CPATH $\tau\epsilon\chi\nu\eta$ Evaluation: Summer '09

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Breaking News

- The SRI ("super evaluator") effort has been substantially redefined:
  - SRI payroll reduced
  - 'All-inclusive' web experiment less ambitious
- Evaluators meeting in October 2009.
- I have been asked to document and disseminate some results, possibly in August 2009.

THE Evaluation Question

Are there quantitative (*incremental ?*) benefits from the $\tau\epsilon\chi\nu\eta$ approach? (student motivation, learning outcomes, instructor motivation)

The proposed Level 2 evaluation design is a Nonequivalent Group with Pre/Post Test Design[1], typically diagrammed as:

NR O_1 X O_2

NR O_1 O_2

where X represents $\tau\epsilon\chi\nu\eta$ (the treatment).

[1] For the trials in Fall 2008, it was be a Post-test only.

Initial cohorts for the quasi-experimental design were proposed in the Fall of 2008 and fall into 4 main course categories.

Ref	School	Course	Coordinator	Pedagogy	Semester
Group QE1: Programming for NON-CS					
1	UNC-W	CSC-112	Narayan	$\tau\epsilon\chi\nu\eta$	
2	CLM	CPSC 111	Duchowski	conventional	F08
3	WCU	CS 140	Dalton	conventional	F08
Group QE2: CS I					
4	CLM	CPSC 101	Westall	$\tau\epsilon\chi\nu\eta$	
5	WCU	CS 150	Holliday	conventional	F08
6	UNC-W	CSC 121	Narayan	conventional	
Group QE3: CS III					
7	CLM	CPSC 212	Geist	$\tau\epsilon\chi\nu\eta$	F08
8	WCU	CS 351	Dalton	conventional	Sp09
9	UNC-W	CSC 332	Narayan	conventional	
Group QE4: DBMS					
10	CLM	CPSC 462	Pargas/Wang	$\tau\epsilon\chi\nu\eta$	F08/Sp09
11	WCU	CS 453	Holliday	$\tau\epsilon\chi\nu\eta$	Sp09
12	UNC-W	CSC 455	Narayan	conventional	

Table 1: Quasi-experimental Design Cohorts and Course Coordinators, NEGD and Level-3 (Proposed Fall 2008).

Evaluation To Date

- For the Fall 2008 semester, Groups QE1 and QE2 were evaluated with both Level-2 (sans pretest) and Level-3 instruments.
- For the Spring 2009 semester, Group QE4 was evaluated with both Level-2 (including pretest) and Level-3 instruments. *The PreTest consisted of 4 quantitative questions (9-12).*
- For the Spring 2009 semester, Groups QE1 and QE2 were evaluated with only Level-3 instruments. This is of secondary interest to NSF; analysis will occur later.
- The future (Fall 2009 - Sp 2010): After lunch

Executive Summary of Results to Date

- Level 2 Statistical Results
  - QE1; Fall 2008; PostTest only: conventional more effective
  - QE2; Fall 2008; PostTest only: (depends upon which test used); $\tau\epsilon\chi\nu\eta$ more effective
  - QE4; Sp 2009; Pre and PostTest: inconclusive (possibly re-instrument and need more data)
- Level 3 Preliminary Results (All groups): Surveys seem to indicate some perception that $\tau\epsilon\chi\nu\eta$ experience generates more enthusiasm and is more 'real'.

Level 3 Data Analysis Strategy

- PostTest only: t, Welsh and relatives
- Pre/Post Test: ANACOVA/OLS

Preliminary Data from QE-1: Level 2 Instrument

There was no pretest (PostTest only).
In these Figures, the y-axis shows an average of the embedded problem grades. The integer grading scale used ranged from 0 (no solution or clueless) to 4 (perfect score).

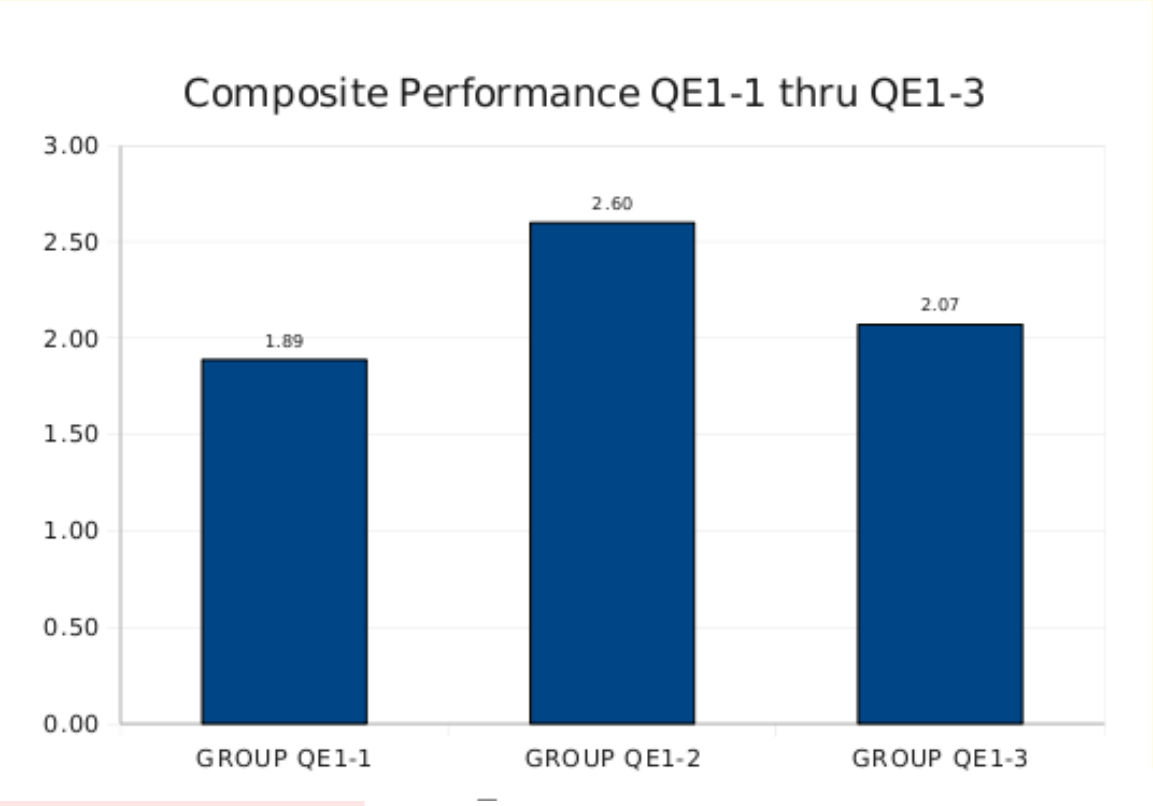


Figure 1: Fall 2008: QE1 Preliminary Composite Data

QE1 Analysis

Notes:
QE1-1 is TEXNH
QE1-2 and QE1-3 are conventional (lumped)

IMPLEMENTATION OF HYPOTHESIS TESTING
avg (mu_i) std number
texnh 1.89 0.7004 16 n1
conventional 2.25 0.94 21 n2

STUDENT'S T assumes equal but unknown variances
H0: mu_1=mu_2 H1: mu_1<mu_2 Alpha=0.05 (one tailed)
nu 35
Sp^2 0.7106
Sp 0.8430
T -1.2874
t_alpha 1.6896 One-tailed; uses 2-tailed formula
test T < -t_alpha FALSE
Result: reject H_0, accept H_1

Welch's t-test

nu 34.9966 num 0.005235
T'-1.3388 den 0.000150
t_alpha 1.6909 ratio 34.996619
here T' > t_alpha; reject H0; accept H1

Preliminary Data from QE-2: Level 2 Instrument

In these Figures, the y-axis shows an average of the embedded problem grades. The integer grading scale used ranged from 0 (no solution or clueless) to 4 (perfect score).

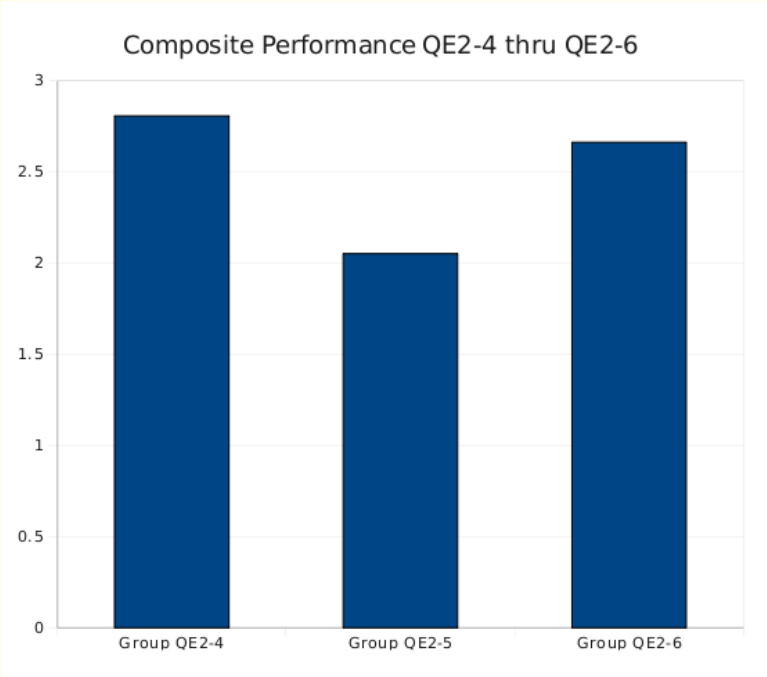


Figure 2: Fall 2008: QE2 Preliminary Composite Data, from Embedded Problems.

- Pool QE2-5 and QE2-6 cohorts into single 'conventional' cohort
- Resulting statistics:

i		μ_i^s	σ_i^s (std)	n_i (number)
1	$\tau\epsilon\chi\nu\eta$	2.81	0.77	24
2	conventional	2.38	1.16	41

Table 2: QE2 $\tau\epsilon\chi\nu\eta$ and conventional (pooled QE2/QE3) statistics

QE2 Fall 2008: Hypothesis Testing

- Hypotheses:

$$H_0 : \mu_1 = \mu_2 \quad or\ \mu_1 - \mu_2 = 0 \quad \textbf{no} \quad \textbf{difference}$$

$$H_1 : \mu_1 > \mu_2 \quad or\ \mu_1 - \mu_2 > 0 \quad \textbf{significant} \quad \textbf{difference}$$

- Level of significance:

$$\alpha = 0.05$$

$$T = \frac{\mu_1^s - \mu_2^s}{S_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

with $\sigma_1 = \sigma_2$ but unknown and $\nu = n_1 + n_2 - 2 = 63$ d.f.,

$$S_p^2 = \frac{(n_1 - 1)(\sigma_1^s)^2 + (n_2 - 1)(\sigma_2^s)^2}{\nu}$$

$$S_p = 1.0336$$

and the critical region is:

$$T > t_\alpha$$

QE2: Results (Handworked and Spreadsheet)

For $\nu = n_1 + n_2 - 2 = 63$ d.f.,

$$t_\alpha = t_{0.05} = 1.669$$

(NIST table and spreadsheet; one-tailed)
Computed

$$T = 1.611$$

Conclusion:

$$T < t_\alpha \Rightarrow \text{ accept } H_0$$

QE2: Welch's t-test

Probably more appropriate due to σ_i^s. Assume $\sigma_1 \neq \sigma_2$, but unknown.

$$T' = \frac{\mu_1^s - \mu_2^s}{\sqrt{\frac{(\sigma_1^s)^2}{n_1} + \frac{(\sigma_2^s)^2}{n_2}}}$$

with

$$\nu = \frac{\left(\frac{(\sigma_1^s)^2}{n_1} + \frac{(\sigma_2^s)^2}{n_2}\right)^2}{\frac{\left(\frac{(\sigma_1^s)^2}{n_1}\right)^2}{n_1 - 1} + \frac{\left(\frac{(\sigma_2^s)^2}{n_2}\right)^2}{n_2 - 1}}$$

Here $T' = 1.79$, $\nu = 62$ and $t_\alpha = t_{0.05} = 1.67$
Conclusion: Since $T' > t_{0.05}$, reject H_0; accept H_1.

Fall 2008 Attitudinal Surveys (snippets)

The topics included satisfaction, effectiveness, opportunity to learn, assignments, engagement, learning. The survey format was 19 questions with an estimated completion time of 10 minutes.

7. I feel my classroom experience in this course generated enthusiasm for the subject.
A) Very little B) A little C) Somewhat D) A lot E) A great deal

8. I feel my software development experience in this course generated enthusiasm for the subject.
A) Very little B) A little C) Somewhat D) A lot E) A great deal

9. I feel the software development experience in this class used real-world examples.
A) Very little B) A little C) Somewhat D) A lot E) A great deal

Sample Data from Fall 2008 Attitudinal Survey

The y-axis indicates the per-unit response to a single question (#7).

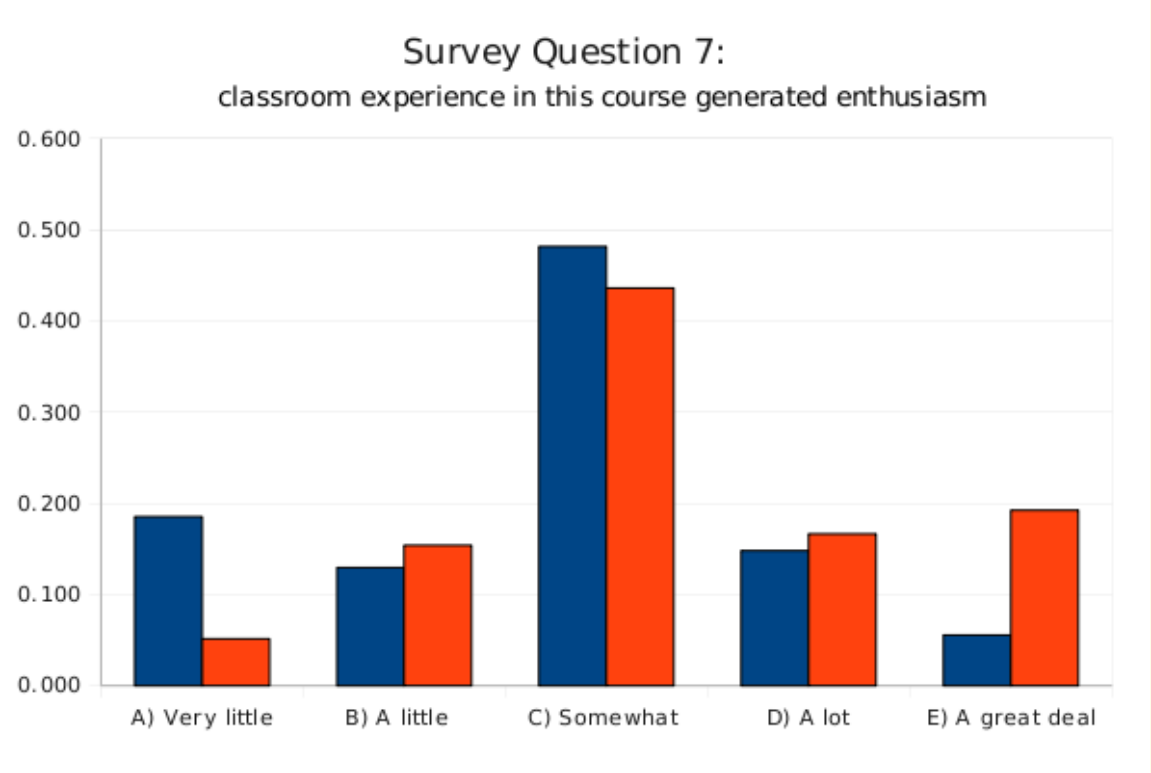
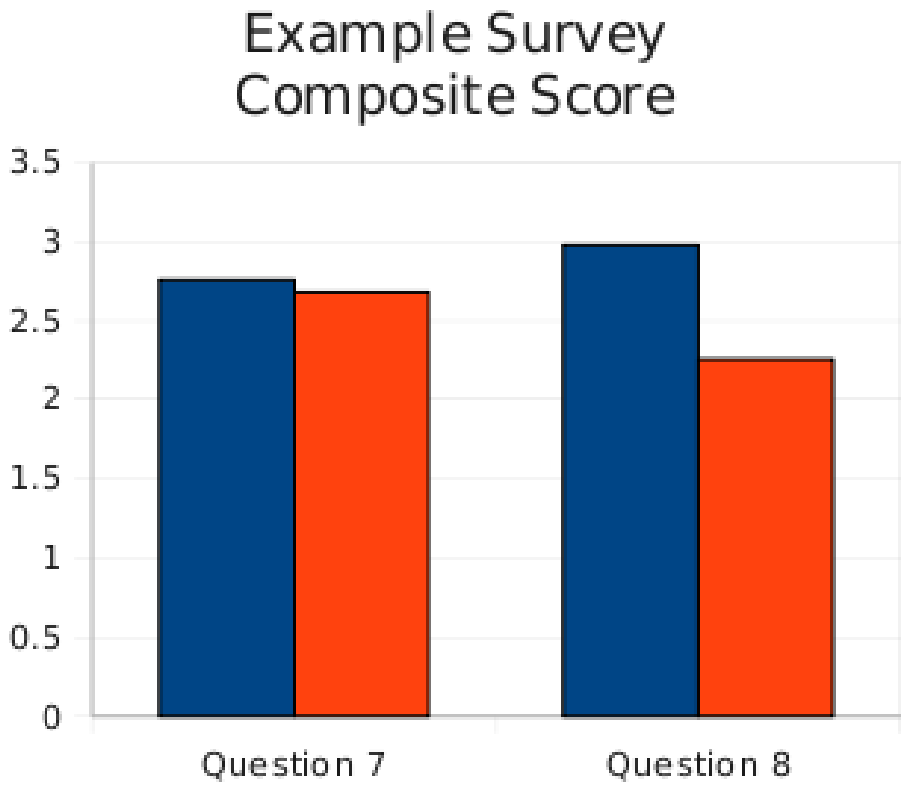


Figure 4: Example of Distribution of Responses for $\tau\epsilon\chi\nu\eta$ and Conventional Survey. Question #7 Shown. Leftmost (Darker) Column is $\tau\epsilon\chi\nu\eta$ Data.

Fall 2008 Survey Data Snippets (cont'd)

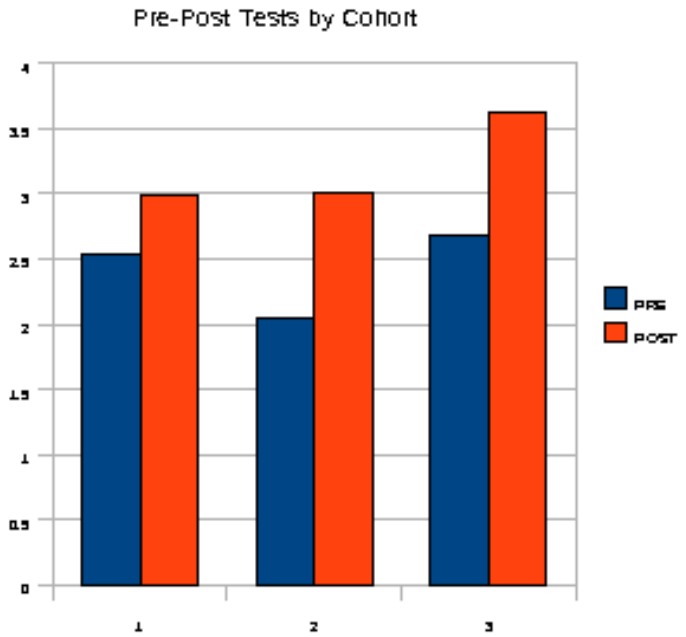
The y-axis represents an average of the weighted responses, where a 1 represents a response of 'Very little' and a 5 indicates a response of 'A great deal'. Leftmost (Darker) Column is $\tau\epsilon\chi\nu\eta$ Data.



Spring 2009 Evaluation: DBMS – Data Summary

class	cohort	PRE	POST
$\tau\epsilon\chi\nu\eta$	QE4-10	2.54	2.98
$\tau\epsilon\chi\nu\eta$	QE4-11	2.04	3.00
conventional	QE4-12	2.68	3.63

Concern: group non-equivalence and/or instructor grading bias (probably requires adjusted pretest distribution).



Spring 2009 Evaluation: DBMS – Level 2 Scatter

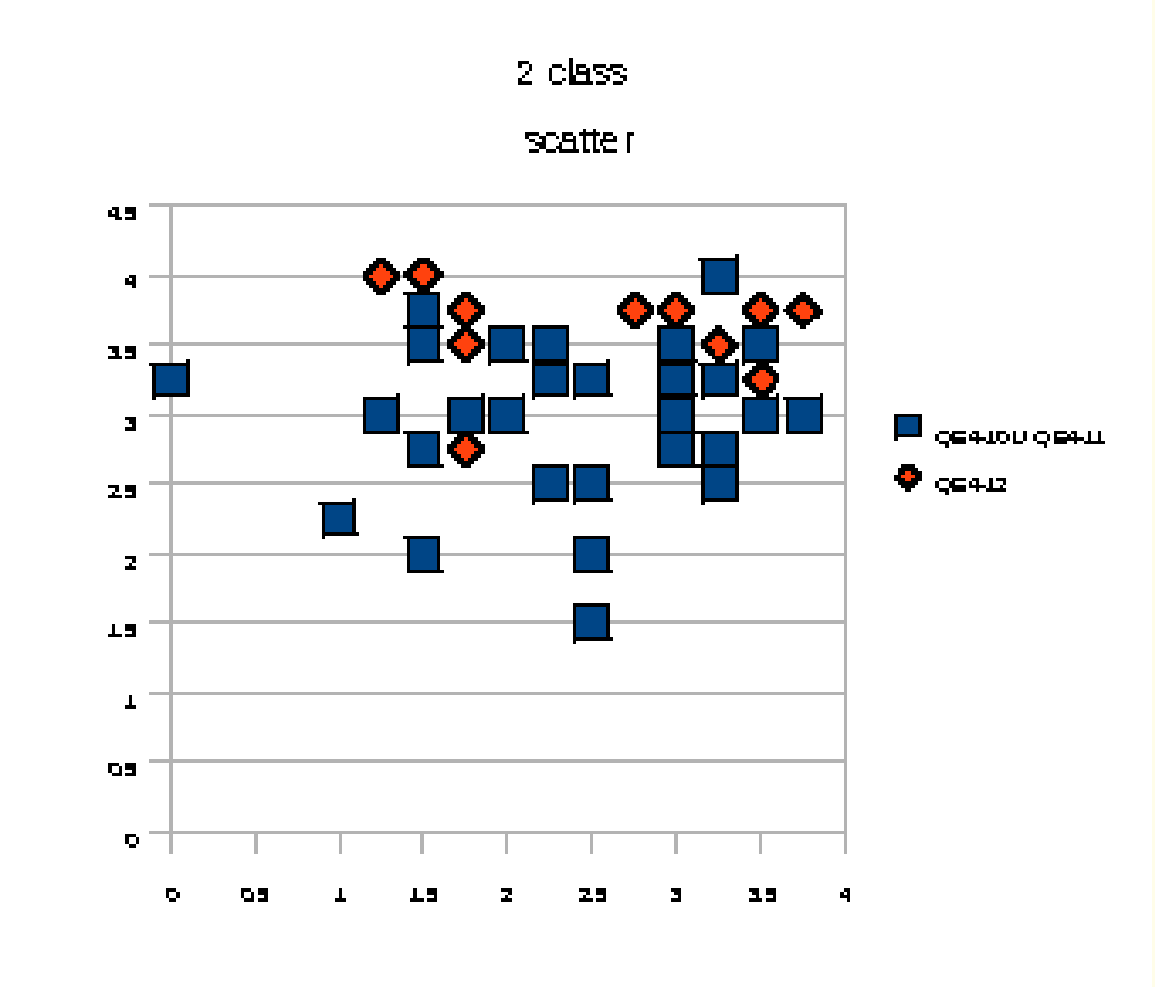


Figure 7: Spring 2009: QE4 Data Scatter, from Embedded Problems.

QE4 PreTest Averages: Stat. Significant Difference?


```
HYPOTHESIS TESTING (pretest differences) Rev. 7-19-09
avg (mu_i) std number
texnh         2.447 0.8587 33 Aggregates QE4-10 and QE4-11 as 'texnh'
conventional 2.679 0.8794 14

STUDENT'S T (assumes equal but unknown variances)
H0: mu_1=mu_2 H1: mu_2>mu_1 Alpha=0.05 (one tailed)
nu 45
Sp^2 0.7477
Sp 0.8647
T 0.8397
t_alpha 1.6794 One-tailed accept H0
```

No.

QE4: (PostTest Only) Analysis


```
IMPLEMENTATION OF HYPOTHESIS TESTING Rev. 6-09-09
FINAL SCORE avg (mu_i) std number
texnh         2.985 0.5363 34 Aggregates QE4-10 and QE4-11 as 'texnh'
conventional 3.625 0.3501 14

STUDENT'S T (assume equal but unknown variances)
H0: mu_1=mu_2 H1: mu_2>mu_1 Alpha=0.05 (one tailed)
nu 46
Sp^2 0.2410
Sp 0.4909
T 4.1070
t_alpha 1.6787 One-tailed Reject H0; accept H1
```

QE4: Ad-hoc PostTest Normalization

Normalize PostTest score with PreTest score average *for cohort*.

```
HYPOTHESIS TESTING (normout) Rev. 7-21-09
normout avg (mu_i) std number
texnh    1.229 0.2651 33 Aggregates QE4-10 and QE4-11 as 'texnh'
conv.    1.353 0.1307 14 pretest avg for normalization

STUDENT'S T (assume equal but unknown variances)
H0: mu_1=mu_2 H1: mu_2>mu_1 Alpha=0.05 (one tailed)
nu 45
Sp^2 0.0549
Sp 0.2343
T 1.6681
t_alpha 1.6794 One-tailed accept H0
```

QE4: Pre/PostTest Normalization (alternate)

Each PreTest and corresponding PostTest score normalized (divided) by cohort average. Thus, cohorts all have 1.0 per unit **PreTest** average. **change** is difference of normalized Pre/PostTest scores.

```
HYPOTHESIS TESTING (normalized change) Rev. 7-21-09
Norm CHANGE avg (mu_i) std number
texnh    .229 0.4126 33 Aggregates QE4-10 and QE4-11 as 'texnh'
conv.    .353 0.3553 14

STUDENT'S T (assume equal but unknown variances)
H0: mu_1=mu_2 H1: mu_2>mu_1 Alpha=0.05 (one tailed)
nu 45
Sp^2 0.1575
Sp 0.3969
T 0.9847
t_alpha 1.6794 One-tailed accept H0
```

Spring 2009 Evaluation: Level 2 Models (several used)

'Standard' regression using *raw or unadjusted* pre-post scores and class:

$$post = const + c_1 * pre + c_2 * class$$

$class = 1$ for texnh; $class = 0$ for conventional

see results (next slide):

- +0.63 effect on PostTest from **conventional**; conversely
- -0.63 penalty for $\tau\epsilon\chi\nu\eta$

Spring 2009 Evaluation: Level 2 Model Results

Model 1: OLS estimates using the 47 observations 1–47
Dependent variable: post

Variable	Coefficient	Std. Error	t-statistic	p-value
const	3.51765	0.267155	13.1671	0.0000
pre	0.0400759	0.0863221	0.4643	0.6448
class	−0.630870	0.160956	−3.9195	0.0003

Mean of dependent variable	3.17553
S.D. of dependent variable	0.573213
Sum of squared residuals	11.0321
Standard error of residuals ($\hat{\sigma}$)	0.500730
Unadjusted R^2	0.270089
Adjusted $\bar{R}^2$	0.236912
$F(2, 44)$	8.14068
p-value for $F()$	0.000981595
Log-likelihood	−32.630
Akaike information criterion	71.2615
Schwarz Bayesian criterion	76.8119
Hannan–Quinn criterion	73.3501

QE4: Pre/PostTest Normalization (Model1–Post)


```
Model 1:
OLS estimates using the 47 observations 1-47
Dependent variable: post

      VARIABLE       COEFFICIENT        STDERROR      T STAT   P-VALUE

  const                 1.30750          0.121988     10.718  <0.00001 ***
  pre                   0.0453601        0.104435      0.434   0.66617
  class                -0.124978         0.0752350    -1.661   0.10379

  Mean of dependent variable = 1.26511
  Standard deviation of dep. var. = 0.238299
  Sum of squared residuals = 2.44814
  Standard error of residuals = 0.23588
  Unadjusted R-squared = 0.06280
  Adjusted R-squared = 0.02020
  F-statistic (2, 44) = 1.47407 (p-value = 0.24)
  Log-likelihood = 2.74813
  Akaike information criterion (AIC) = 0.503744
  Schwarz Bayesian criterion (BIC) = 6.05419
  Hannan-Quinn criterion (HQC) = 2.59241
```

QE4: Pre/PostTest Normalization (Model2–change)


```
Model 2:
OLS estimates using the 47 observations 1-47
Dependent variable: change

      VARIABLE       COEFFICIENT        STDERROR      T STAT   P-VALUE

  const                 1.30629          0.122042     10.704  <0.00001 ***
  pre                  -0.954150         0.104482     -9.132  <0.00001 ***
  class                -0.124567         0.0752684    -1.655   0.10505

  Mean of dependent variable = 0.264681
  Standard deviation of dep. var. = 0.396922
  Sum of squared residuals = 2.45032
  Standard error of residuals = 0.235985
  Unadjusted R-squared = 0.66189
  Adjusted R-squared = 0.64652
  F-statistic (2, 44) = 43.0682 (p-value < 0.00001)
  Log-likelihood = 2.72724
  Akaike information criterion (AIC) = 0.545511
  Schwarz Bayesian criterion (BIC) = 6.09595
  Hannan-Quinn criterion (HQC) = 2.63418
```

QE4: Level 3 Snippet


```
Question 7

"my classroom experience in this course generated enthusiasm for the subject"


overall
        3.26 Texnh
        2.7 Conventional

Question 8

"my software development experience in this course generated enthusiasm for the subject"

overall
        3.63 Texnh
        2.5 Conventional


Question 9

"the software development experience in this class used real-world examples"

overall
        4.23 Texnh
        3.5 Conventional
```

Review: Summary of (Mixed) Results to Date

- Level 2 Statistical Results
  - QE1; Fall 2008; PostTest only: conventional more effective
  - QE2; Fall 2008; PostTest only: $\tau\epsilon\chi\nu\eta$ more effective (using Welsh)
  - QE4; Sp 2009; Pre and PostTest: no difference or inconclusive (possibly re-instrument and need more data)
- Level 3 Preliminary Results (All groups): Surveys seem to indicate some perception that $\tau\epsilon\chi\nu\eta$ experience generates more enthusiasm and is more 'real'.

Major Challenges to Date

- The Fall 2008 and Spring 2009 experiments were illustrative and should improve our design and implementation for Fall 2009 and Spring 2010.
- Noteworthy in the data reporting and survey implementation from the Fall 2008 were the pragmatics of collecting, selecting and distributing sets of common exam problems at the very end of a semester, as well as administering surveys. Spring 2009 only had minor glitches in grading and reporting (scale).
- The Spring 2009 experiment may indicate potential selection bias or (more likely) instructor grading bias. We need to address this (later).

Minor Point: Issues With Spring 2009 Level-3 (survey)

- many students 'missed' back of pages
- multiple answers
- silly answers (handwritten)

Major Issues With QE4

- instrumentation threats:
  - pretest and/or posttest validity
  - model validity
  - grading variability ?
- possibly nonequivalent groups ??

Proposed Future Evaluation Efforts

Continued development and refinement of the evaluation instruments and procedures:

- Timetable for development of Level-2 instruments.
- Identification of cohorts and courses for Fall 2009 and beyond.
- Implementation (follow rubric; 0-4 vs. 0-5).
- Reporting.
- Keep evaluator in the loop.

Proposed Future Evaluation Efforts (cont'd)

- Especially significant is uniform pre/post-test grading. We must maximize objectivity in the process (instructor-neutral).
- I suggest multiple choice.
- I suggest a larger number of questions.
- All cohorts should participate in exam design.
- Use common numbering system.