What the Hake?
Using Normalized Gain to Measure Student Learning

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Participant Learning Outcomes

Assumptions:

1. You have or know how to construct a pre/post assessment. (Research “Concept Inventories”[1-2])
2. If your course is a General Education (GE) course, you have identified questions in your pre/post assessment or will add questions that map to GE competency outcomes.

Participants will . . .

1. Define normalized (Hake) gain and explain how it can be a measure of student learning. **(Overview of normalized learning gains.)**
2. Articulate the **mathematical calculation** of Hake gain.
3. **Build and use an Excel spreadsheet to calculate** Hake gain for a pre/post assessment. *(Interactive example)*
4. Appropriately **interpret** a Hake gain score **in the contexts of** course and General Education **student learning outcomes**. (Closing the loop)

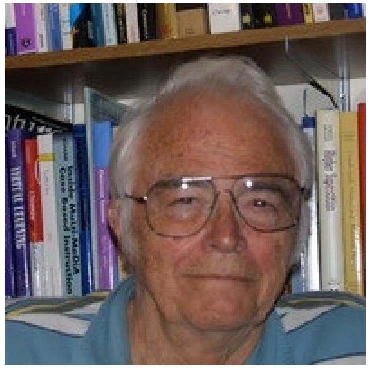
Learning Gain

Learning Gain - *Improvement in a student's learning* ***between the beginning and end*** *of a course.*[3]

- Single, final assessment (e.g. nationalized exams) not necessarily the most valuable
  - absolute result
- How do students benefit from their **time in class**?
  - academic quality
  - pedagogical/andragogical effectiveness
  - impact and value of higher education

What is Hake Gain?

- Richard Hake, Emeritus Professor of Physics, Indiana University
  - "... aware of the manifest failure of traditional university pedagogy to promote conceptual understanding."
  - 1998 landmark paper on Force Concept Inventory
    - 62 introductory physics courses (N = 6542 students)
    - greater gains in courses with interactive engagement methods



$$g = \frac{\text{post - pre}}{100\%\text{-pre}}$$

⟵ absolute improvement in student's score

⟵ how much the student could have improved

Normalized Learning Gain

Some examples …

$$g_+ = \frac{(S_f - S_i)}{(1 - S_i)}$$

N = 10 Δ = +1 Student

Si	Sf	g_+
1	2	0.11
5	6	0.20
7	8	0.33
9	10	1.00

Normalized Learning Gain

Protocol

- Students complete *in-class* pre-course / post-course diagnostic.
- $S_{i/f}$ = fraction of students who correctly answered pre-course / post-course.

- Normalized Learning Gain (Hake gain) is computed.
- Normalized Learning Gains are plotted against pre-course results.

Interactive Example
Using Excel to Calculate Hake Gain

Normalized Learning Gain
(also called Hake gain)

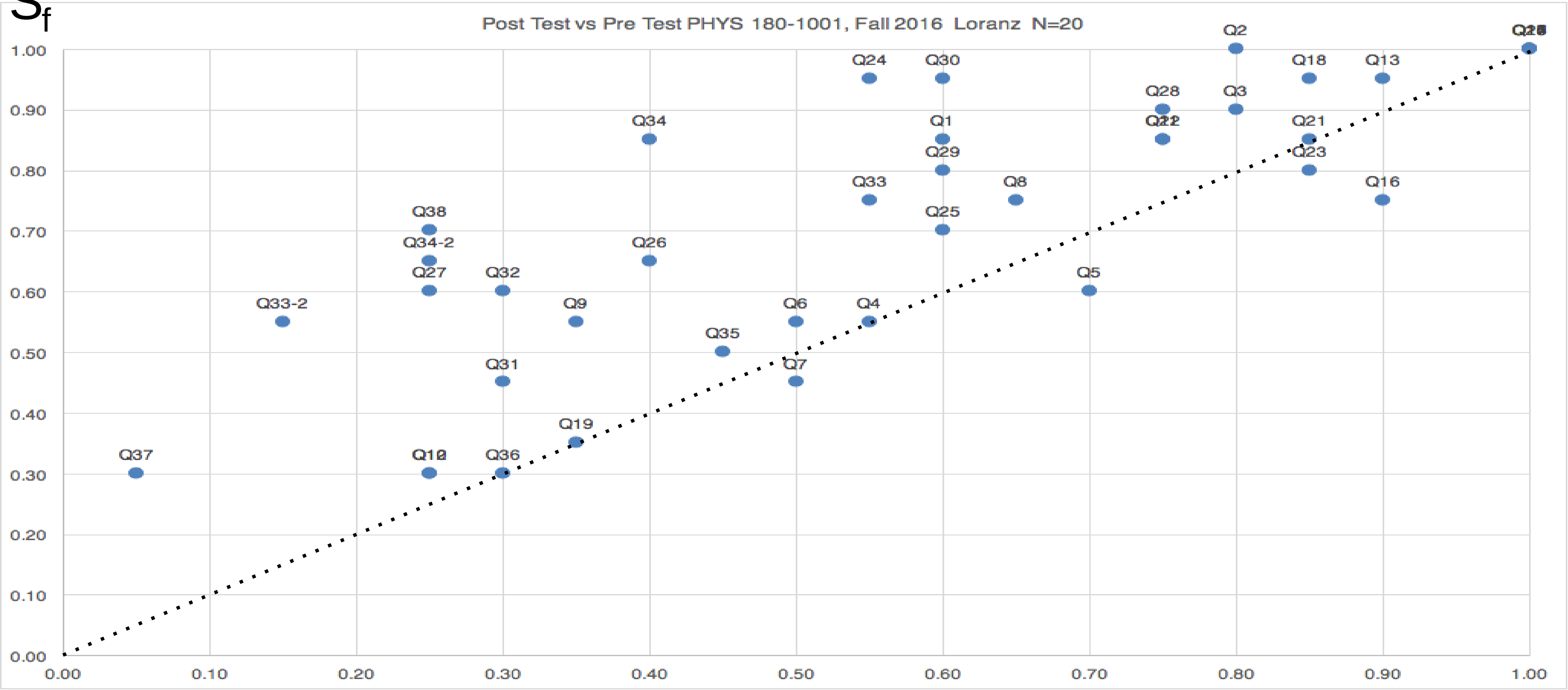
$$g_+ = \frac{\text{Measured Gain}}{\text{Max Possible Gain}} = \frac{(S_f - S_i)}{(1 - S_i)}$$

$$g_- = \frac{\text{Measured Loss}}{\text{Max Possible Loss}} = -\frac{|S_f - S_i|}{|0 - S_i|}$$

Why use Normalized Learning Gain?

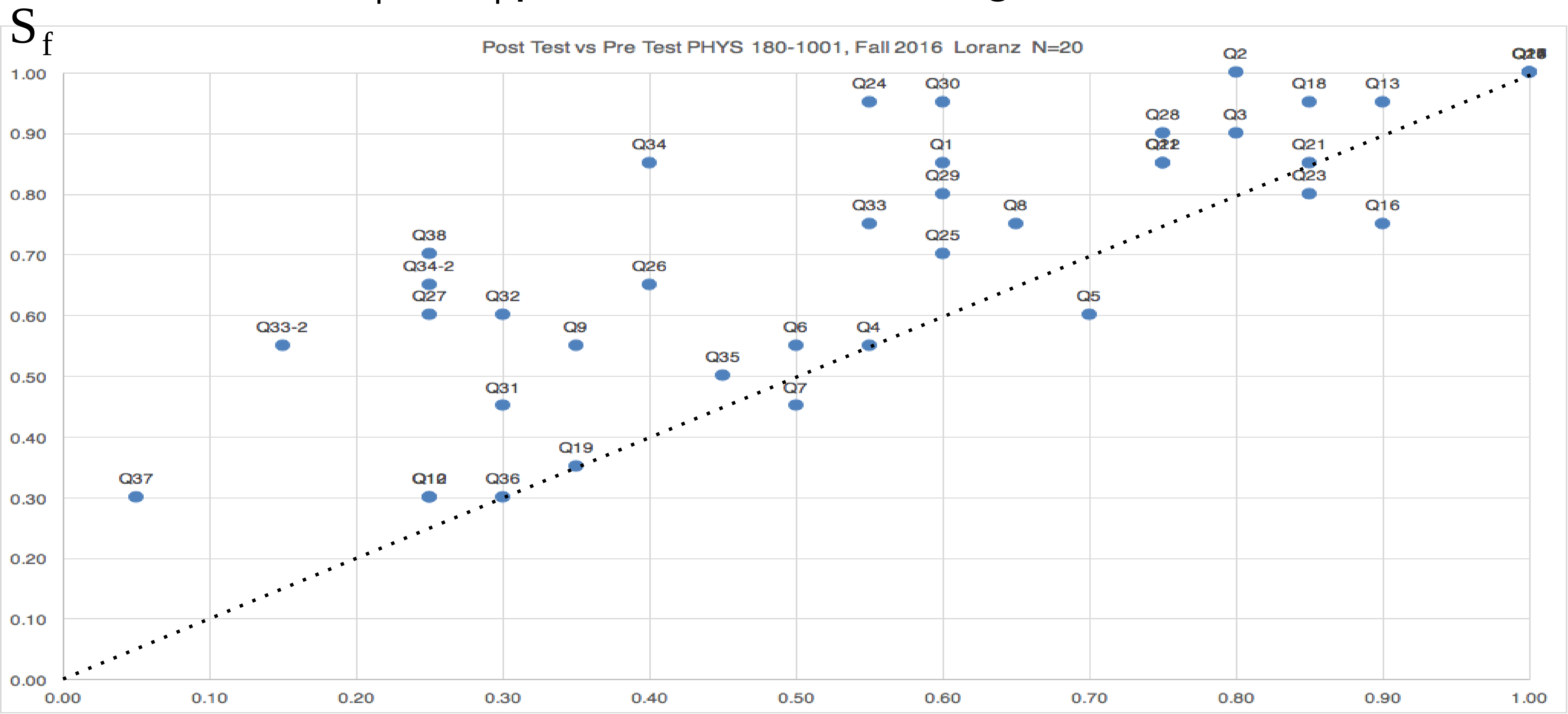
Why use Normalized Learning Gain?

S_f



S_i

S_f vs S_i plot shows absolute gain.



S_i

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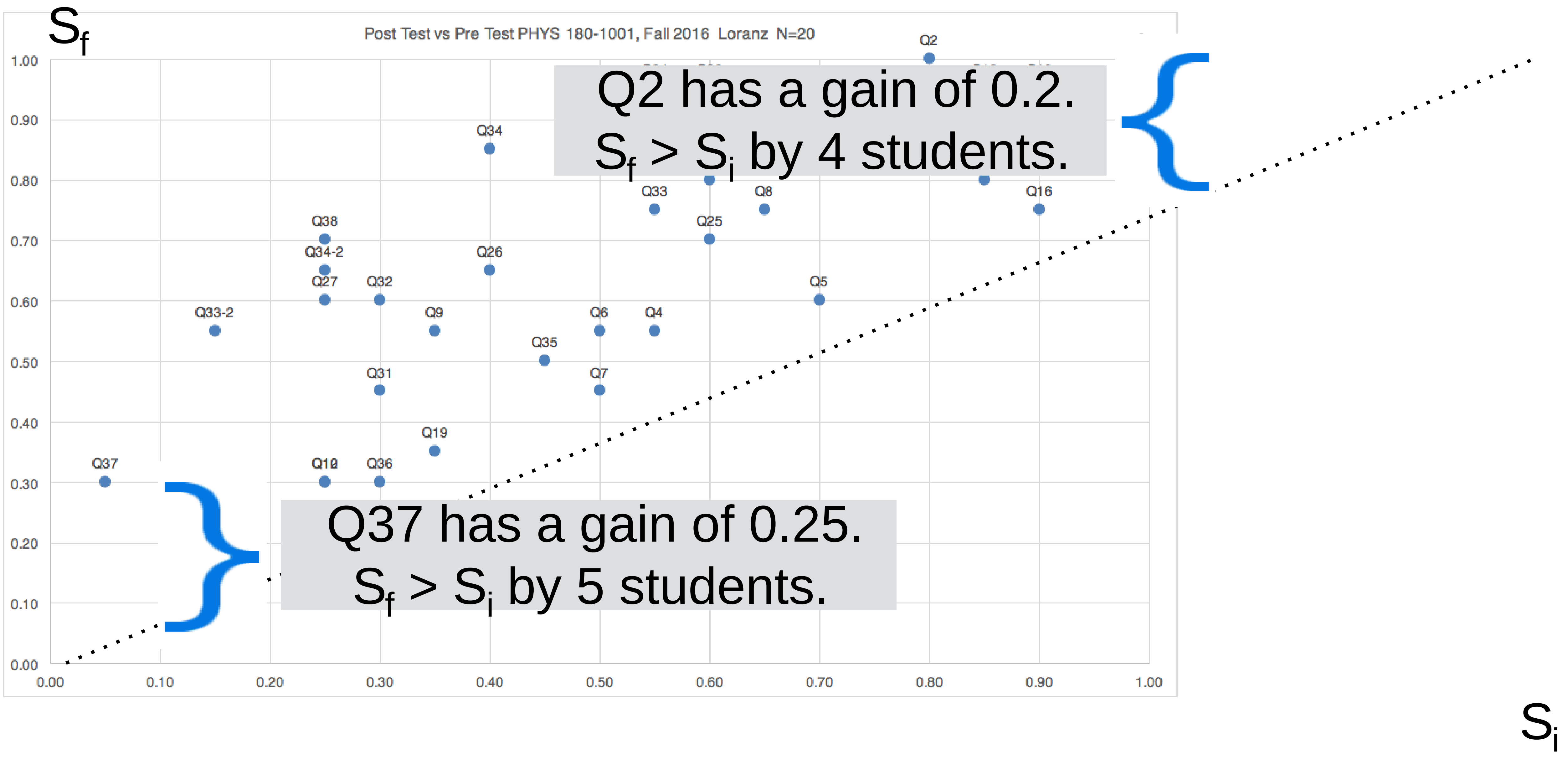
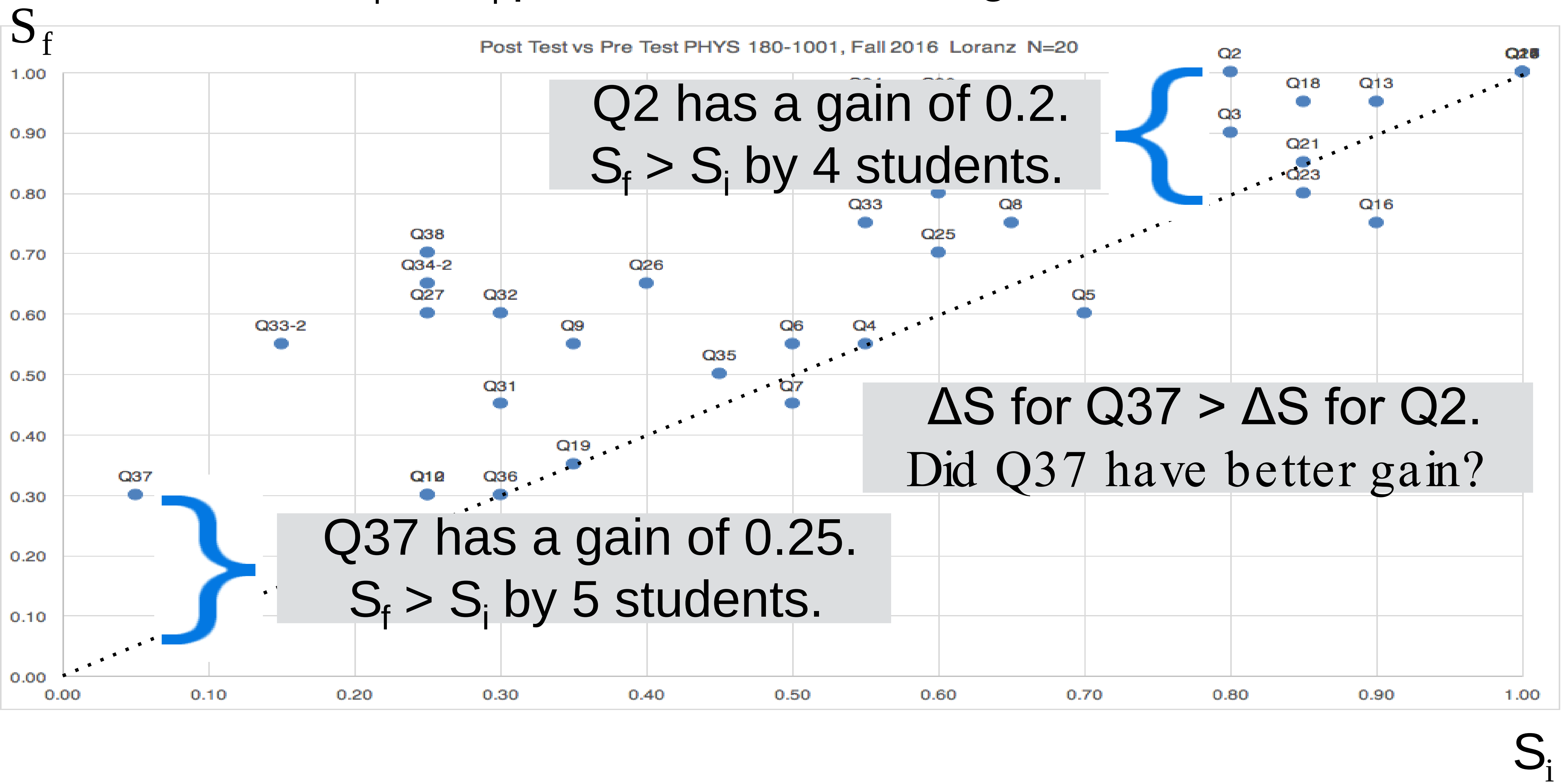
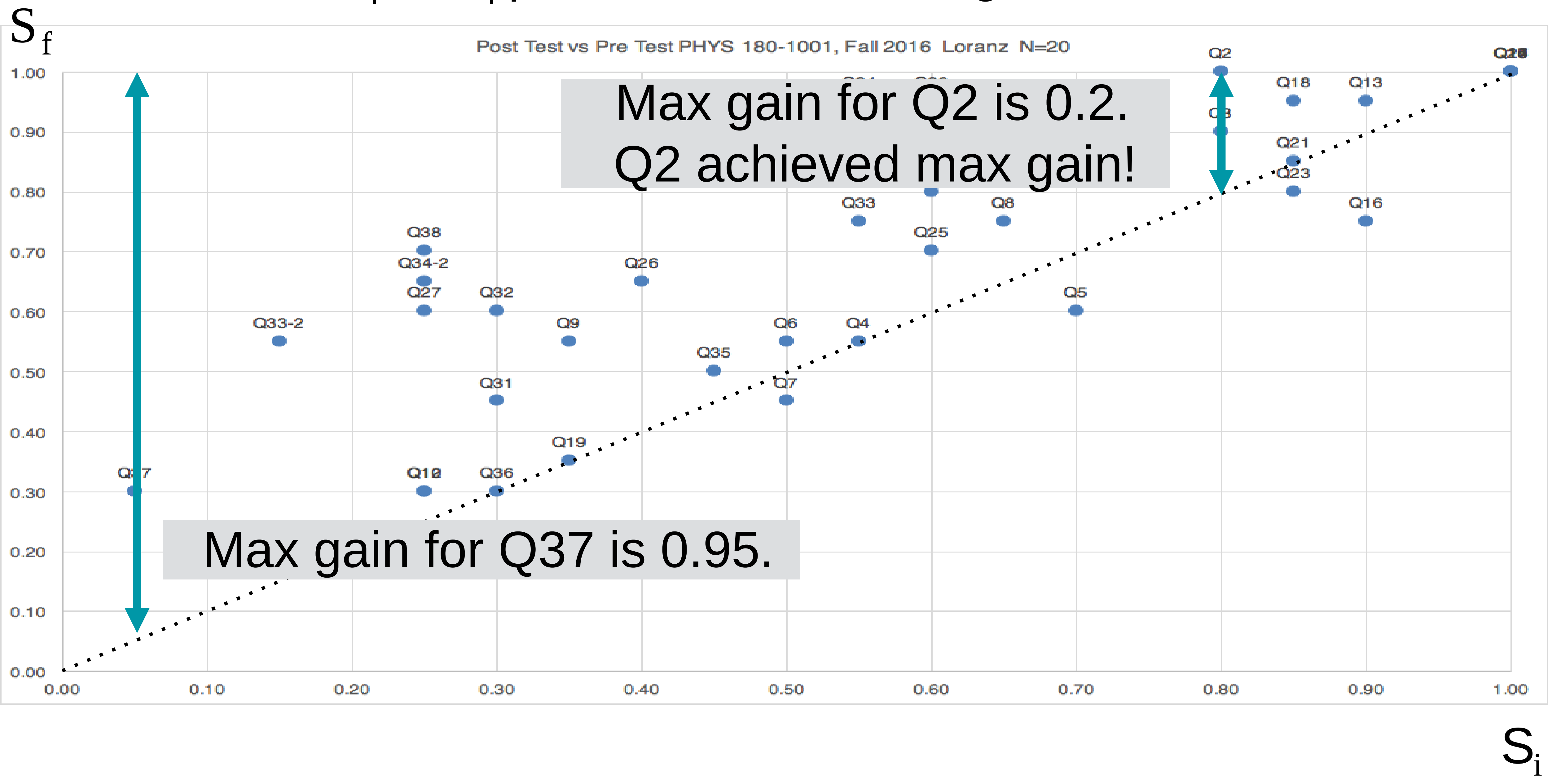


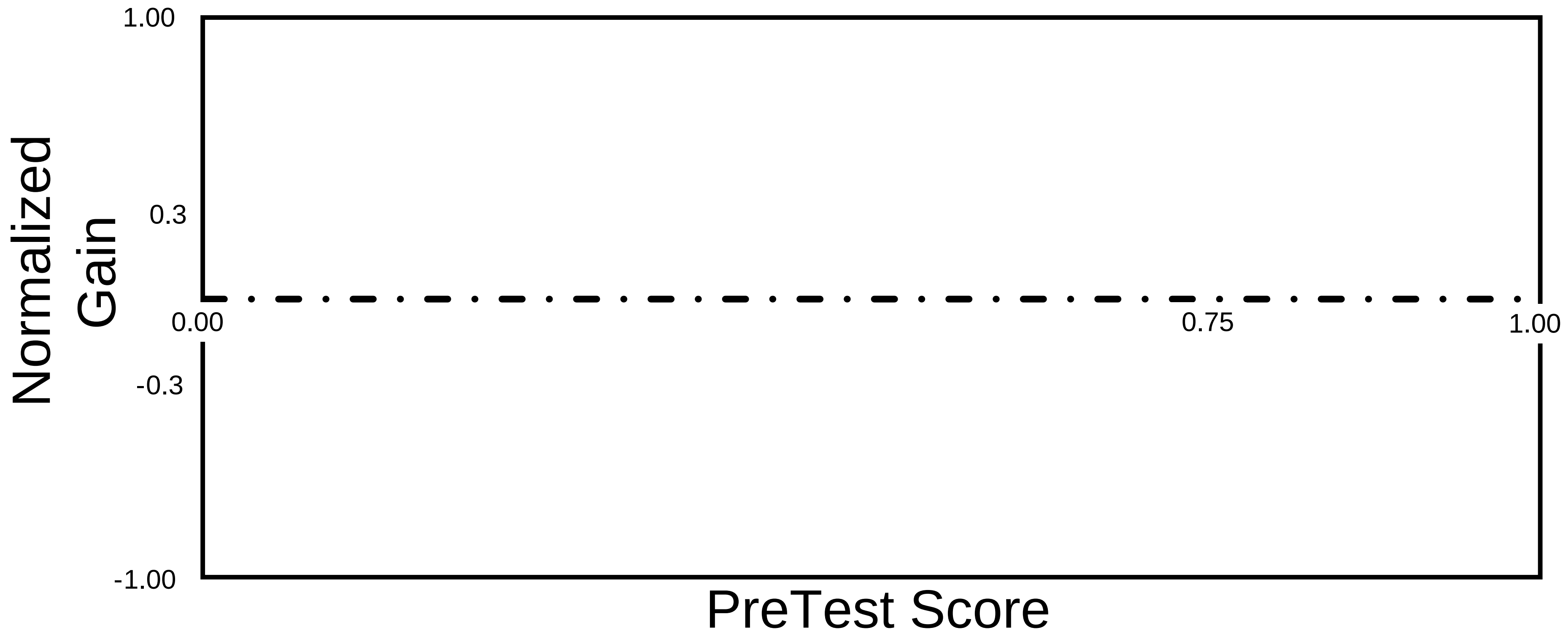
S_f vs S_i plot shows absolute gain.



S_f vs S_i plot shows absolute gain.



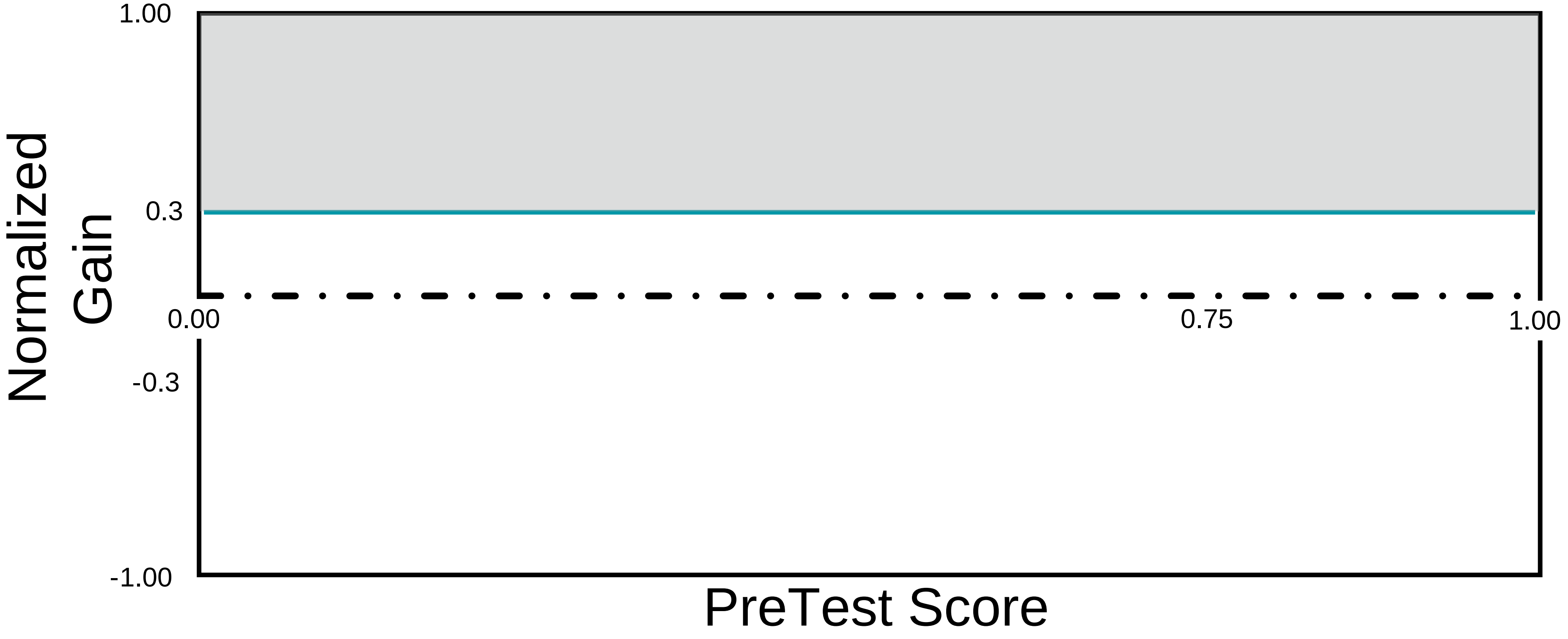
Plot Normalized Learning Gain vs S_r



Plot Normalized Learning Gain vs S_i

Take Note of …

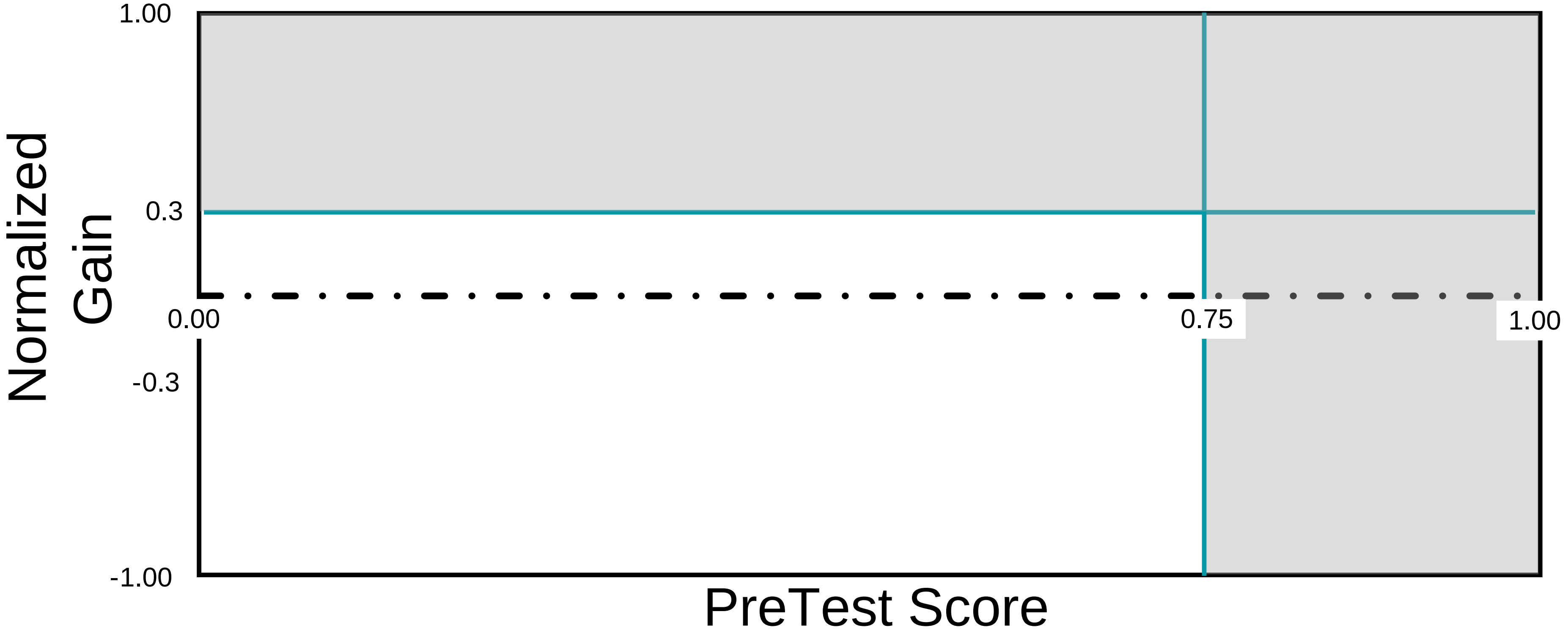
Normalized Gains less than 0.3 …



Plot Normalized Learning Gain vs S_i

Take Note of …

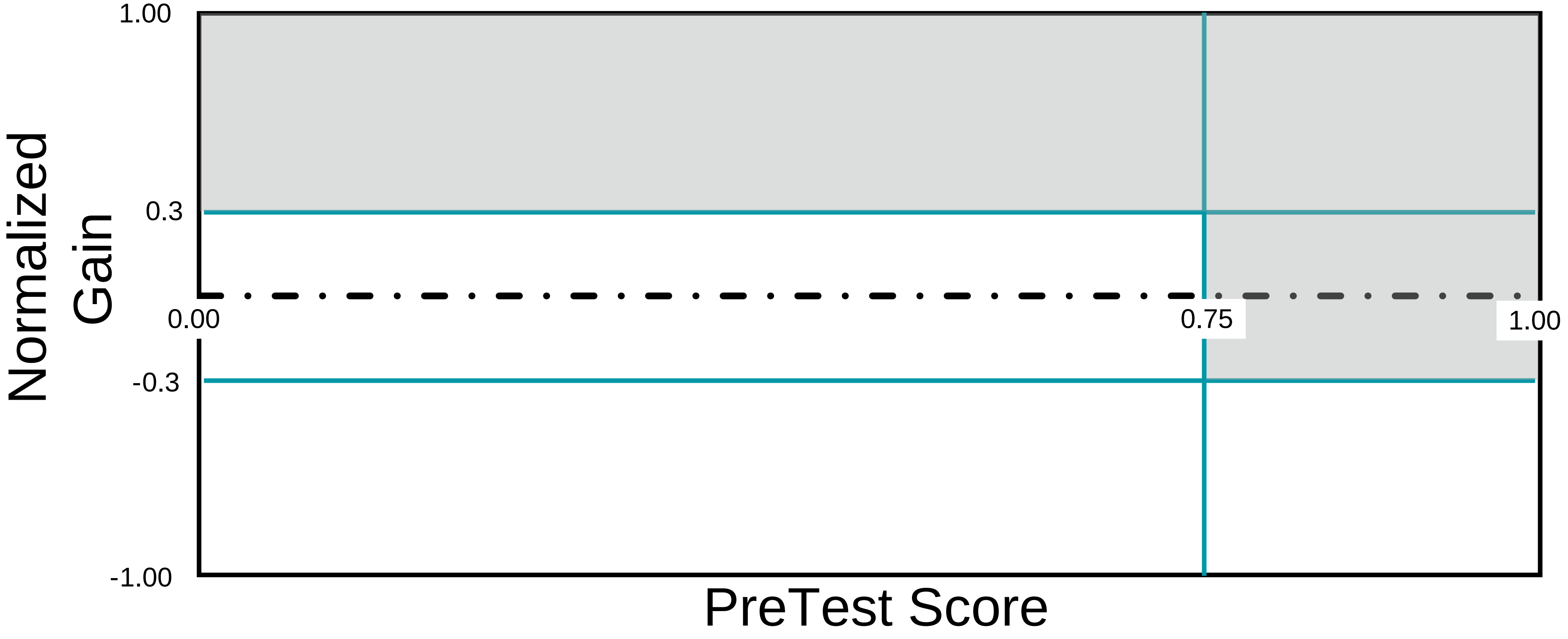
when $S_i < 0.75$ …



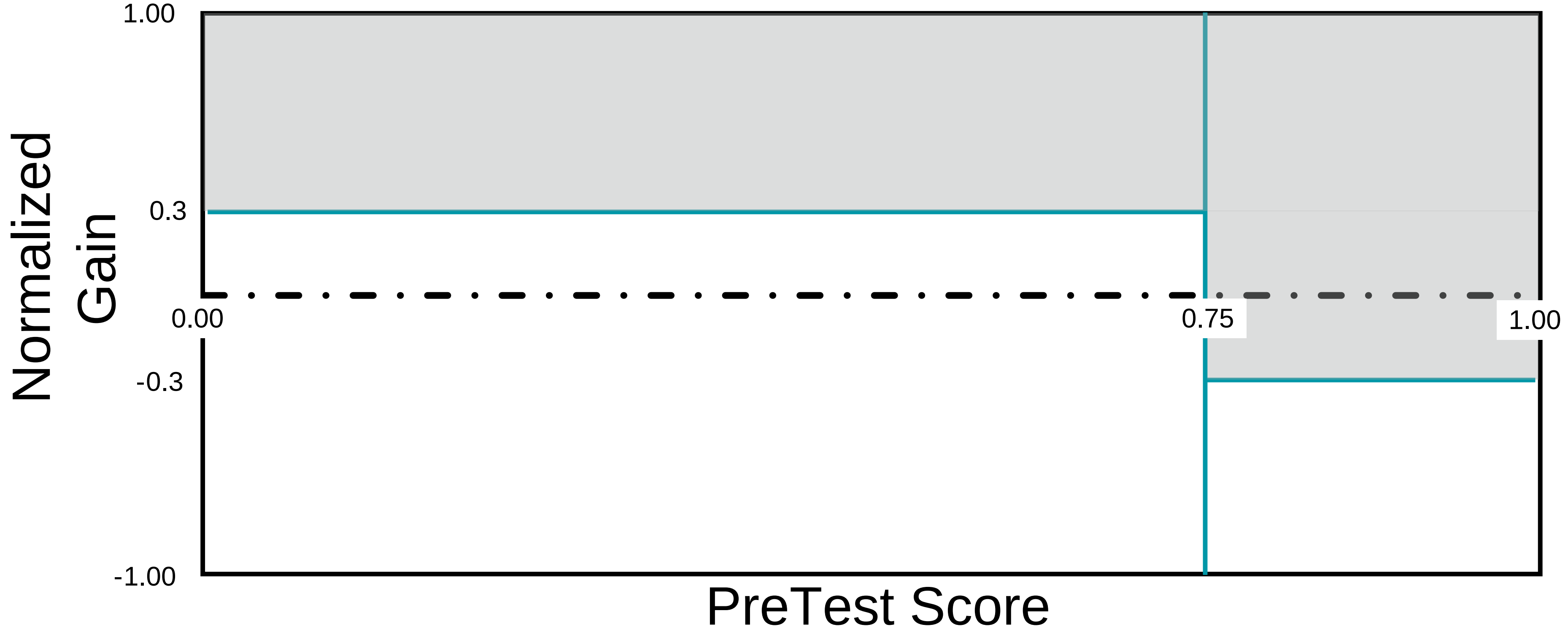
Plot Normalized Learning Gain vs S_i

Take Note of …

and also when normalized loss < −.3



Plot Normalized Learning Gain vs S_r



PHYS 180/180L & PHYS 151 Assessment

Section

PHYS 180 - 1001 Spring 2017

PHYS 180 - 1001 Fall 2016

PHYS 180 - 1002 Fall 2016

PHYS 151 - 1001 Spring 2017

PHYS 151 - 2001 Spring 2017

PHYS 151 - 1001 Fall 2016

PHYS 151 - 2001 Fall 2016

For CAR, looking at course topics.

For GEAR, looking at Gen Ed Competencies.

$S_{i/f}$ can be … Question Scores ***OR*** Student Scores.

Normalized Learning Gain

$$g_+ = \frac{\text{Measured Gain}}{\text{Max Possible Gain}} = \frac{(S_f - S_i)}{(1 - S_i)}$$

$$g_- = \frac{\text{Measured Loss}}{\text{Max Possible Loss}} = -\frac{|S_f - S_i|}{|0 - S_i|}$$

PHYS 180/180L & PHYS 151 Assessment

Gen Ed Assessment

Gen Ed Protocol

- Students complete ***in-class*** pre-course / post-course diagnostic.
- Calculate normalized learning gain (g) for each student.
- Categorize learning gains according to Gen Ed Rubric.

Exemplary is	$g \geq 0.5$
Proficient is	$0.3 < g < 0.5$
Marginal is	$0 \leq g \leq 0.3$
Unacceptable is	$g < 0$

PHYS 180/180L & PHYS 151 Assessment

Gen Ed: Quantitative Reasoning #1

Students will use the mathematics appropriate to a particular problem to obtain correct solutions.

PHYS 180/180L & PHYS 151 Assessment

Gen Ed: Quantitative Reasoning #1

Students will use the mathematics appropriate to a particular problem to obtain correct solutions.

2. Catherine is hired to paint the ceiling of her aunt's living room. She covers the ceiling with a uniform coat of paint. The ceiling has a surface area of 580 square feet. After finishing, Catherine notes that she used 2.4 gallons of paint. Catherine divides 580 by 2.4 and gets 241.7.

   Which of the following statements about the number 241.7 is true?

   a. 241.7 is the total number of gallons of paint used.
   b. 241.7 is the total number of square feet of surface area covered by the paint.
   c. 241.7 is the number of gallons of paint that covers one square foot.
   d. 241.7 is the number of square feet that one gallon of paint covers.
   e. None of the above.

PHYS 180/180L & PHYS 151 Assessment

Gen Ed: Quantitative Reasoning #1

Students will use the mathematics appropriate to a particular problem to obtain correct solutions.

25 of 40 questions from diagnostic fit GE: QR#1.

Gen Ed: QR#1	Exemplary	Proficient	Marginal	Unacceptable
PHYS 180/180L 1001 Spring 2017 (24)	8%	21%	50%	21%
PHYS 180/180L 1001 Fall 2016 (20)	15%	25%	45%	15%
PHYS 180/180L 1002 Fall 2016 (14)	8%	21%	57%	14%
PHYS 151 1001 Spring 2017 (10)	10%	0%	40%	50%
PHYS 151 2001 Spring 2017 (11)	9%	0%	73%	18%
PHYS 151 1001 Fall 2016 (16)	13%	13%	69%	5%
PHYS 151 2001 Fall 2016 (9)	45%	11%	33%	11%

PHYS 180/180L & PHYS 151 Assessment

Gen Ed: Quantitative Reasoning #5

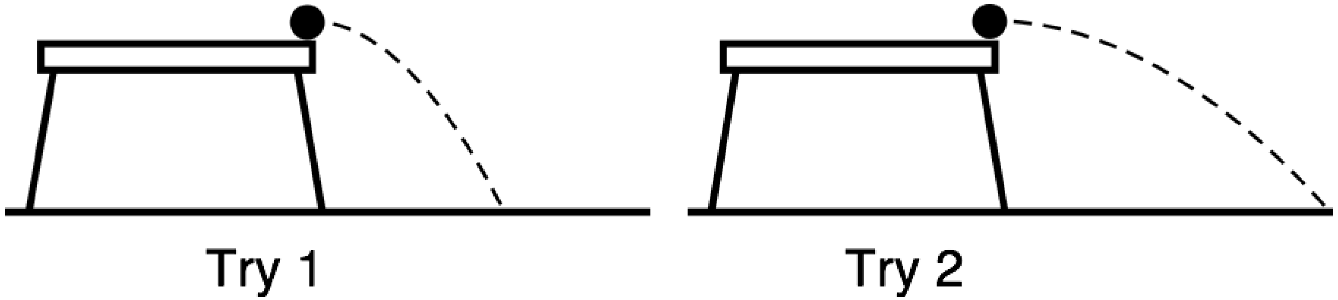
Students will deduce the consequences of a particular model under different contexts, scenarios, and/or constraints.

PHYS 180/180L & PHYS 151 Assessment

Gen Ed: Quantitative Reasoning #5

Students will deduce the consequences of a particular model under different contexts, scenarios, and/or constraints.

24. In two tries of an experiment, a ball is knocked horizontally off a table. In Try 2 the ball is knocked twice as hard as in Try 1 and so lands farther from the table. In which try is the ball in the air for a longer time before hitting the floor?



a. The ball is in the air longer for Try 1.
b. The ball is in the air longer for Try 2.
c. The ball is in the air for the same amount of time for both tries.
d. There is not enough info to answer this question.

PHYS 180/180L & PHYS 151 Assessment

Gen Ed: Quantitative Reasoning #5

Students will deduce the consequences of a particular model under different contexts, scenarios, and/or constraints.

13 of 38 questions from diagnostic fit GE: QR#5.

Gen Ed: QR#5	Exemplary	Proficient	Marginal	Unacceptable
PHYS 180/180L 1001 Spring 2017 (24)	42%	17%	38%	3%
PHYS 180/180L 1001 Fall 2016 (20)	50%	10%	40%	0%
PHYS 180/180L 1002 Fall 2016 (14)	79%	7%	7%	7%
PHYS 151 1001 Spring 2017 (10)	10%	10%	60%	20%
PHYS 151 2001 Spring 2017 (11)	9%	27%	64%	0%
PHYS 151 1001 Fall 2016 (16)	25%	6%	56%	13%
PHYS 151 2001 Fall 2016 (9)	45%	33%	22%	0%

Interpretations of Hake Gain

Using Hake Gain allows us to

- Determine how many students display learning gains in a topic (allow reporting for GEARS).
- Look for areas where we as individuals can influence student success or are doing well.
- Make comparisons between sections of courses to look for effective teaching strategies.
- Allow for analysis of the diagnostic to see if it is an effective measure of learning.

Caveats: *The analysis is NOT statistically rigorous and should not be used as a method of teaching evaluation.*

Interpretations of Hake Gain

1) Determine how many students display learning gains in a topic (allow reporting for GEARS).

From the data just processed (NormGain-Final), we can see that

- 8% of the students scored as exemplary
- 21% of the students scored as proficient
- 50% of the students scored as marginal
- 21% of the students scored as unacceptable

Exemplary is	$g \geqslant 0.5$
Proficient is	$0.3 < g < 0.5$
Marginal is	$0 \leq g \leq 0.3$
Unacceptable is	$g < 0$

Interpretations of Hake Gain

2) Look for areas where we as individuals can influence student success or are doing well.

3) Make comparisons between sections of courses to look for effective teaching strategies.

Interpretations of Hake Gain

2) Look for areas where we as individuals can influence student success or are doing well.

3) Make comparisons between sections of courses to look for effective teaching strategies.

These are both part of “Closing the Loop”

CHEM 122 Spring 2017	1001		1003		2001		All sections	
Topic	**Raw**	**Hake**	**Raw**	**Hake**	**Raw**	**Hake**	**Raw**	**Hake**
Buffer composition ^	72%	0.674	64%	0.613	31%	0.225	60%	0.551
Catalysts and reaction profiles ^	52%	0.442	27%	0.151	62%	0.542	45%	0.353
Chemical equilibrium concepts ^	76%	0.662	77%	0.623	77%	0.41	77%	0.61
Colligative properties*^	40%	0.063	41%	-0.18	46%	0.115	42%	0
Colligative properties and molar mass*	24%	0.208	45%	0.409	23%	0.135	32%	0.269
Conjugate Acids/Bases	76%	0.556	82%	0.667	62%	0.377	75%	0.545
Electrochemistry and spontaneity ^	48%	0.342	45%	0.304	38%	-0.016	45%	0.257
Electrolytic processes *	36%	0	41%	0.28	31%	0.042	37%	0.137
Entropy and chemical reactions	56%	0.527	77%	0.753	54%	0.483	63%	0.598
Entropy of phase changes *	44%	0.349	68%	0.64	85%	0.808	62%	0.553
Equilibrium constants*	76%	0.647	86%	0.803	85%	0.808	82%	0.75

CHEM 122 Spring 2017	1001		1003		2001		All sections	
Topic	**Raw**	**Hake**	**Raw**	**Hake**	**Raw**	**Hake**	**Raw**	**Hake**
Chemical equilibrium concepts ^	76%	0.662	77%	0.623	77%	0.41	77%	0.61

Interpretation:

We're doing well in all sections of this course. Students are understanding this concept and showing good learning gains.

Question to ask: Since students are doing well, do we want to continue to test this particular topic?

CHEM 122 Spring 2017	1001		1003		2001		All sections	
Topic	**Raw**	**Hake**	**Raw**	**Hake**	**Raw**	**Hake**	**Raw**	**Hake**
Electrolytic processes *	36%	0	41%	0.28	31%	0.042	37%	0.137

Interpretation:

We’re are not doing well on this topic. Why?

- Topic is the very last one we cover in the semester...are faculty rushing to complete it? Are students just exhausted?
- Is the topic one with which students historically struggle?
- Is the question an appropriate measure of the topic?

CHEM 122 Spring 2017	**1001**		**1003**		**2001**		**All sections**	
Topic	**Raw**	**Hake**	**Raw**	**Hake**	**Raw**	**Hake**	**Raw**	**Hake**
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Interpretation:

We're are not doing well on this topic. Why?

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- Is the topic one with which students historically struggle?
- Is the question an appropriate measure of the topic?

Caveat: Keep in mind that the range 0 to 0.3 is a "statistical noise" range, meaning we cannot make an interpretation of a Hake gain of 0.28 being so much better than a gain of 0.042.

CHEM 122 Spring 2017	**1001**		**1003**		**2001**		**All sections**	
Topic	**Raw**	**Hake**	**Raw**	**Hake**	**Raw**	**Hake**	**Raw**	**Hake**
Buffer composition ^	72%	0.674	64%	0.613	31%	0.225	60%	0.551

Interpretation:

One section is not doing well on this topic. What are the other instructors doing differently?

Caveat: Keep in mind that there are factors other than the instructor that can influence an individual section (attendance, student demographics, etc.)

For More Information . . .

1. D'Avanzo, C. *BioScience*, Volume 58, Issue 11, 1 December 2008, Pages 1079–1085,https://doi.org/10.1641/B581111.
2. Libarkin, J. 2008. Concept Inventories in Science: Manuscript prepared for the National Research Council Promising Practices in Undergraduate STEM Education Workshop 2 Washington, D.C., Oct. 13-14, 2008.
3. Galloway, R and Lancaster, S. The Royal Society of Chemistry: https://eic.rsc.org/feature/learning-gains/2000094.article#ref.
4. R R Hake, *Am. J. Phys.*, 1998, **66**, 64 (DOI: **10.1119/1.18809**).
5. PhysPort: https://www.physport.org/.

Questions?