

Changing Scientific Reasoning And Conceptual Understanding In College Students

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Abstract. Data from several years and several different classes have shown that Lawson test scores do not change much over the course of a single semester and are strongly correlated with FCI gains. So what does change Lawson scores? We have new data that we think shows that more interaction with materials that demand reasoning (and not just clicker questions and end of chapter Homework problems) improves reasoning ability and subsequently conceptual development.

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INTRODUCTION

In the early 1970s, a concern developed among science educators that incoming students were ill-prepared to study college level physics. Anton Lawson's Classroom Test of Scientific Reasoning (LCTSR) [1,2] provided evidence of this lack of preparation in a guest editorial AJP letter by Lawson and Robert Karplus [3] where they showed that only a small fraction of incoming college students were reasoning at a level that would allow them to deal cognitively with abstract and complex concepts.

In a 2005 AJP paper [4], Coletta and Phillips reported data showing a correlation between conceptual understanding and scientific reasoning as measured by the Force Concept Inventory (FCI) and the LCTSR. I took this challenge to BYU-I and over the next several years measured student reasoning, attitudes using the Epistemological Beliefs Assessment for Physical Science (EBAPS) [5], and conceptual understanding in as many of our introductory physics classes as I could get access to. The purpose of this paper is to report on these results.

METHODOLOGY

I administered the LCTSR, EBAPS and FCI [6], CSEM [7], or HTCE [8] for the mechanics, E&M, or thermodynamics classes, respectively. Student scores were paired pre and post, and then analyzed. All data shown here are from my own classes. Note that the Fall 2008 class was a general education Physical Science 100 class, the two middle sets were Physics 105 (an algebra-based course in mechanics) and the winter 2011 class is a calculus-based course for scientists and engineers in thermodynamics, waves,

and optics. All but the PHS100 class met daily for an hour, and the PHS100 class met thrice weekly for an hour each time. The PH 105 class has the lab activities integrated with the course but the calculus-based sequence has separate labs with a computational emphasis so I did short inquiry-based activities about once a week during the hour-long class time.

RESULTS AND DISCUSSION

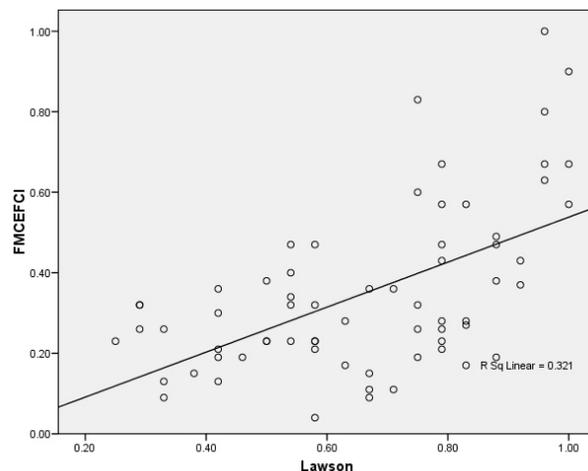


FIGURE 1. Lawson/FCI scores for Fall/Winter 2007

The strong correlation between reasoning and understanding shown in Figure 1 may indicate that reasoning can be a limiting factor in conceptual development in intro physics. The almost step-like character of the Lawson/FCI data at about the 60% level on the Lawson test seems to verify this, perhaps representing pre-operational versus formal operational cognitive levels. Lawson pre-post scores for these

classes shown in Figures 2 and 3 indicated no change even with extensive interactivity in the form of peer instruction and simple home-made inquiry activities.

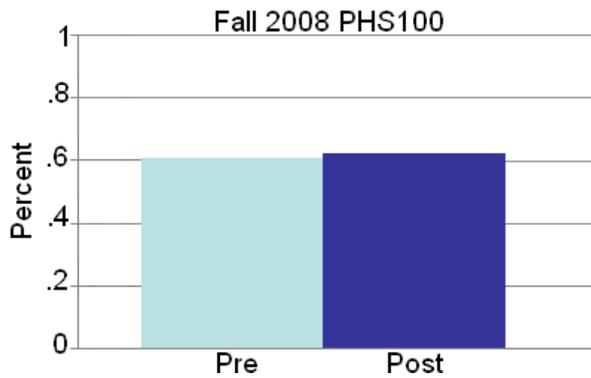


FIGURE 2. Lawson pre-post data by percent Fall 2008

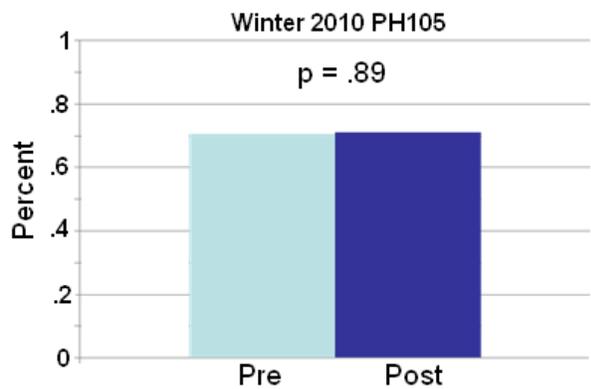


FIGURE 3. Lawson pre-post data by percent Winter 2010

If there was such a strong correlation with understanding, it seemed incumbent on me then, to try to improve reasoning in order to meet the main goal of conceptual understanding. Adding the University of Washington Tutorials in introductory physics [9] in Fall 2010 resulted in statistically significant gains in Lawson scores, but not really FCI scores. By adding the student workbook assignments accompanying Randall Knight's textbook [10] (but not changing the rest of the course except not doing the tutorials) in the winter 2011 class resulted in both Lawson gains and a dramatic improvement in conceptual understanding as shown in Figures 4, 5 and 6. Also note that reasoning ability as measured by the LCTSR improved slightly from each class level to the next, with the pre-med students reasoning slightly higher than the GE students and the science majors reasoning a bit higher than the pre-meds.

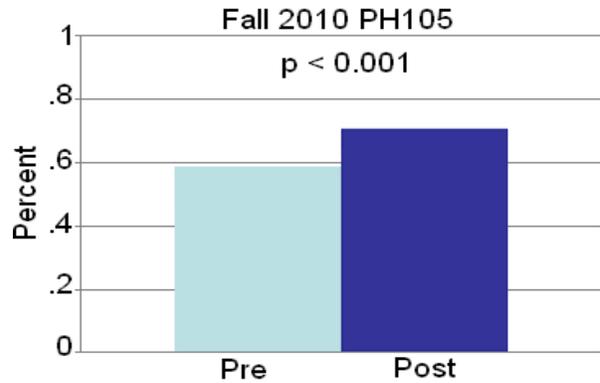


FIGURE 4. Lawson pre-post data by percent Fall 2010 having added the tutorials.

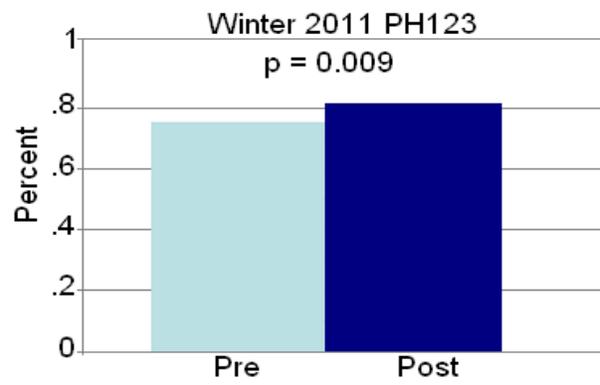


FIGURE 5. Lawson pre-post scores by percent Winter 2011 with the Knight workbooks added.

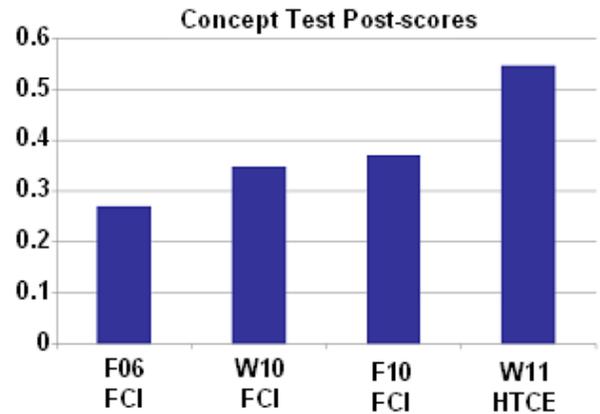


FIGURE 6. Concept evaluation post-test scores.

It should also be noted that the tutorials are based on extensive research and require faithful implementation to be effective. Another possibly-confounding variable is that the workbook assignments accompanying the Knight text generally take the students much longer to complete than the tutorials do. The students work on the workbook assignments primarily outside of class and mostly

individually, although I encourage them to work on them in groups. The time-on-task students spend on the workbooks may have dramatic effects on their conceptual development. Lastly, the students generally had poor (but not *very* poor) attitudes about both the tutorials and the workbook assignments, but also generally agreed, when pressed, that the tutorials and workbooks contributed in positive and non-negligible ways to their understanding.

CONCLUSION

The take-home message is that the sorts of activities that require students to develop, explain and defend their reasoning help them develop cognitively in ways that lectures or even peer interactions in a lecture-like environment cannot. We cannot assume that our incoming students are able to reason in the sophisticated ways they need to really understand abstract and complex concepts like force and energy. If we do really care that our students get these concepts, we need to provide explicit opportunities to improve their reasoning. This research shows both that student reasoning can be improved by a judicious application of explicit interventions. These interventions need to be interactive and demanding enough to engage the students in using formal reasoning skills. Practice in the use of these cognitive abilities is necessary in order for their skills to improve. Improvement of these types of reasoning skills seems to be pre-requisite for conceptual understanding.

ACKNOWLEDGMENTS

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