

Investigating the Relationship between Cognitive Ability and Academic Achievement in Elementary Reading and Mathematics

Abstract

This study used an existing 4th grade assessment database from a suburban Portland, Oregon school district to examine the relationship between cognitive ability and academic performance in reading and mathematics. As expected, a strong, positive correlation was found for both reading and mathematics. Possible implications for standards-based reform models are discussed.

Literature Review

It is a firmly established principle of educational psychology that there is a strong positive relationship between measures of cognitive ability and measures of academic achievement, especially in those content areas emphasizing verbal and mathematical concepts and operations. Further, cognitive ability has been shown to strongly influence the extent to which students benefit from formal instruction. That is, learning difficulties increase and the rate of learning slows inversely proportional to cognitive ability.

It is presumed that measures of cognitive ability are indirect measures of biological differences in brain morphology and/or function and that these organic differences cause differences in the rate, quality¹ and retention of academic learning. While these differences do not appear to set specific limits on learning, they do cause achievement differentiation among students, especially when students are exposed to similar learning resources.

For an extensive review and discussion of the research base related to cognitive ability see: I. J. Deary, **LOOKING DOWN ON HUMAN INTELLIGENCE FROM PSYCHOMETRICS TO THE BRAIN** (Oxford University Press, New York, 2000). A more accessible book by Deary on the same topic is also available, **INTELLIGENCE: A VERY SHORT INTRODUCTION** (Oxford University Press, New York, 2001). For another accessible account see S. Pinker, **THE BLANK SLATE**. Finally, see the American Psychological Association's position paper on intelligence summarized by V. N. Quinn, **SETTING THE RECORD STRAIGHT: WHAT IS KNOWN AND UNKNOWN ABOUT INTELLIGENCE**.

Problem Statement

It is commonplace for school reformers to advocate for the implementation of grade level and graduation content and performance standards. Implicit in their recommendation is an assumption that cognitive differences among students either make no or very little difference in the rate or level of achievement that is possible in a given time frame. As a consequence, reformers generally argue that it is appropriate to apply the same standards to all students and hold them accountable for meeting them.

¹ Quality in this context refers to the thorough and complete mastery of concepts and skills. In addition it refers to the degree of success attained in applying new concepts and skills to novel situations and problems. Throughout the core curriculum, successful, independent application of academic learning represents the primary purpose of instruction.

But is this approach reasonable and, perhaps more importantly, psychologically defensible? Is it true that cognitive ability makes no difference in the rate or level of achievement? And if ability does make a difference, what are consequences for the design of standards-based systems?

First, let's be clear what is meant by cognitive ability. For the purposes of this discussion, the definition of cognitive ability will be restricted to verbal and quantitative processes related to academic achievement. Cognitive ability, then, refers to biology-based differences in the make-up of the human brain that affect the capacity of an individual to benefit from instruction. Cognitive ability influences the rate, quantity and quality of new learning. Ability also affects how well new learning is converted to long term memory and how well the new learning can be applied to new situations. Put simply, some brains are more efficiently wired to process the kind of learning provided in the core public school curriculum. To a certain extent, cognitive ability places constraints on the amount and type of learning that can be attained in a given time frame. Certainly all children can learn. But they can't all learn the same amount in the same time frames with exposure to basically the same learning resources.

Hypothesis

The hypothesis to be investigated in this study is a simple one that has been verified many times. It is as follows: cognitive ability, which is a measure of organic cognitive variation among students, affects the rate and quality of school learning, and therefore accounts for a significant proportion of academic achievement variation among students of similar age.

Method

The hypothesis was tested using assessment data from a group of 452, 4th students which were collected during the 2008-09 school year. The students all attended public elementary schools in one suburban Portland, Oregon school district.

Three different assessments were administered. First, each student completed a group-based, nationally-normed assessment of cognitive ability, InView Level 2, published by CTB/McGraw-Hill. This timed, multiple-choice examination, comprised of five sub-tests², includes 100 items to be completed in 95 minutes. While scores are reported in several forms, only the Cognitive Skills Index score was used in this study. This equal interval scale has, by definition in the Level 2 form, a mean of 100 and a range of 70-141. The national group scores form a normal distribution with a standard deviation of 16. InView was administered during the month of November 2008.

Reading and mathematics achievement were assessed using the Oregon Assessment of Knowledge and Skills (OAKS). Each subject is tested separately through a computer adaptive multiple-choice test. The typical test is composed of an average of 40 items. Each student had the opportunity to take the assessment three times during the 2008-09 school year. If more than one test was taken, the highest score was used in this analysis.

OAKS assessments are power tests allowing students to continue to work as long as progress continues to be made. The scores used in this analysis were the standard RIT scores. For reading, the range of possible scores was 153-267. For mathematics the range was 149-268. The majority of scores reported

² InView sub-tests include: Sequences, Analogies, Quantitative Reasoning, Verbal Reasoning – Words, Verbal Reasoning – Context.

here were obtained through assessments administered in January 2009. The range of testing dates was December 2008 through May 2009.

Results

95.5% of the 4th graders enrolled on October 1, 2008 completed all of the administered tests. This represents an unusually high proportion of the cohort and confirms a very low mobility rate for the group. Students not included in the data set did not complete one or more of the assessments.

See Figure 1 for a summary of relevant demographic characteristics. On these dimensions the cohort is also a bit atypical compared with the State of Oregon data.

2008-09 4th Grade Demographics

| Category | Study Sample | All Oregon |
|-------------------------|--------------|------------|
| Total Enrollment | 485 | |
| # of Students Tested | 463 | |
| # of Complete Data Sets | 448 | |
| % Complete Data Sets | 95.5% | |
| % Special Education | 12.9% | 12.9% |
| % Talented and Gifted | 14.5% | 7.5% |
| % Low Income | 6.5% | 46.7% |
| % Limited English | 1.3% | 9.5% |

Table 1

The distribution of InView CSI scores is shown in Figure 2. The calculated mean CSI score for the cohort was 108.8. It should be noted, however, that 14 students obtained the highest raw score possible on the Level 2 test. As a result, the Level 2 test does not accurately report their CSI, which is likely higher than the maximum reported score of 141. Considering this ceiling effect, the true mean CSI for this group of 4th graders is actually somewhat higher than the reported mean.

Regardless, it can be concluded that the test group is not a perfect mirror image of the InView national norming group which has, by definition, a mean of 100. The 4th grade cohort data used in this investigation represents an unusually high ability group. However, it does not appear that the shift in the mean CSI of the group biased the outcome of the study because the overall score range remained sufficiently broad.

The relationship between Cognitive Skills Index scores and the OAKS achievement test scores was established using the Pearson product-moment correlation statistic. See Figure 3 for the CSI-reading correlation and Figure 4 for the CSI-mathematics correlation. The correlation between reading and cognitive ability was 0.68 and for mathematics it was 0.69. These are strong, positive correlations, mirroring previous findings from similar studies.

Discussion

As expected, the hypothesis was confirmed. As noted earlier, the relationship between cognitive ability and academic achievement is a well-established psychological principle. If cognitive ability and achievement are proportionally related to each other and if differences in cognitive ability affect student ability to benefit from instruction, what are the consequences for educational reform projects based on common standards?

Let's start with individual student accountability. In 2008-09, the Oregon 4th grade performance standard for reading achievement was 211 and the performance standard for mathematics was 212. In the present study, more than 95% of the included students met or exceeded the standard for both reading and mathematics. Both of these results are well above the statewide means. Why have these students done so well?

In part it is due to the cognitive ability profile for the group. As described earlier, the students included in this study had higher than average cognitive ability scores. Nearly all of the students who failed to meet the reading and mathematics standard for 4th grade had lower cognitive ability scores.

But all students in the study group had access to roughly the same educational resources – the same number of school days, the same number of school hours per day, about the same amount of time per day devoted to reading and mathematics instruction, and similar curriculum and instruction resources.

The application of the same resources produced different outcomes for different students, in part as a function of cognitive differences. As long as resources are held roughly constant, it is inherently unfair to apply common standards to any group of students with wide-ranging cognitive abilities without compensating for ability differences. Particularly if there are sanctions attached for failing to meet the standards.

The same logic applies to groups of students in schools. This study also suggests that not all districts and schools have the same cognitive ability profiles. If this is true, comparisons of schools based solely on achievement score is misleading and unfair since differences in cognitive ability in part account for differences in achievement. And students obviously have no control over their genetic constitution.

Is it possible to compensate for these differences in cognitive ability when evaluating student performance or comparing different groups of students?

The methodological tools already exist to equate achievement data for ability variations. However, the baseline ability data needed is not generally available. As a first step, districts and states need to measure academic ability in valid and reliable ways. Once these data are available, then existing achievement datasets can be analyzed through the lens of ability.

Empirical norms can be established, preferable around annual growth scores, and achievement scores modified to equate them based on ability. Once the equating is completed for individual students, results can be aggregated to the school level.

Once these calculations are completed, something approaching a fair-minded accountability review can then proceed.

Conclusions

There are significant differences in cognitive ability among students. These differences affect the rate, accuracy and retention of what is learned. In part, as a result of cognitive differences, levels of achievement vary and generally grow greater over time, especially when students only have access to roughly equivalent learning resources.

This study strongly suggests that standards-based accountability systems that are based on fixed grade level content and performance standards are inherently unfair because they do not account for ability variations over which students have no control.

Achievement variation is normal. To fairly compare individuals and groups of students (classrooms and schools), achievement levels must be equated using empirically derived norms for various levels of ability. Once equalizations have been completed, we can legitimately begin to identify practices that are most effective for promoting learning for students of all ability levels, identify schools that are effective for students with various ability profiles, and potentially identify teachers who are particularly successful with students of varying ability profiles.

Subsequent research extending this study could be fruitful. By adding annual achievement updates to the dataset in this study, it may be possible to better understand the extent to which achievement gaps stabilize or expand over time based on ability. Because of unusually low student mobility rates, it may be possible to follow the 4th grade cohort described here through several years of educational experience, perhaps even through high school graduation. Longitudinal studies of this kind would be invaluable in constructing the empirical equating models needed to fairly implement standards-based systems.

In addition, a second round of ability tests administered to these same students when they enter 7th or 8th grade would be useful in establishing the reliability of the fourth grade SCI scores and might help develop an estimate of the extent to which ability can be modified through instruction.

Figure 2 - CSI Score Distribution

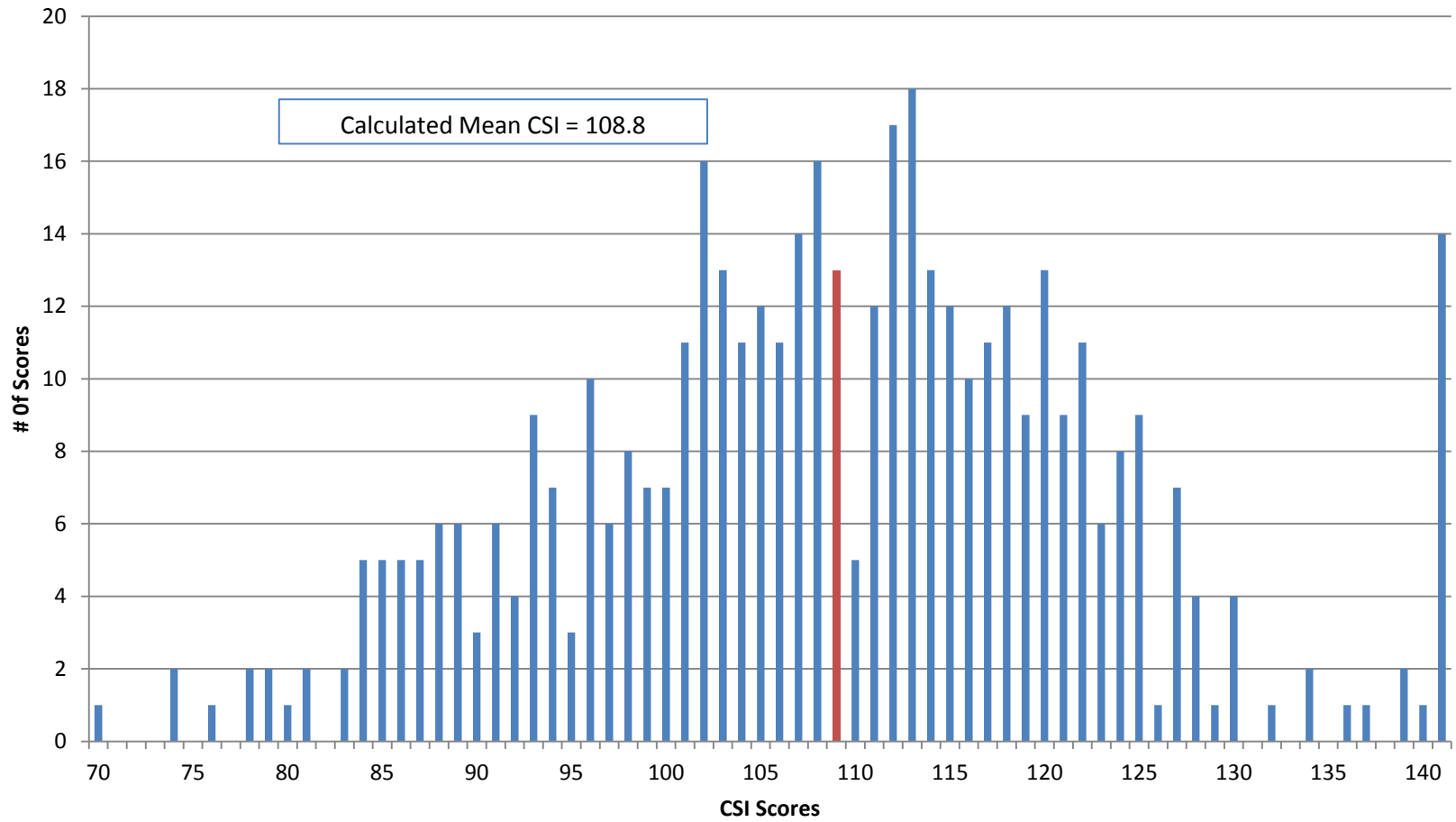


Figure 3 - Ability vs. Reading Achievement

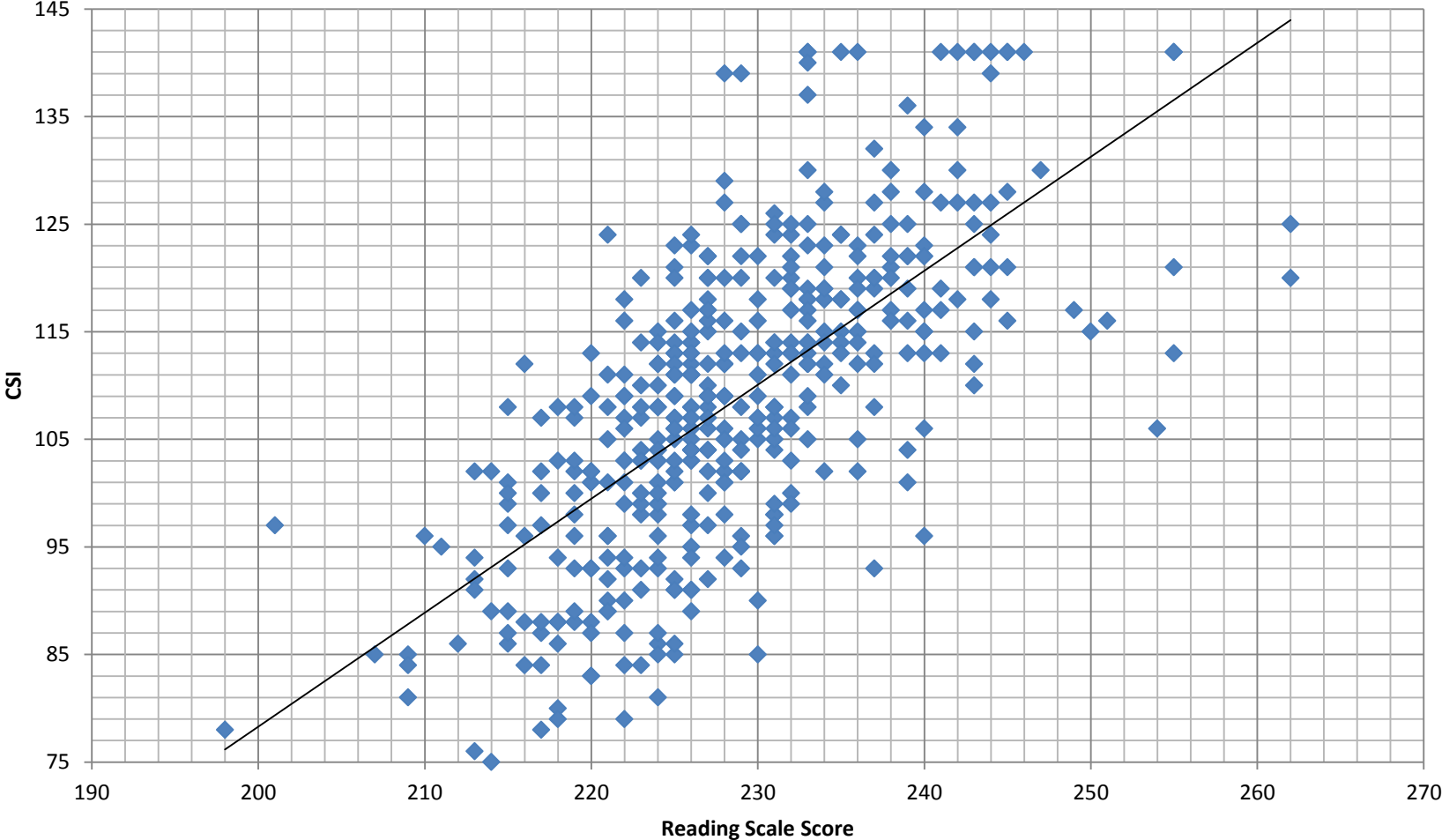


Figure 4 - Ability vs. Math Achievement

