Relationship Between Mathematics Preparation and Conceptual Learning Gains

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Assessment of Instruction

- Need measure of instructional effectiveness.
- Posttest by itself measures what students ***know***, not what they've ***learned.***
- *Key measure: student learning* ***gain*** *(****change*** in score) on some diagnostic instrument.

“Normalized” Gain [*g*]

- Practical problem: maximum score = 100%, so if students have different pretest scores their maximum ***possible*** gain is different.
- One solution: Use ***normalized gain “g”*** (introduced by R. Hake)

  g = gain/max. possible gain

  = [posttest score-pretest score] / [100%-pretest score]

→ ***Normalized gain yields a gain score that corrects for pretest score.***

What affects *g*?

Study of 6000 students by Richard Hake (1998):

- Mean normalized gain <***g***> on the FCI is ***independent of instructor*** for traditional instruction.
- ***<g>*** is ***not*** correlated with mean FCI pretest score.
- ***<g>*** ***<u>does</u>*** depend on instructional method: ***higher*** for courses with "interactive engagement."

® ***Equal*** *instructional effectiveness is often assumed to lead to* ***equal <g>*** *for all groups of students* ***regardless*** *of pretest score.*

(<g> > 0.35 a "marker" of interactive engagement)

Is Normalized Gain Correlated With ***Individual*** Students' Pretest Score?

- We investigate learning gains on "Conceptual Survey of Electricity" (CSE) by O'Kuma, Hieggelke, Maloney, and Van Heuvelen (conceptual, qualitative questions).
- Four student samples, two different universities
- Algebra-based general physics: instruction used interactive lectures, "peer instruction," "tutorials," etc.

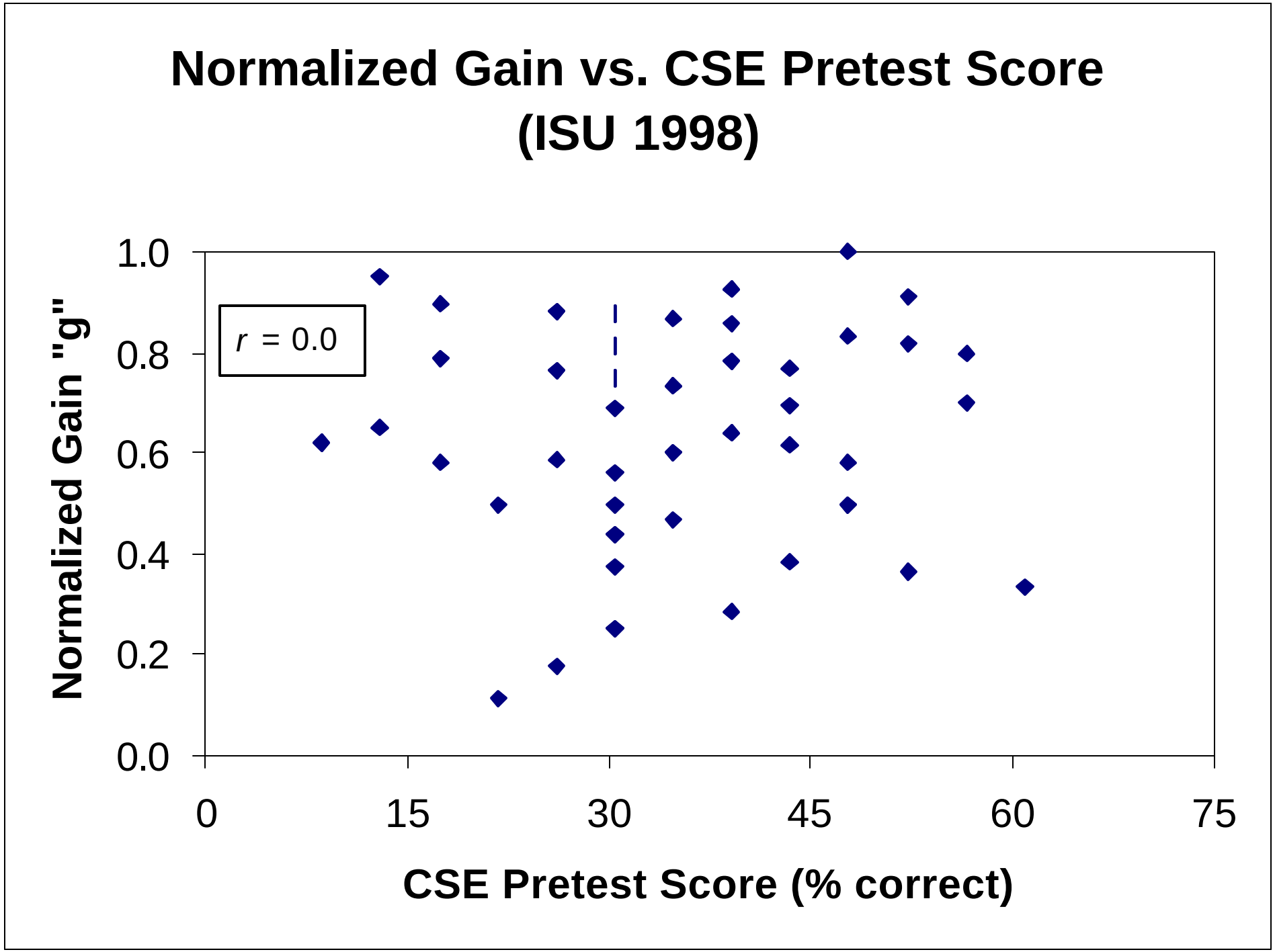
Diagnostic Instruments

- Conceptual Survey of Electricity (23-item abridged version), by Hieggelke, Maloney, O'Kuma, and Van Heuvelen. It contains qualitative questions and answers, virtually no quantitative calculations. **Given both as pretest and posttest.**
- Diagnostic Math Skills Test (38 items) by H.T. Hudson. Algebraic manipulations, simultaneous equations, word problems, trigonometry, graphical calculations, unit conversions, exponential notation. ***Not*** a "mathematical reasoning" test. **Given as pretest only.**

Sample Populations

(All algebra-based physics, second semester)

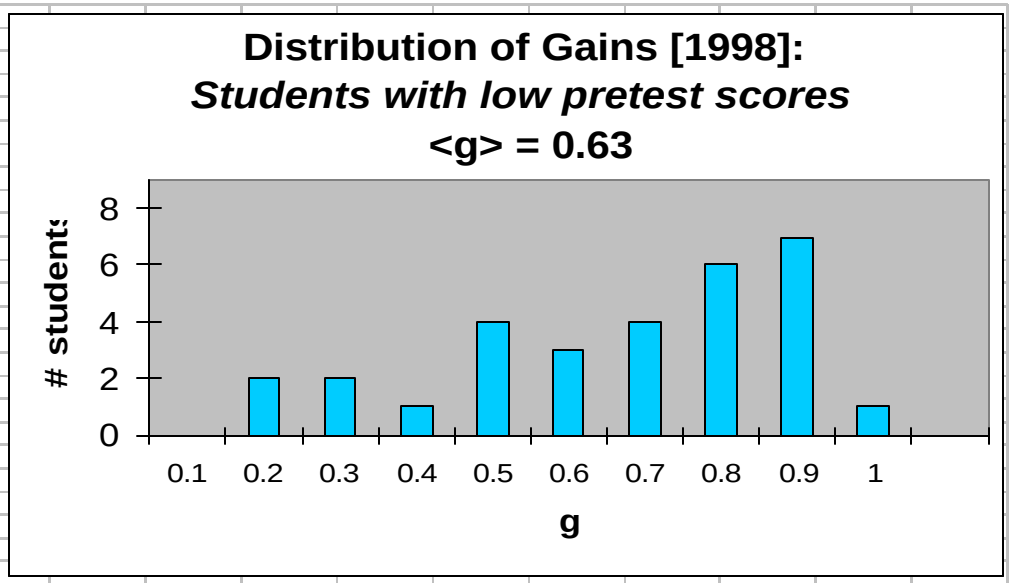
- **SLU 1997**: Southeastern Louisiana University, Fall 1997: $N = 46$
- **SLU 1998**: Southeastern Louisiana University, Spring 1998: $N = 37$
- **ISU 1998**: Iowa State University, Fall 1998: $N = 59$
- **ISU 1999**: Iowa State University, Fall 1999: $N = 78$

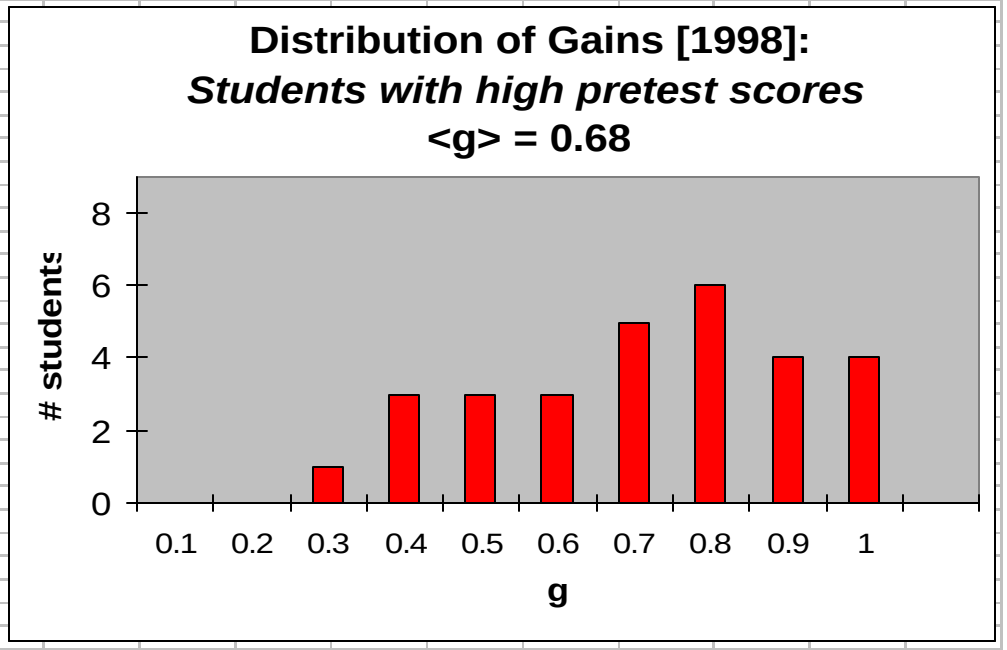

Normalized Gain vs. CSE Pretest Score
(ISU 1998)
Normalized Gain "g"
1.0
0.8
0.6
0.4
0.2
0.0
r = 0.0
0
15
30
45
60
75
CSE Pretest Score (% correct)

Is a student's learning gain ***g*** correlated with their ***pretest*** score?

	N	Correlation coefficient between student learning gain ***"g"*** and CSE pretest score	Statistical significance
SLU 1997	46	0.07	*p* = 0.65 ***(not significant)***
SLU 1998	37	0.10	*p* = 0.55 ***(not significant)***
ISU 1998	59	0.00	*p* = 0.98 ***(not significant)***
ISU 1999	78	0.10	*p* = 0.39 ***(not significant)***

® ***No statistically significant relationship Between g and pretest score.***


Distribution of Gains [1998]:
Students with low pretest scores
<g> = 0.63
students
8
6
4
2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
g

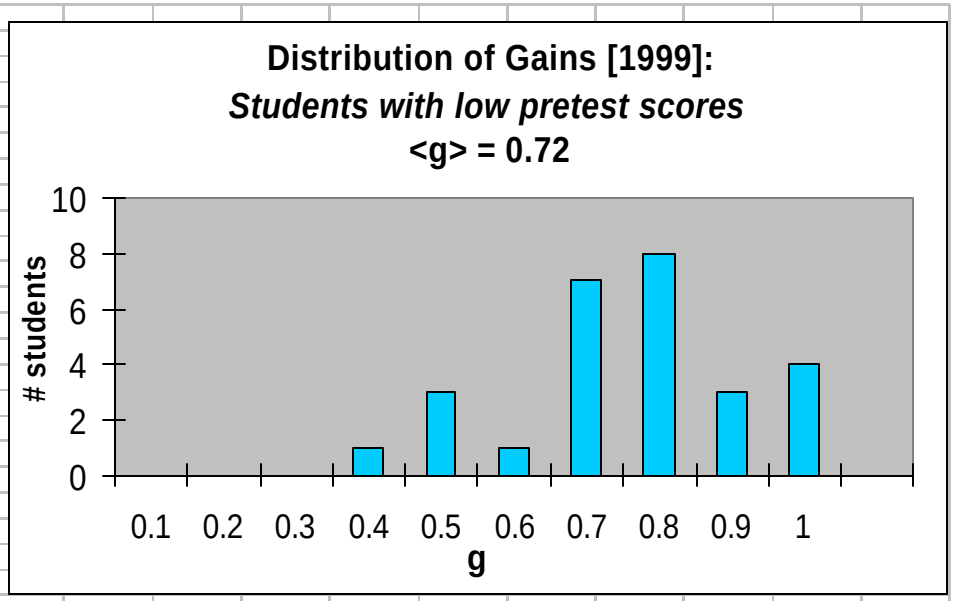

Distribution of Gains [1998]:
Students with high pretest scores
<g> = 0.68
students
8
6
4
2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
g

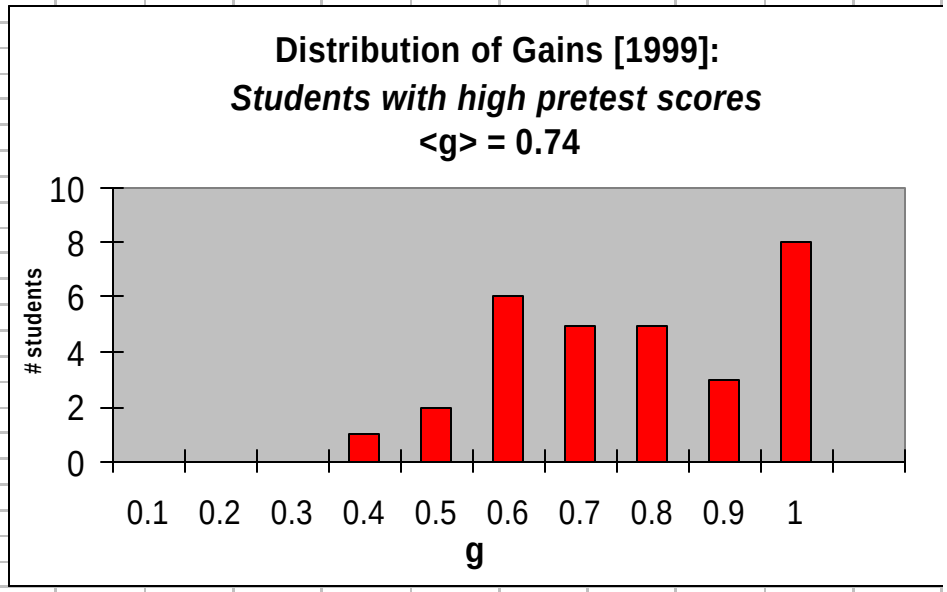
Gain comparison, students with high and low CSE pretest scores [1998]

	N	**CSE Pretest Score**	**<g>**
Top half	29	44%	0.68
Bottom half	30	25%	0.63
			$D\langle g \rangle = 0.05$ ***(not significant)***
Top quartile	15	50%	0.65
Bottom quartile	16	20%	0.66
			$D\langle g \rangle = 0.01$ ***(not significant)***

Gain comparison, students with high and low CSE pretest scores [1999]

	N	CSE Pretest Score	<g>
Top third	30	43%	0.74
Bottom third	27	18%	0.72
			D<g> = 0.02 ***(not significant)***
Top fifth	14	49%	0.73
Bottom fifth	15	14%	0.67
			D<g> = 0.06 ***(not significant)***


Distribution of Gains [1999]:
Students with low pretest scores
<g> = 0.72
students
10
8
6
4
2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
g


Distribution of Gains [1999]:
Students with high pretest scores
<g> = 0.74
students
10
8
6
4
2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
g

Consistent Result: ***No*** Correlation of ***g*** With Pretest Score on CSE

- Even though lower half of class scored ≈20% on pretest (random guessing), while upper half scored 40-50%, ***both groups achieved <u>same</u> normalized gain***.
- Implication: Can ***not*** use pretest score to predict student's performance (as measured by ***g***).

So . . . Can ***Any*** Preinstruction Measure Predict Student Performance?

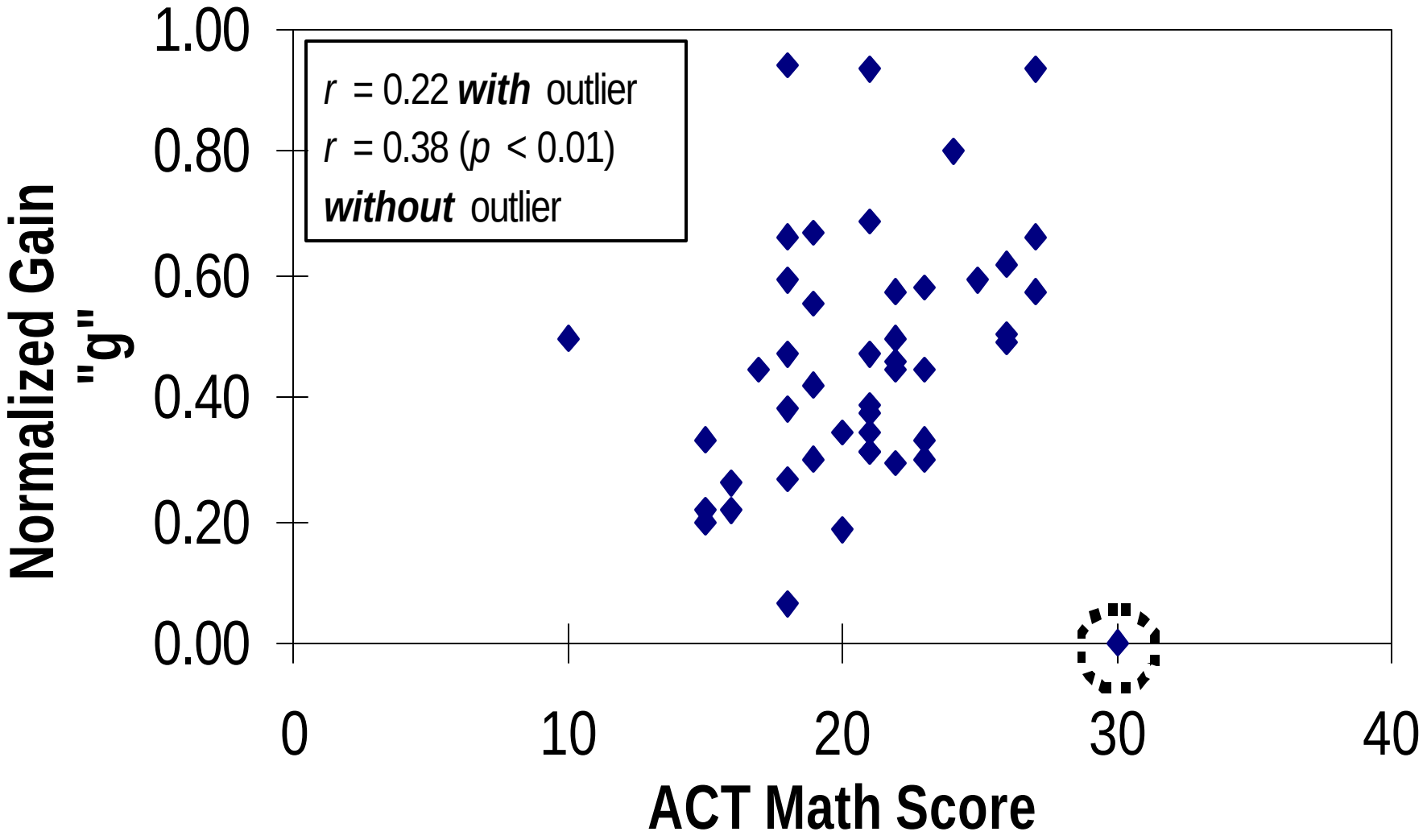
® Many studies have demonstrated a correlation between ***math skills*** and physics performance, HOWEVER:

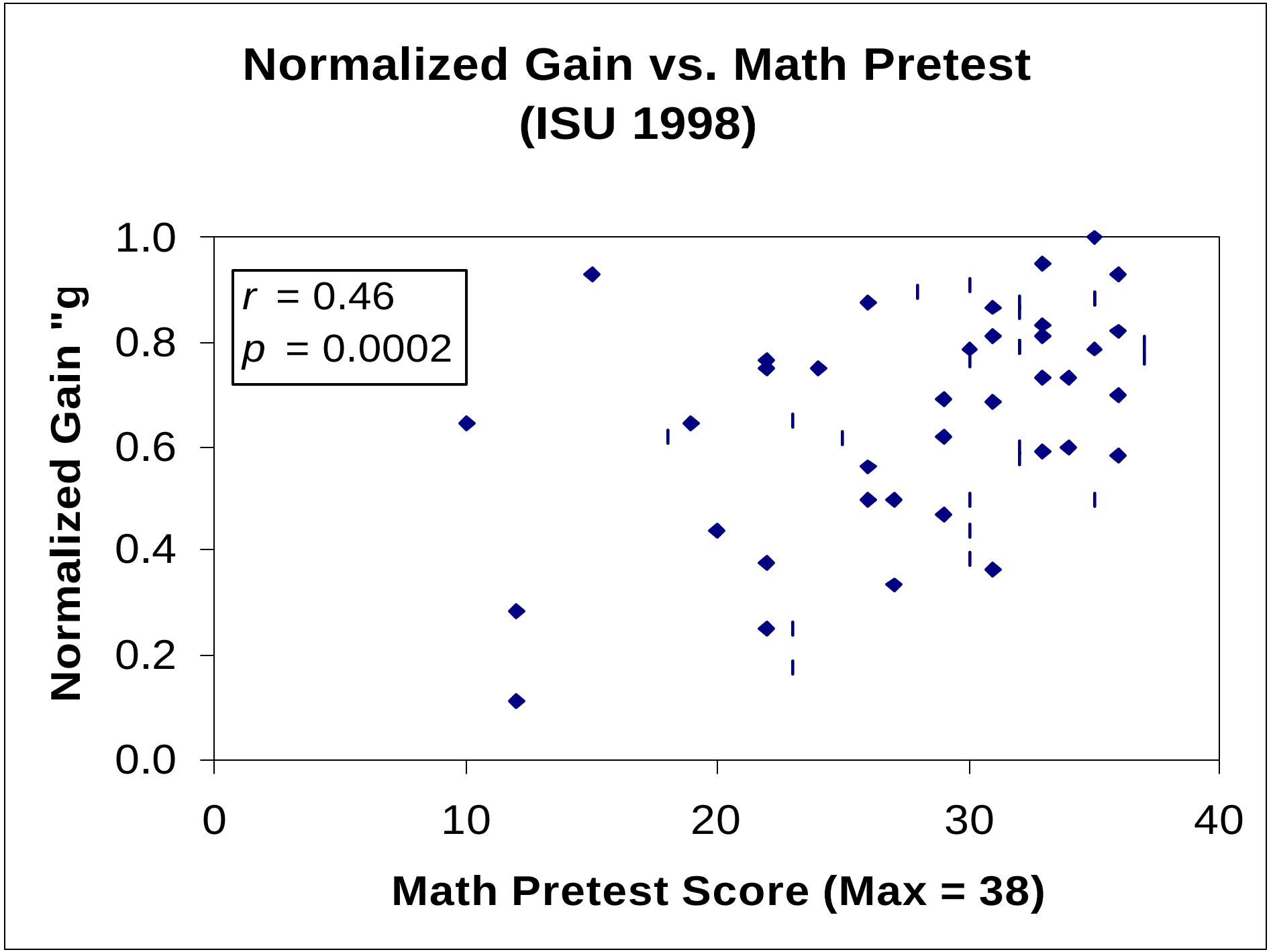
- performance was measured by traditional quantitative problems
- student's pre-instruction knowledge was not taken into account (i.e., only posttest scores were used)

Is Physics Performance Correlated With Students' Math Skills?

- Measure performance on conceptual, qualitative questions (CSE);
- Define performance as ***normalized gain g***, i.e, how much did the student ***learn.***
- Use pre-instruction test of math skills:
  - ***SLU 1997, 1998: ACT Math Score***
  - ***ISU 1998, 1999: Algebraic skills pretest***

Normalized Gain vs. ACT Math Score (SLU 1997)




Normalized Gain vs. Math Pretest
(ISU 1998)
r = 0.46
p = 0.0002
Normalized Gain "g
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
Math Pretest Score (Max = 38)

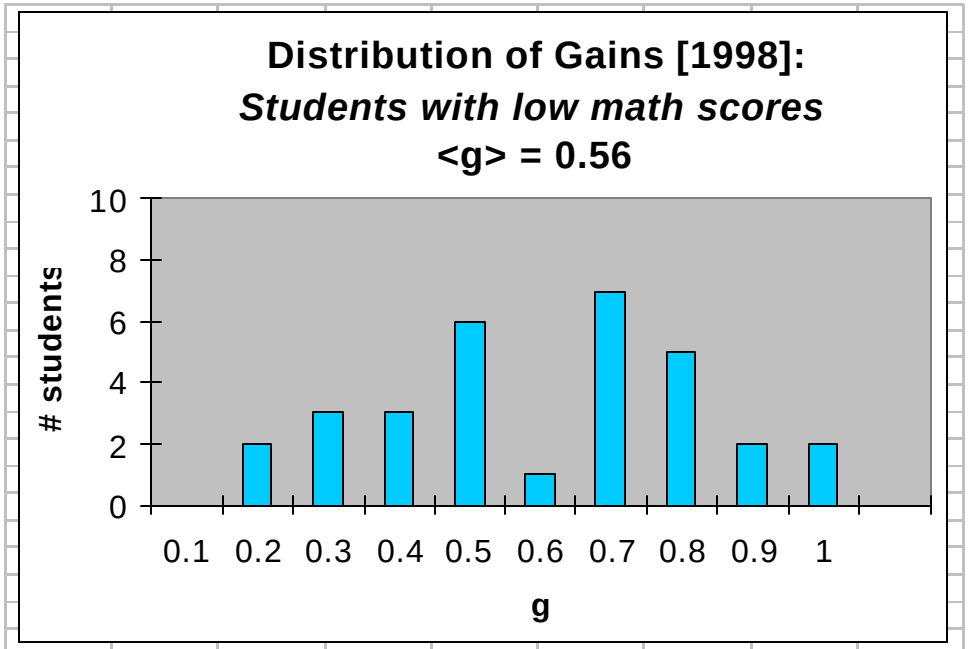
Is a student's learning gain ***g*** correlated with their ***math*** score?

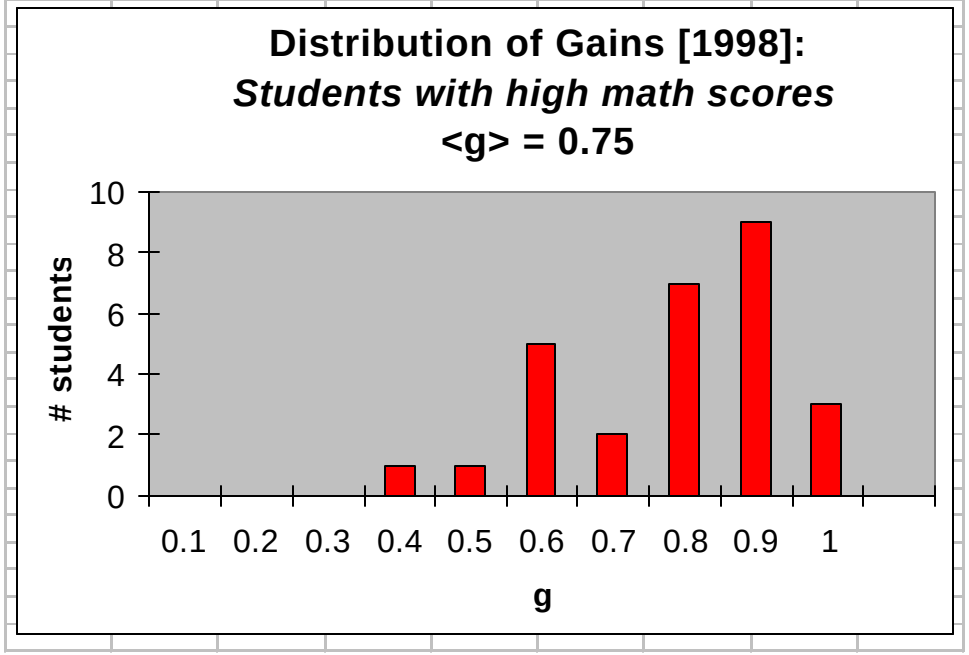
	N	Correlation coefficient between student learning gain ***"g"*** and math pretest score	Statistical significance
SLU 1997 ***with*** *outlier*	46	0.22	$p = 0.14$ ***(not significant)***
SLU 1997 ***without*** *outlier*	45	0.38	$p < 0.01$
SLU 1998	37	0.10	$p = 0.55$ ***(not significant)***
ISU 1998	59	0.46	$p = 0.0002$
ISU 1999	78	0.30	$p < 0.01$

® ***Three out of four samples show strong evidence of correlation between g and math pretest score.***

Gain comparison, students with high and low math scores [1998]

	N	Math Score	<g>
Top half	28	89%	0.75
Bottom half	31	63%	0.56
			$D\langle g\rangle = 0.19$ $p = 0.0001$
Top quartile	13	93%	0.77
Bottom quartile	14	49%	0.49
			$D\langle g\rangle = 0.28$ $p = 0.001$


Distribution of Gains [1998]:
Students with low math scores
<g> = 0.56
students
10
8
6
4
2
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
g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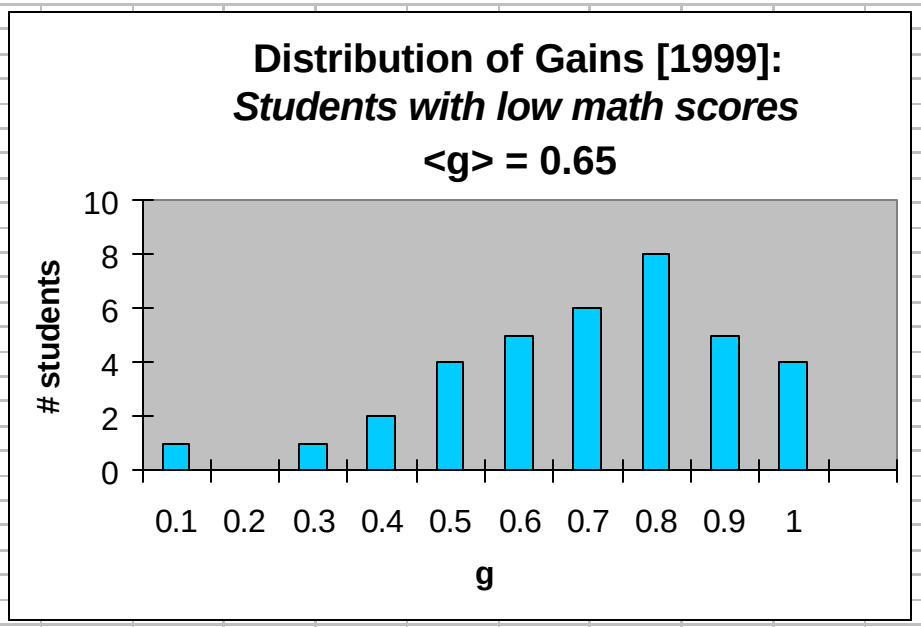
Students with high math scores
<g> = 0.75
students
10
8
6
4
2
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
g

Significant changes in instruction, ISU 1999:

- Both TA's were members of Physics Education Research Group.
- There was an additional undergraduate TA present during many tutorials.
- Both TA's and course instructor spent ***many*** out-of-class hours in individual instruction with weaker students.

Gain comparison, students with high and low math scores [1999]

	N	Math Score	<g>
Top half	37	86%	0.75
Bottom half	36	55%	0.65
			$D\langle g\rangle = 0.10$ $p = 0.03$
Top quartile	21	90%	0.78
Bottom quartile	20	44%	0.60
			$D\langle g\rangle = 0.18$ $p < 0.01$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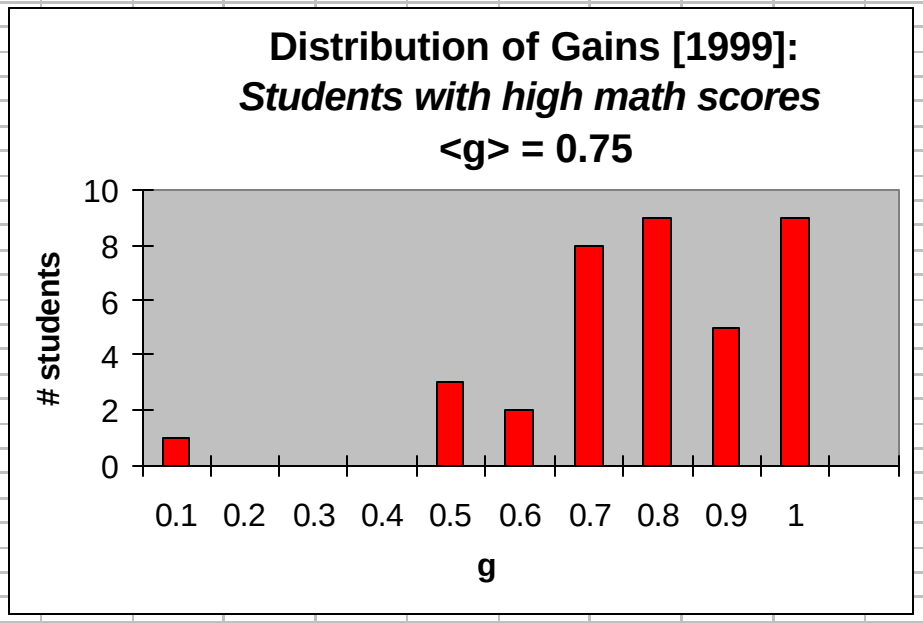
<g> = 0.65
students
10
8
6
4
2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
g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Students with high math scores
<g> = 0.75
students
10
8
6
4
2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
g

Are the ***g's*** different for males and females?

		N	<g>	Δ<g>	*p*
SLU 1997	male female	29 17	0.46 0.45	0.01	0.41 ***(not significant)***
SLU 1998	male female	16 21	0.52 0.50	0.02	0.38 ***(not significant)***
ISU 1998	male female	22 37	0.71 0.62	0.09	0.05
ISU 1999	male female	33 45	0.77 0.65	0.12	0.004

® ***No consistent pattern!***

Is learning gain ***g*** correlated with math score for both males and females?

	N	Correlation coefficient between student learning gain ***"g"*** and math pretest score	Statistical significance
ISU 1998: males	22	0.58	$p < 0.01$
ISU 1998: females	37	0.44	$p < 0.01$
ISU 1999: males	33	0.29	$p = 0.11$ ***(not significant)***
ISU 1999: females	45	0.33	$p = 0.03$

® ***Three out of four subsamples show strong evidence of correlation between g and math pretest score.***

Summary

- Strong evidence of *correlation* (***not causation!***) between computational math skills and conceptual learning gains. (Consistent with results of Hake et al., 1994.)

  (Are there additional "hidden" variables?)

- Results suggest that diverse populations may achieve significantly different ***normalized*** learning gains (measured by "***g***") ***even with identical instruction.***