From FCI To CSEM To Lawson Test: A Report On Data Collected At A Community College

Karim Diff and Nacira Tache

Department of Natural Sciences, Santa Fe Community College, Gainesville, FL 32606 USA

Abstract. As part of an ongoing assessment of our introductory physics courses, we have administered the Force Concept Inventory (FCI) and the Conceptual Survey of Electricity and Magnetism (CSEM) in the three different levels of physics courses offered at Santa Fe Community College: Applied physics, algebra-based physics and calculus-based physics. We present data collected this past year, including an analysis of the correlations between normalized FCI and CSEM gains for the past four years. In addition, we report results obtained this past year in a study of correlations between the Lawson classroom test of scientific reasoning and gains on the FCI and CSEM.

Keywords: Lawson Test, FCI, CSEM, scientific reasoning.
PACS: 01.40.Fk, 01.40.Ha

INTRODUCTION

Assessment instruments such as the Force Concept Inventory (FCI) [1] or the Conceptual Survey of Electricity and Magnetism (CSEM) [2] are valuable tools to measure instructional effectiveness in introductory physics courses. Recent articles [3,4,5] have attempted to determine whether some "hidden variables" such as scientific reasoning abilities as measured by the Lawson Test[6] or mathematical skills may correlate with normalized gains on diagnostic tests. To investigate that idea, as part of an ongoing assessment of our courses, we gave the FCI, the CSEM, and the Lawson test to three different student populations (applied physics, algebra-based physics, calculus-based physics). Preliminary results show positive, significant correlations between scores on the Lawson test and normalized gains on the FCI and CSEM. We also identified a cohort of students who took both the FCI and the CSEM but found no significant correlation for this case.

FCI-LAWSON CORRELATIONS

Following a suggestion made by Coletta and Phillips [3] we examined the relationship between normalized gains on the FCI and scores on the Lawson test for a group of students taking their first semester physics course at Santa Fe Community College in the Fall 0f 2006. The students were split among three different physics courses: Applied physics (which requires Intermediate Algebra as its pre-requisite) and the usual algebra-based and calculus-based courses. Our aggregate results are shown in figure 1 below. A small ($r = 0.36$), significant ($p = 0.00007$, at the usual 95% confidence interval) correlation is found.

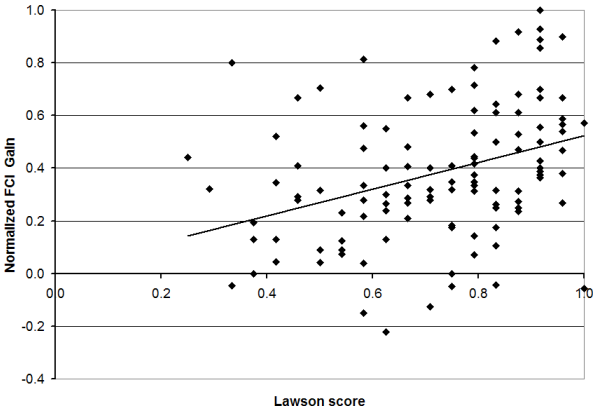

FIGURE 1. Normalized FCI gain versus Lawson score. Number of students: N = 116. Correlation: r = 0.36. Significance level p = 0.00007. Slope s = 0.50.

We also examined the relationship between pre-instruction scores on the FCI and the normalized gains. In his extensive survey published in 1989, Hake [7] found no correlation between class-averaged pre-instruction scores and normalized gains. Our results, shown in figure 2, indicate a positive correlation,

$r = 0.37$, with a significance level $p = 0.0004$, for single-student normalized gains. Coletta and Phillips suggest some explanations for this discrepancy, but we need further analysis of our data to make a determination.

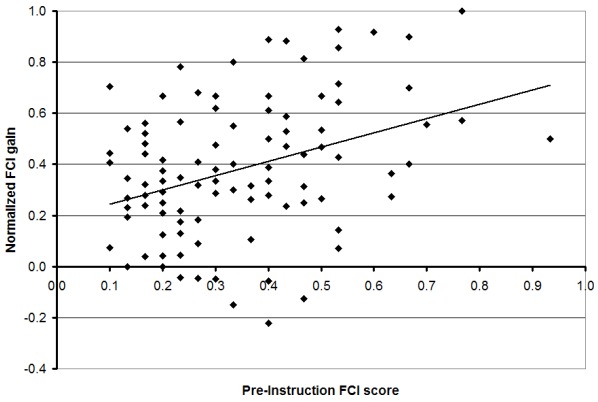

FIGURE 2. Normalized FCI gain versus pre-instruction score. Number of students: N = 116. Correlation: $r = 0.37$. Significance level $p = 0.0004$. Slope $s = 0.56$.

CSEM-LAWSON CORRELATIONS

During the spring and summer 2007 semesters we examined the relationship between scores on the CSEM and Lawson test. Although this was not part of our study, we took advantage of the fact that many students were returning from the previous semester to conduct an ad-hoc pre-post analysis of their Lawson test scores and found no significant changes. A more thorough investigation of this aspect will be the subject of a future publication. In figure 3 we show normalized gains on the CSEM versus Lawson test scores. We find another positive correlation, $r = 0.35$, with a significance level $p = 0.0004$ for N=100 students tested.

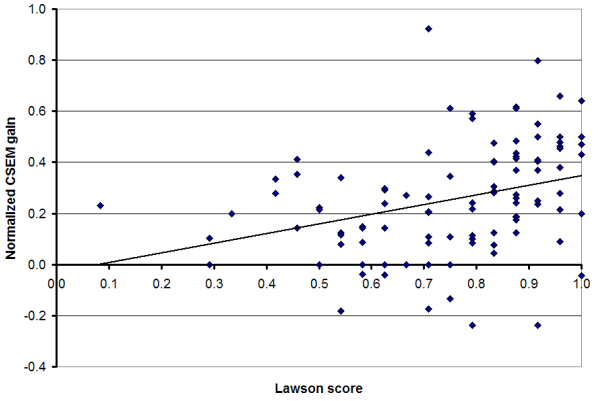

FIGURE 3. Normalized CSEM gain versus Lawson score. Number of students: N = 100. Correlation: $r = 0.35$. Significance level $p = 0.0004$. Slope $s = 0.38$.

It is interesting to note that in this case no correlation is found between normalized CSEM gains and pre-instruction CSEM scores as shown in figure 4. As discussed by Maloney et al. [2] students are rarely familiar with the more abstract concepts, language and phenomena of electricity and magnetism (as opposed to mechanical concepts studied in first semester physics.) The correlation between scores on the Lawson test and the CSEM normalized gain opens an interesting possibility concerning the predictive power of the Lawson test.

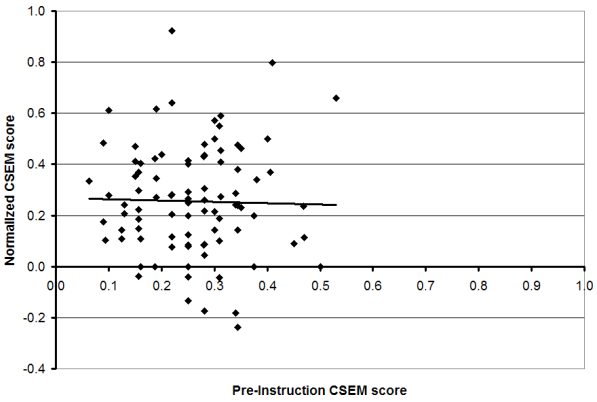

FIGURE 4. Normalized CSEM gain versus pre-instruction CSEM score. Number of students: N = 100. Correlation: $r = -0.02$. Significance level $p = 0.8$. Slope $s = -0.05$.

FCI-CSEM CORRELATIONS

While casual observation indicates that students struggle more with second-semester physics than with first-semester physics, we wanted to know whether students who had large normalized gains on the FCI would also have large normalized gains on the CSEM. Normalized FCI gains ranging from 0.2, for traditional classes, to 0.70 for highly interactive classes have been reported extensively[7]. For CSEM gains, the national average is 0.25[8].Using data collected over the past four years we were able to identify a cohort of students (N= 54) in our calculus-based physics who completed the pre- and post-instruction assessments both times. Their average FCI gain was 0.40 and their CSEM average gain was 0.41. However, as shown in the figure below, we obtained a small ($r = 0.21$) but not significant ($p = 0.12$) correlation. To obtain reasonable sample sizes, given the small size of our classes, we had to collect data over multiple years. This limits our ability to interpret the data as classroom conditions may change significantly over such a time span.

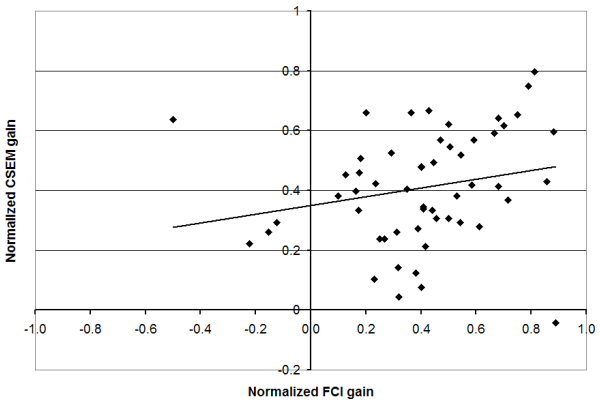

FIGURE 5. Normalized CSEM gain versus normalized FCI gain. Number of students: N = 100. Correlation: $r = 0.21$. Significance level $p = 0.12$. Slope $s = 0.15$

One of the striking results of our analysis is the wide discrepancy that exists across our three different types of courses. Table 1 below breaks down the normalized gains and Lawson averages by class type. Cognitive factors, as measured by the Lawson test may offer some clues about this discrepancy, but there could be other factors at work as well. Mathematical skills vary widely across the three classes and could interfere with conceptual learning as discussed by Meltzer [4]. The effectiveness of the classroom techniques used may also be a factor. While students in the algebra and calculus-based courses have been very receptive of the various modifications made to the courses, with an emphasis on interactive engagement, students in the applied physics courses have been less willing to embrace departures from the classical lecture model. We are currently implementing a more hands-on curriculum [9] that we hope will result in greater learning gains for our students in applied physics.

CONCLUSION

We have investigated the relationship between student scores on the Lawson Classroom Test of Scientific Reasoning and their normalized gains on the FCI and the CSEM. We find small, but significant correlations between Lawson scores and gains on both the FCI and the CSEM. If confirmed by further analyses, these correlations could help instructors identify at-risk students and establish effective intervention programs. This could also contribute to a better understanding of factors, other than instruction format, that contribute to significant gains on standardized assessments. On the FCI scores we also find a correlation between pre-instruction scores and normalized gains. Such a correlation does not exist, in our data, between pre-instruction and normalized gains for the CSEM. We also do not find a significant correlation between FCI normalized gains and CSEM normalized gains for a cohort of students in calculus-based physics. Another finding of our analysis is the spread of learning gains between students in our applied physics courses and their counterparts in algebra-based and calculus-based physics.

TABLE 1. FCI, CSEM, and Lawson test by class type.

Course	Normalized FCI gain	Normalized CSEM gain	Lawson score (%)
Applied Physics	0.23	0.15	69.7
Algebra-based Physics	0.38	0.32	70.5
Calculus-based Physics	0.48	0.29	78.8
All students	0.38	0.25	73.6

REFERENCES

1. D. Hestenes, M. Wells, and G. Swackhamer, *Phys. Teach.* **30** (3),141-158 (1992). The revised version of 1995 was used for this study. The test is available online at http://modeling.asu.edu/R&E/Research.html to authorized educators.
2. D. P. Maloney, T. L. O'Kuma, C. J. Hieggelke, and A. Van Heuvelen *Phys. Educ. Res., Am. J. Phys.Suppl.* **69** (7*)* S12-S-23 (2001).
3. V. P. Coletta and J. A. Phillips, *Am. J. Phys.* **73** (12*)* 1172-1182 (2005).
4. D. E. Meltzer, *Am. J. Phys.* **70**(12*)* 1259-1268 (2002).
5. V. P. Coletta, J. A. Phillips, and J. J. Steinert *Phys. Rev. ST Phys. Educ. Res.* **3**,010106 (2007)
6. A.E. Lawson, *J. Res. Sci. Teach.* **15** (1), 11-24 (1978)
7. R. R. Hake, *Am. J. Phys.* **66** (1*)* 64-74 (1998). Additional details concerning this study can be found online http://www.physics.indiana.edu/%7Esdi/IEM-2b.pdf
8. "Creating a New Physics Education Learning Environment."http://www.wcer.wisc.edu/archive/Cl1/ilt/case/joliet/summative_outcomes.htm
9. ICP21: Introductory College Physics/21st century. http://www.ztek.com/