Assessing the effectiveness of a computer simulation in conjunction with *Tutorials in Introductory Physics* in undergraduate physics recitations

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Introduction

We present two studies documenting the use of a *PhET*[1,2] computer simulation, entitled the Circuit Construction Kit (CCK), with *Tutorials in Introductory Physics*[3] in a transformed college physics course to investigate its possible impact on students' conceptual understanding.

Research Questions:

- Can a computer simulation in this environment be as effective as real equipment?
- Does the explicit visual model for current flow provided by CCK have any beneficial or deleterious effects on students' conceptual development of DC circuits?

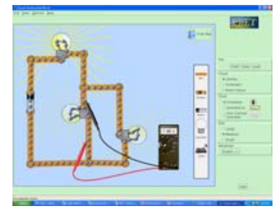
PhET Project Overview

The *Physics Education Technology* (PhET) Project is an on-going effort to create a suite of interactive simulations and related education resources that aid in the teaching and learning of physics.

- Elaborate Java- and Flash-based simulations
- Resources for both educators and students
- Research to formally assess their influence on student learning and attitudes in a variety of settings
- More than 40 physics-related PhET simulations exist and are being used in introductory physics courses around the world
- We employ a design philosophy that incorporates our own[2] and other's research in multimedia learning

Circuit Construction Kit (CCK)

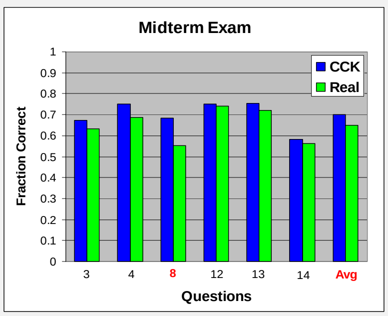
- Students build, manipulate, & test realistic DC circuits
- Current is explicitly modeled by moving little blue dots
- Students can observe cause-and-effect relationships
- Available *free* online http://phet.colorado.edu
- Designed by the *Physics Education Technology* project (PhET) at CU-Boulder[2,3]

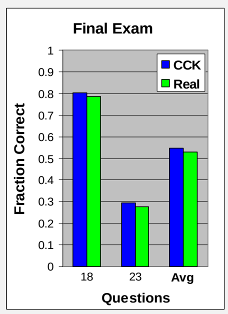


Fall 2004 Study

- All students participated in the two *Tutorials* on DC circuits in calculus-based Physics 2 (N=445)
- **CCK**, N=184. Students completed the same 2 *Tutorials* using only CCK (with the explicit current model)
- **Real**, N=180. Students completed these 2 tutorials using the real equipment
- Conceptual performance was measured on four exams (midterm, final exam, pre/post BEMA[4])

Results: DC Circuit Q's on Midterm & Final Exam

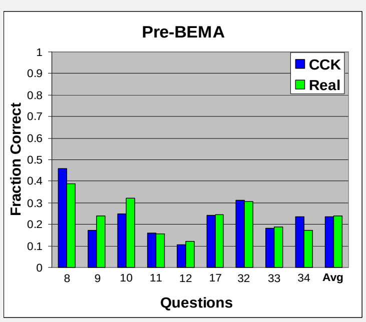


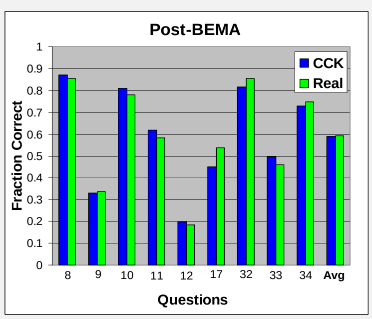


Exam given 4 weeks after intervention. Two groups perform statistically different on Question #8 and Average ($p_8 = 0.009$, $p_{Avg} = 0.014$).

Exam given 8 weeks after intervention. Performance by 2 groups is statistically similar on all questions and Average.

Results: DC Circuit Q's on BEMA Exam





Exam given during first week of instruction. No question is statistically different. Average of all 9 questions is similar.

Exam given 8 weeks after intervention. No question is statistically different. Average of all 9 questions is similar.

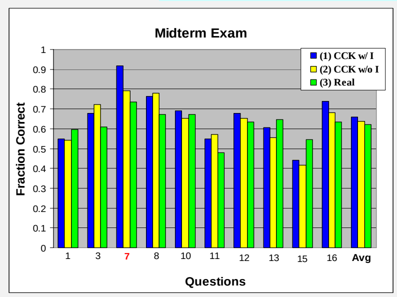
Conclusion

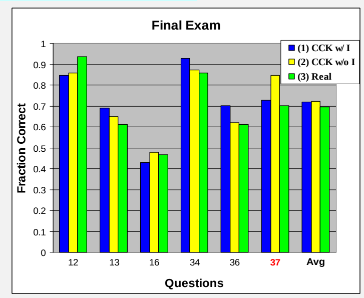
- Performance on pre-BEMA indicates a matched sample
- CCK students demonstrate slightly greater conceptual mastery of DC circuits than students using real equipment soon after intervention
- At the end of term, CCK students perform just as well as students who used real equipment

Spring 2005 Study

- All students participated in two *Tutorials* on DC circuits in calculus-based Physics 2 (N=311)
- **(1) CCK w/ I**, N=84. Students completed 2 *Tutorials* using only CCK with the explicit current model
- **(2) CCK w/o I**, N=72. Students completed the same 2 *Tutorials* using only CCK *without* the explicit current model
- **(3) Real**, N=79. Students completed the same 2 *Tutorials* using only real equipment
- Conceptual performance measured on four exams (midterm, final exam, pre/post BEMA)

Results: DC Circuit Q's on Midterm and Final Exam

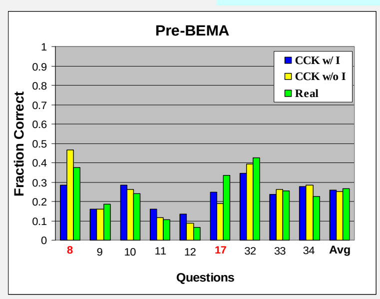


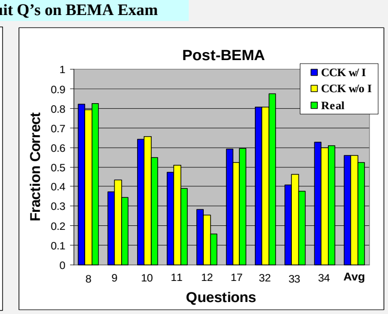


Question 7 is statistically different ($p_{12} = 0.03$, $p_{13} = 0.0017$). Performance by all 3 groups is similar on Average of all questions.

Question 37 is statistically different ($p_{23} = 0.03$); Average of each group on all questions is similar.

Results: DC Circuit Q's on BEMA Exam





Questions 8 & 17 are statistically different. Averages of all questions for 3 groups are similar.

No question is statistically different. All 3 groups perform similarly on average of all questions.

Conclusion

- On midterm, final exam, and post-BEMA, CCK students perform just as well as Real students at answering conceptual questions on DC circuits
- Explicit current model does not seem to have any harmful effects on students' conceptual understanding
- Differences in performance on individual questions are observed, but no difference between the 3 groups on aggregate questions relating to DC circuits

Conclusion

- CCK can be successfully used in lieu of real equipment with *Tutorials*
- In all cases observed so far, CCK promotes the same or greater conceptual mastery for students than the use of real equipment, agreeing with previous studies[5]
- CCK's explicit current model has no significant effects on aggregate exam questions
  - Individual questions may reveal differences of explicit visualization
  - Further studies in progress to better understand the influence of explicit visual models

End Notes

References

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Acknowledgements

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