Teasing out the effect of tutorials

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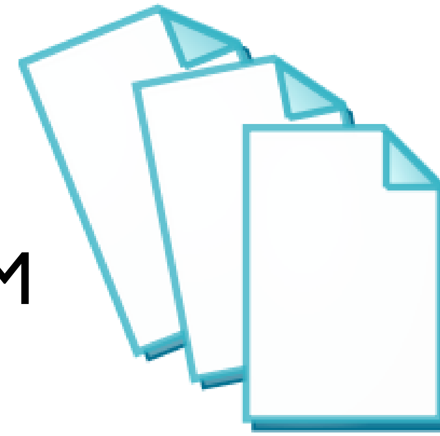
Introduction & Claims

We wished to discern the effects of individual course elements in a multi-faceted course transformation.

Even when student background variables are taken into account via multiple regression, **optional tutorials affect student performance on a conceptual assessment** in junior E&M.

Course exams (for credit) were <u>not</u> affected by tutorial attendance. Other elements that increase student time-on-task (e.g., lecture attendance and recitations) <u>do not</u> achieve the same impacts.

Methods



- Transformed first-semester of junior E&M
  - Concept Tests / Clicker Questions
  - Learning Goals
  - Tutorials
  - Modified Homework
  - Student Difficulties

The full set of course materials are available at
www.colorado.edu/sei/departments/physics_3310.htm

- Developed conceptual diagnostic, the CUE* [2]
- Performed multiple regression** to determine effect of tutorial attendance frequency and student background variables (including BEMA***) on traditional exams & CUE

**Lift up to see info

** CUE = Colorado Upper-Division Electrostatics assessment*
**** BEMA = Basic Electricity & Magnetism Assessment*

Multiple regression analysis

- **Background variables** = Pre-requisite math courses, pre-requisite physics courses, GPA in prior math courses, GPA in prior physics courses, cumulative GPA, CUE pre-test, lecture attendance, and post-introductory physics BEMA*
- We model **outcome variables** (CUE post-test score, course exam z-score) using a regression equation**. Variables entered manually, background variables entered until a model with a high R^2 and fewest background variables is obtained.
- Variable **"Tutorials"** representing the percent of tutorials attended throughout the term is then added. Coefficient (b_k) for "tutorials" gives relative impact of attending the tutorials on the outcome variable

* *Basic Electricity & Magnetism Assessment*

** $OUTCOME = b_0 + \left(\sum_{k=1}^{N} b_k \times VAR_k\right) + (b_{TUT} \times TUTORIAL)$

BACKGROUND

The CUE

17-question open-ended conceptual test with high inter-rater reliability and validity.

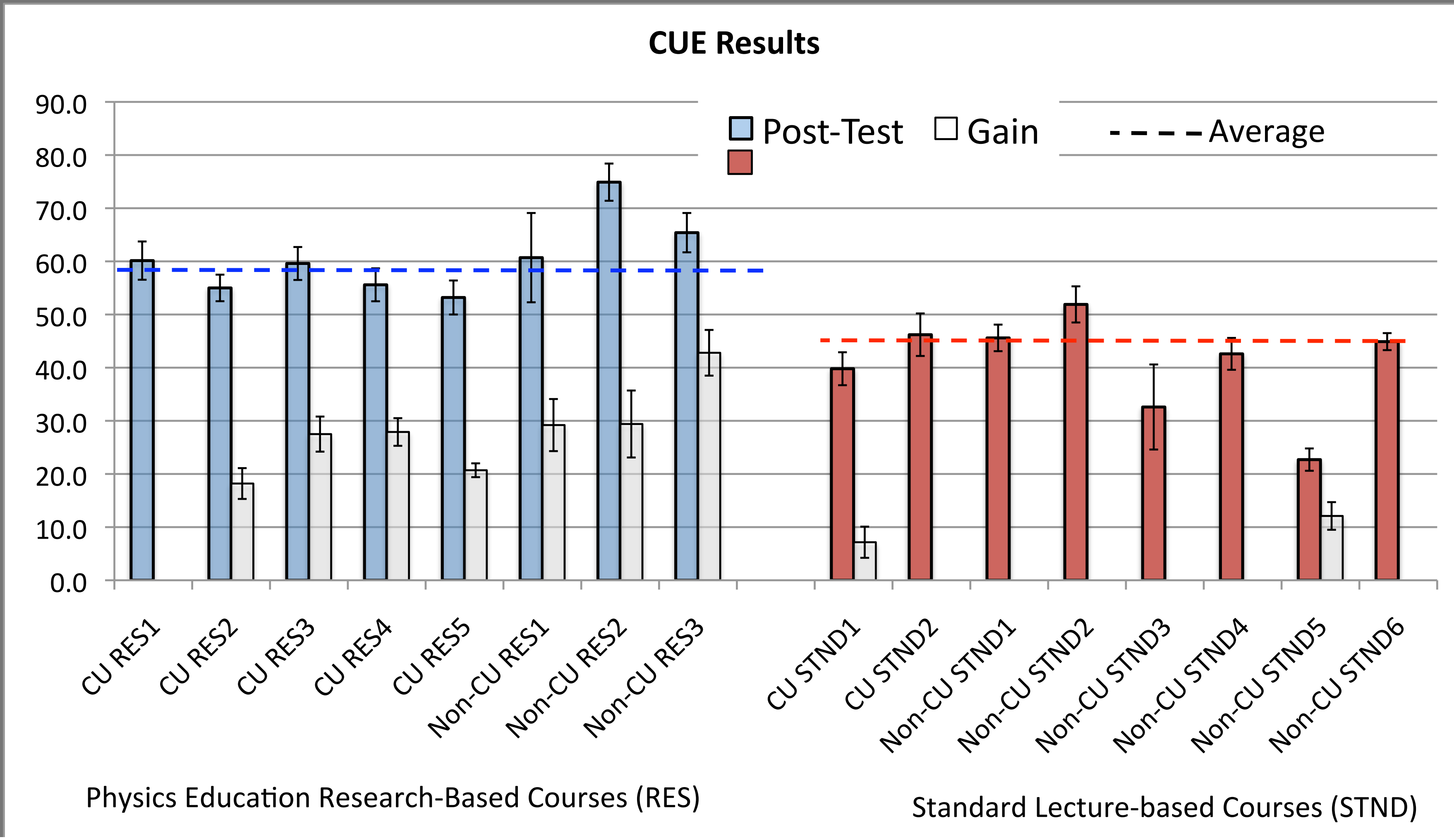
Tests the ability to choose a problem-solving method, sketch and graph fields and potential, and explain the physics and mathematic in common problems.

Students in courses using our transformed materials score higher on the CUE (58.2 +/- 1.4%) than those in standard courses (44.6 1.6%). *N* = 488.

Lift up to see data

Image from Linuxerist, Tango! and PdDemeter on Wikimedia

Data: CUE Performance



Error bar represent ±1 SE of mean. "Gain" represents student absolute gains on the 7-questions on the Post-test which match the 7-question Pre-test; Gain (and SE) estimated for TRAD and RES1 (based on consistent Pre-test data in later semesters). Non-CU TRAD is an average of three courses at another large research university. Non-CU RES is the average of three courses at three institutions that used our research-based materials. Post-test N's are as follows: CU TRAD(27), RES1-5 (20, 42, 27, 35, 59), Non-CU TRAD (221), Non-CU RES (31).

The Tutorials

Developed over two years based on developing research on student difficulties:

- Optional (30-44% attendance)
- Work in groups of 3-5
- Worksheet-based with small whiteboards
- Aim to develop conceptual & metacognitive problem-solving skills

"They were (generally) fun, interesting, and a good jump-start to keep me excited over the weekend. Also, I learned a lot." - student

Instructors & students positive about tutorial experience. Provides additional instructor/student interaction, giving instructors a window into student thinking

Who goes to tutorials?

Tutorial-attending* students are typically better students:

- Higher course grades (3.2 vs 2.5)
- Higher exam z-scores (0.23 vs -0.19)
- Higher lecture attendance (87% vs 73%)
- Higher CUE score (60.7% vs 47.9%)

The percent of tutorials attended correlate with many course measures:

- Exam scores (r = 0.27)
- Course grades (r = 0.36)
- CUE scores (r = 0.26)
- These correlations are stronger for students with lower pre-requisite GPA's

So, tutorials may be beneficial, but clearly affected by self-selection. We turned to multiple regression

* Attending more than 3 out of the ~12 tutorials. All $p<0.01$.

RESULTS

BEMA score predicts CUE score

For those students for whom we have post-intro physics BEMA scores (N=87), the BEMA is a better predictor of CUE performance than any other background variables

- Accounts for 40% of variance in CUE score
- Coefficient (b_k) = 0.64

Physics GPA predicts CUE score

For the population as a whole (N=156), the GPA in all prior physics courses is a good predictor of CUE score

- Accounts for 23% of the variance
- Coefficient (b_k) = 0.48

Tutorials predict CUE score

In both cases, the addition of "Tutorials" significantly improves the model. Thus, even when background variables are taken into account, tutorial attendance helps improve conceptual exam performance.

- As determined by the F-test
- The effect of "Tutorials" is roughly 1/3 that of "Physics GPA" or "BEMA"

Lift up to see data

Data: Regression

TABLE 1. Multiple regression models to determine impact of tutorials on CUE and exam scores

Model:	**CUE Model 1A**	**CUE Model 1B (w/ tutorials)**	**CUE Model 2A**	**CUE Model 2B (w/ tutorials)**	**Exam Model 1**	**Exam Model 2**
Population	*All students*	*All students*	*Students with BEMA*	*Students with BEMA*	*All students*	*Students with BEMA*
Model statistics						
N	156	156	87	87	192	103
Multiple R^2	0.23	0.26	0.40	0.46	0.46	0.60
F statistic	47.24	27.08†	580.8	36.77††	166.93	156.3
Residual std. error	12.26	15.04	13.01	12.41	0.77	0.66
Predictors	b_k	b_k	b_k	b_k	b_k	b_k
Phys GPA	0.48**	0.45**			0.68**	0.78**
BEMA			0.64**	0.63**		
Tutorials		0.17*		0.24**		

Multiple regression statistics: The F-statistic is large if the model's predictive capability is large relative to background variables and error. The residual standard error measures the amount of variance unaccounted for by the model. R^2 is the proportion of variability that is accounted for by the model. All F statistics are significant at $p<0.0001$ value. Coefficients reported are significant at the $p<0.05$ (*) and $p<0.01$ (**) level; if a coefficient is not reported, then it did not enter into the model as a significant predictor. The y-intercept (b_0) is insignificant for all models, and thus is not reported. Significant differences from the previous listed model, as determined by the F-test, is designated by †, $p<0.05$ and †† $p<0.01$.

Only Physics GPA predicts exams

Neither BEMA scores nor tutorial attendance predict performance on traditional exams. Only Physics GPA enters into the model.

- Predicts 46% of the variance
- Coefficient (b_k) = 0.68

Etc. - Homework & Lectures

- Homework score predicted by attendance at homework help sessions
- High lecture attendance appears to be self-selection -- it did not predict student performance

Conclusions

Student performance on conceptual exams is well-predicted by their performance on other conceptual exams - which could be a measure of student ability or intrinsic motivation (or both)

The upper-division PER community's focus on worksheet-based tutorials appears to be well-supported: They appear to provide students with conceptual reasoning skills

These gains occurred *despite* the fact that research into student difficulties, guiding tutorial development, is in its infancy.

However, tutorial attendance does *not* predict success on traditional exams. Also, student performance on a post-quiz on the material does not improve after tutorial attendance.

So, do tutorials need to be rethought?

We argue that they don't. We feel that the value of tutorials is *not* in learning specific concepts, but in gaining attitudes, communication practice, habits of mind, and improved student/instructor communication.

These multiple advantages help offset the time of development and facilitation.

Lift for quotes

Instructor quotes

"The asset that came as a surprise to me, because I thought I knew it all, was how valuable the feedback is that I'm getting in the tutorials… The tutorials seem to reveal to me the students' thinking, or lack of it, in a way that watching them struggle with the homework doesn't…. It's just eye-opening."

"And it's also fun for us. I enjoy the tutorials a lot. It's really a great time"

"And what all of this, from doing the homework help session the way you do it, to doing the tutorials, to doing the concept test questions, it lets me talk more directly to and hear, listen to, the average student, the middle-of-the-pack student. And it lets me focus my attention much more on them."

"I get the sense that the have, in tutorials, a nice opportunity to work slowly in a guided fashion via some of the concepts they've seen on the blackboard. They have to interact with them, they talk to each other. I'm thinking that in the best case, the really learn things well interactively with each other."

References & Acknowledgements

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