Excerpts from:

Assessing the Opportunity for Success of Beginning Physics Students

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Abstract

The study described in this paper investigates which of the available local measures is best able to predict success in a first year physics course. A sample of approximately 240 physics students in the School District of Elmbrook [SDE] with similar elementary and middle school backgrounds were tested with the Wisconsin Knowledge and Concept Evaluation [WKCE] in the year preceding enrollment in physics. Students enrolled in physics were also pre-examined using a simple scientific reasoning test. Finally, the Force Concept Inventory [FCI], a well-recognized Newtonian physics concept instrument (Hestenes, Wells & Swackhamer, 1992) was used to establish the final level of mastery. The purpose is to help students, parents, and guidance counselors decide whether basic or honors physics is the more suitable course selection.

Introduction

Students enrolling in their first high school physics course commonly do so with a certain amount of apprehension. The source of this concern is often two-dimensional. First, many students are simply unfamiliar with the subject matter; for example, they are unaware of exactly what they will be studying. Second, for most students, physics is the first course requiring substantial conceptual understanding as well as an ability to think abstractly. Students in the School District of Elmbrook [SDE] are not assessed expressly for their development in abstract or conceptual thinking. Consequently, there are limited indicators for success in first year physics. As a result, teachers, parents, and guidance counselors may advise a prospective student simply by talking to the student and guessing, or basing placement on previous performance in mathematics courses; after all, physics clearly demands a certain level of mathematical application. The question is whether placement based upon only mathematics is the most optimal approach. While mathematics is commonly used to solve physics problems, previous performance in mathematics may not be sufficient to simultaneously indicate whether a student is also able to think abstractly and conceptually.

Not only must it be decided whether physics is an appropriate course choice for a given student, but it also must be decided whether basic or honors physics is the appropriate level of entry. As in many high schools, the School District of Elmbrook offers first year physics students a choice between basic or honors physics. Therefore, there are actually three levels of participation: not to enroll, to enroll in basic physics or to enroll in honors physics. At this writing, the choice between basic and honors physics is fairly important, since students who do not maintain at least a B average in honors physics are required to change to basic physics by the end of the first quarter or semester grading periods. Being required to "drop down" to basic physics is unsettling for students, and has unfavorable implications for class scheduling. While there is no test specifically designed to encourage correct placement in physics, correct student placement is desirable.

The State of Wisconsin, in its WKCE testing program, routinely tests all tenth grade students in the areas of mathematics, science, social studies and verbal skills. The purpose of this study is to determine whether WKCE results or a basic scientific reasoning test are able to predict first year physics performance, and thus provide appropriate direction for students, parents and guidance counselors. Specifically, this study explores whether there is a positive relationship between standard assessments given in science, mathematics, reading, social studies, and finally, scientific reasoning.

Results

Findings

Summary data consisting of Pearson Product-Moment Correlation coefficients, as well as mean and standard deviation values are found in *Table 1*. Pre-FCI data is also provided to reflect the initial and final levels, as well as the change in student performance. *Graphs 1-5* display scatter-plots, linear regression equations, and R^2 values for final FCI performance against each of the five variates. *Graph 6* represents the frequency distribution for the scientific reasoning test.

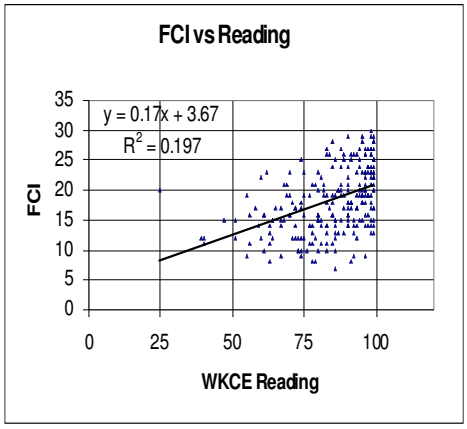
Table 1

Means, Standard Deviations, and Correlation Matrix for

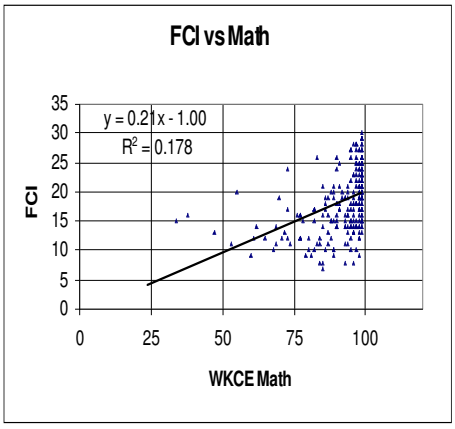
Input Variables and FCI Scores ($N = 239$)

Variable Number - Name	Mean	SD	1	2	3	4	5	6
1 - Reading	84.38	13.90	1					
2 - Mathematics	91.74	10.84	0.483	1				
3 - Science	84.88	14.07	0.571	0.414	1			
4 - Social Studies	85.08	12.40	0.490	0.431	0.493	1		
5 - Scientific Reasoning	6.19	2.13	0.405	0.490	0.435	0.424	1	
6 - Post FCI	18.18	5.38	0.444	0.422	0.463	0.474	0.600	1
Pre FCI	8.43	3.42						

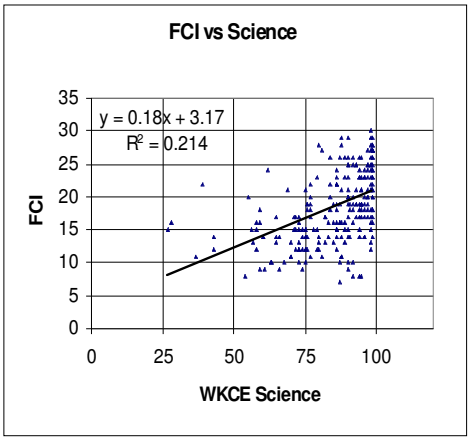
Graph 1



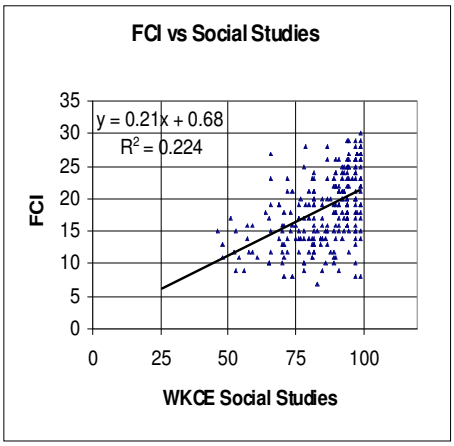
Graph 2



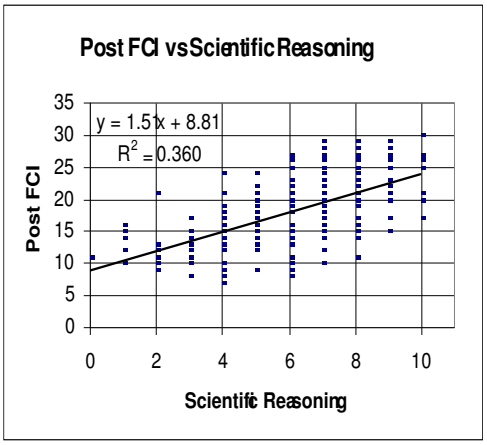
Graph 3



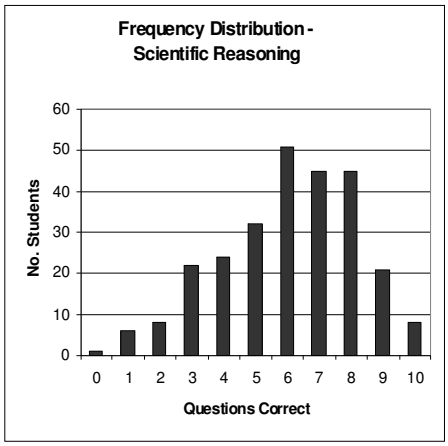
Graph 4



Graph 5



Graph 6



Analysis and Discussion

It is noteworthy that based upon the mean scores the overall performance on the FCI improved from 8.43 to 18.2, or approximately an increase of 115%. This is typical of the average gains experienced in the district since the modeling method was adopted in the high schools five years ago. Consequently, the data used in this study should not be construed as untypical.

First, inspection of the scatter-plots shows that in each WKCE area, none of frequency distributions can be considered *normal*. A normal distribution for these exams results only if the population is typical of the national norm. In a normal distribution 33% of the population falls above the 77 percentile, while study results place 74%, 92%, 72%, and 77% of this population for reading, math, science, and social studies, respectively, in this range. Similarly, a normal distribution would reflect a mean of 50%, while study results yielded 84.4%, 91.7%, 84.9%, and 85.1%, respectively. The distribution is clearly skewed toward the top. Consequently, to result in a linear relationship, students performing at the top on a WKCE scale would need to perform almost perfectly on the FCI. The construction of the FCI is contrary to that outcome. In reflection, the results are consistent with the intent of these measures, i.e., WKCE examinations are constructed to demonstrate expected mastery in specific core areas, while the FCI intentionally incorporates instinctive experiential responses to challenge students' to Newtonian concepts. This study could likely have been improved had these core areas been evaluated with measures that resulted in more normal distribution. Alternative instruments, such as the ACT or SAT tests, do not necessarily precede the physics course, nor is one or the other necessarily taken by all students. In another context, the WKCE may be more applicable across a more homogeneous population.

Critically, the scientific reasoning measure most closely correlates (0.600) with post-FCI results, followed by social studies (0.474), while mathematics shows the weakest correlation (0.422). Thus, results demonstrate that compared to the more elaborate WKCE series, the simple ten-question test of scientific reasoning was shown to best predict physics success. In consideration of previous discussion concerning normal distribution and *Graphs 1-6*, the reasoning measure most closely resembles a normal distribution. This may be *the* important distinction. While a normal distribution may not be sufficient to establish prediction, it may be a necessary characteristic for any prospective measure. The correlation of performance with scientific reasoning is well documented both by Lawson (1985) and Shemesh, Eckstein, and Lazarowitz (1992). Improvement in this aspect of the study is certainly possible with the adoption or development of a more specific test of reasoning. This is the essential recommendation derived from this investigation.

The position of social studies as the next greatest correlation coefficient might be considered something of a wonder. However, it was suspected at the outset that whichever WKCE measure called for the most skill in analysis and evaluation might favorably correlate with the criterion FCI. This seems to be the case.

Finally, it may also not have been suspected that mathematics would correlate the least. Once again, the necessary but not sufficient reasoning may apply. This point was reflected in the cited writings of Champagne, Klopher and Anderson (1980), and Halloun and Hestenes (1985). Additionally, it is also notable that on the average the highest WKCE performance for this population was in mathematics, which is consistent with the results.

One observation outside the scope of this study is the apparent correlation between the areas of science and reading, while not similarly reflected in social studies. At the outset it seemed both social studies and science performance could expect to depend comparably on reading skill. This finding appears to echo the 1994 results of Gustin, Corazza, and Luciano where verbal ability was cited as being "consistently more valuable as a predictor of success in science" (p. 161), but perhaps less critical in the case of physics and the FCI.

Conclusion

Wisconsin Knowledge and Concepts Examinations were generally less able to provide sufficient differentiation of the population to provide decisive correlation with physics success. While this population should not be considered typical, it seems clear the WKCE is not universally the best option for this purpose. However, it is concluded that a measure of scientific reasoning holds considerable promise as a predictor of physics success. Accordingly, the following recommendations will be made. First, in cases where course enrollment is in question, it is advisable to administer a scientific reasoning measure. Should these results be inconclusive, the student WKCE social studies results may be useful secondarily. Second, mathematics is a necessary skill, but should not be used as an indicator for success. Finally, in the absence of more conclusive information, a student's WKCE reading achievement may be useful in counseling students regarding science course selection.

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