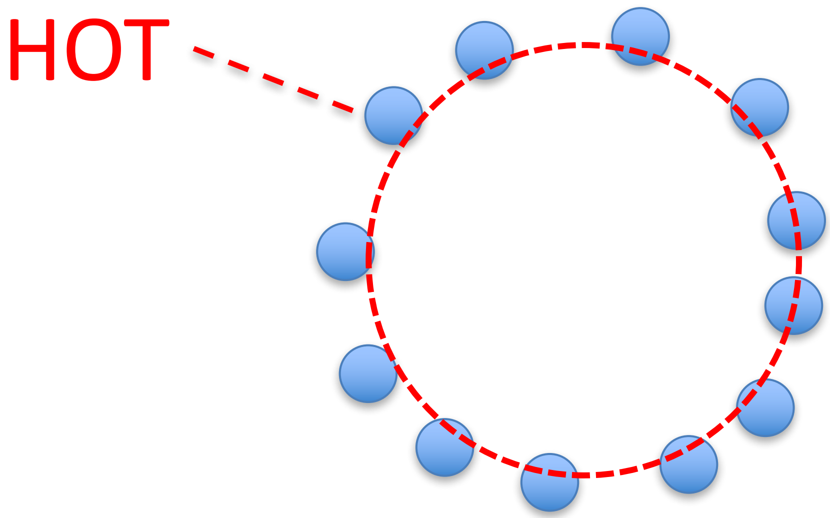


Thermal expansion



Thermal expansion



Thermal expansion