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Educating Engineers

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Abstract

In this paper we discuss educational pedagogy vis-á-vis its impact on preparing students for careers in engineering. We relate their learning needs to the field of Educational Psychology by defining this focus group in terms of IQ metrics and relate these metrics to child development theory. We point out where we believe the current educational system is failing them. We then present a vertical study that follows eight students from 1st through 5th grade, emphasizing the improvements gained between third and fifth grade after the new approach was used. The traditional pedagogy was used in grades 1-4, while the suggested changes were incorporated in grade 5.

Introduction

On September 2, 1958, the United States passed the National Defense Education Act to increase the number of students pursuing careers in science and mathematics. The initial push, through the 1960's, was modestly successful. Since 1969, however, steady declines have put our nation at risk (Cofield, 2010). After reform, we now prepare significantly less students for science, technology, engineering and math (STEM) careers than we did in 1958. Currently New Zealand, Australia, Japan, and even Iran continue to perform significantly higher on international assessment metrics. While many students remain interested in STEM majors in college, a significant number change their majors, mostly due to failing grades (EOS Vol. 94 No. 37 Sept. 2012 NEWS). In 1983 the national commission on excellence in education [i.e. A Nation at Risk] concluded that the US is

> "being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people….For the first time in the history of our country, the educational skills of one generation will not equal, will not even approach, those of their parents."

In the [World Economic Forum] they assessed the state of US education in 1983, noting that

- compared with other industrialized nations, US education never places first, and frequently places last,
- tens of millions of American adults are functionally illiterate,
- average achievement test scores have declined for nearly half a century - science showed a steady decline for the 15 years preceding the study,
- more than 50% of gifted students do not achieve their projected ability,
- fully one third of 17-year-olds lack critical thinking skills, and cannot make reasonable conclusions from written material while fully two thirds cannot solve multi-step mathematics problems, and
- collegiate graduate achievement tests show a marked decline.

There is a "nearly desperate need for increased support for the teaching of mathematics and science … declines in educational performance are in large part the result of *disturbing inadequacies in the way the educational process itself is often conducted.*"[A Nation At Risk] (emphasis added). A more recent report, (Schwab,

2011) indicates that the decline has continued into the twenty-first century.

In (Spellings, 2005) they relate the state of post-secondary education to the secondary educational system as follows: "Several national studies confirm the insufficient preparation of high school graduates for either college-level work or the changing needs of the workforce. Dismal high school achievement rates nationwide have barely budged in the last decade. Close to 25 percent of all students in public high schools do not graduate." US mathematics and science rankings are clustered with less developed countries such as Kenya, despite half a century of effort.

The US is not the only country concerned with declining science and engineering graduation rates. Australia and England, despite placing significantly higher in international rankings, are also facing declining enrollment in science and mathematics. None of the reforms that have been tried over the past several decades has been able to reverse the participation trend (Noorden, 2008).

Underfunding Gifted Education

Our rankings in science and mathematics are far lower than countries that focus their educational efforts towards future Engineers and Scientists. In the United States an opposite focus exists. Our Government mandates specific levels of special education. When resources decline, the states' obligations to provide a minimum level of support for students significantly below normal intelligence levels, in conjunction with their need to balance their budgets, frequently requires underfunding gifted education which is not mandated by the federal government.

The US economy is far stronger than our K-12 rankings merit. The World Economic Forum's data offers an explanation for this dichotomy (Schwab, 2011). The US ranks third in the world for attracting talented people as workers. This skill extends to attracting talented college students from around the world. While the US ranks 50th for secondary education quality, we rank 6th for College education quality. US High School math and science education rankings are dead last of the industrialized countries, yet our colleges graduate some of the best engineers and scientists. Our K-12 STEM educational programs have failed, and US Engineering disciplines are being kept alive by borrowing brain power from other nations.

Focus on Engineering

In this paper we focus on the population of elementary students who have the potential to become engineers. We explain how and where we believe the current educational system is failing them. To support this belief we present a grade 1-5 vertical study, following eight students. All eight students attended a highly regarded Kindergarten program, and were very prepared for first grade. These students then used the Chicago math pedagogy from 1st through 4th grade, taught by certified elementary education teachers, and then had a 5th grade math class taught by a scientist who followed a pedagogy not un-like the interactions Richard Feynman describes occurring with his father when he was a child. Today we would say they are curiosity-driven, inquiry-based studies that are *technically correct and mathematically rigorous*.

Our vertical study is not large enough to be conclusive. Rather, combined with the scientists voices from the California Curriculum commission, strengthens the merit of their recommendations.

The overall K-12 pedagogy studies are directed towards students falling within one standard deviation of the norm (84<IQ<116). In addition there are persistent albeit inconsistent efforts directed towards individuals two or more standard deviations away from the norm in the positive direction (IQ >132). These populations are well studied (c.f. the publications of C. Tomlinson).

This leaves 13.5% of our population, those that lie between one and two standard deviations away from the norm in the positive direction (116<IQ<132), underserved. Table 1 lists average IQ's for different fields, where we see that such students are, on average, significantly equipped to enter traditional STEM disciplines.

130	Physics
129	Mathematics
129	Computer Science
128	Economics
127	Chemical Engineering
127	Material Science
126	Electrical Engineering
126	Mechanical Engineering
125	Philosophy
124	Chemistry
123	Earth Sciences
122	Industrial Engineering
122	Civil Engineering
121	Biology
120	English/Literature
120	Religion/Theology
120	Political Science
120	History
118	Art history
118	Anthropology/archeology
116	Architecture
116	Business
115	Sociology
114	Psychology
114	Medicine
112	Communication
109	Education
106	Public Administration

Table 1: Average IQ for various Professions. Notice that the professions from 116-130 are employing individuals with an IQ between one and two standard deviations above the norm.

The US educational pedagogies in place today are not serving these potential Engineering majors, those with average IQ's between 122-130, are not a primary focus in K-12 educational institutions - research articles on this population were difficult to locate. This vertical study, therefore, adds one data point focused on this particular population.

Analysis

An examination of math and science textbooks before and after the 1960's shows an obvious shift. The earlier texts are significantly shorter, and include the development of very narrow topics one physical or mathematical example at a time (cf. (Faraday, 1861)). They focus on the subtle details of the science and the critical thinking needed to correctly assemble these details into a mental model – they do not attempt to entertain the reader but rather engage their curiosity to deeply understand the subtleties of the topic. For example, Faraday's book, written at the end of the 1800's, walks the reader through the subject as if they were an apprentice, rather than as if they were students in a lecture class. One can follow and confirm his results with a series of experiments that can be performed independently with very few resources, and then understand the explanations he presents, *without having to read an excessive amount of information in textual form*. In contrast, most current education is classroom based and the textbooks, aiming for Universality, include significant textual information.

Discrete vs. Continuous Subjects

Math and science courses are fundamentally different that English and History courses. English and Social Studies may be viewed as continuum courses, while other subjects, such as mathematics, are taught as discrete classes. Continuum classes are typically text-based. They focus on students with normal to superior IQ who are good with non-mathematical critical thinking skills (verbal reasoning). In the US success in continuous courses with language-based support has improved over the last half century (Glatthorn, 1987) for some fields. These same reforms have been added to US discrete subject courses, but have failed to stop the continuing qualitative and quantitative reasoning declines in courses that require a quantitative reasoning skill sets.

In order to improve discrete subject courses, where language-based pedagogical approaches are currently failing, we propose two paradigm shifts. First, re-focus our efforts *in these classrooms only* towards the student population more likely to enter those professions (rather than our current focus on keeping uninterested students from becoming bored (Feynman)). The current math and science curriculum could be differentiated allowing students with aptitude and/or interest to pursue a parallel course of study more directed towards the engineering and science professions, with less language-based descriptions and more hands-on and critical thinking work. A course, in short, designed for those who have IQ's between 1 and 2 standard deviations above the norm, who are superior in quantitative reasoning, but who may not be as talented and/or interested in text-based methodologies.

Our second proposal is motivated by the thinking presented in [1] by Cofield and Popkin who emphasize that "the key challenge to implementing good teaching practices is … have physicists teaching physics". In Asian countries, being a STEM teacher is considered one of the best jobs in the country (Gentile, 2012). To communicate a subject, the speaker needs be both passionate about and a master of that subject.

Richard Feynman vs. the State of California

In 1964 the Nobel laureate physicist Dr. Feynman served on the Curriculum Commission for the state of California (they adopt textbooks). He included some of the details in his book "Surely You're Joking, Mr. Feynman!". I have shortened the chapter in which he decries this experience, but I use his own words to let the reader see his displeasure with the educational reform efforts at that time and with their associated pedagogy. Italics have been added for emphasis. The excerpt is rather lengthy, but its message is seminal to our argument as the vertical study follows a teacher who emulated his conversations with his father as a way to teach and motivate similarly aged young people.

> … the [text]books were so lousy. They were false. They were hurried. They would try to be rigorous, but they would use examples which were almost OK, but in which there were always some subtleties. The definitions weren't accurate. Everything was a little bit ambiguous -- they weren't smart enough to understand what was meant by "rigor." They were faking it. *They were teaching something they didn't understand*, and which was, in fact, useless, at that time, for the child. …. Anyhow, I'm looking at all these books, all these books, and none of them has said anything about using arithmetic in science …
>
> Finally I come to a book that says, "We will give you an example from astronomy"… "Red stars have a temperature of four thousand degrees, yellow stars have a temperature of five thousand degrees . . ." -- so far, so good. It continues: "Green stars have a temperature of seven thousand degrees, blue stars have a temperature of ten thousand degrees, and violet stars have a temperature of . . . (some big number)." *There are no green or violet stars*, but the figures for the others are roughly correct. It's vaguely right -- but already, trouble! That's the way everything was: Everything was written by somebody who didn't know what the hell he was talking about, so it was a little bit wrong, always! And *how we are going to teach well by*

using books written by people who don't quite understand what they're talking about, … Then comes the list of problems. It says, "John and his father go out to look at the stars. John sees two blue stars and a red star. His father sees a green star, a violet star, and two yellow stars. What is the total temperature of the stars seen by John and his father?" -- and I would explode in horror … it was perpetually like that. Perpetual absurdity! There's no purpose whatsoever in adding the temperature of two stars. Nobody ever does that … It was awful! All it was was a game to get you to add, and they didn't understand what they were talking about. It was like reading sentences with a few typographical errors, and then suddenly a whole sentence is written backwards. The mathematics was like that. Just hopeless!

… What finally clinched it, and made me ultimately resign, was that the following year we were going to discuss science books. I thought maybe the science would be different, so I looked at a few of them … there was a book that started out with four pictures: first there was a windup toy; then there was an automobile; then there was a boy riding a bicycle; then there was something else. And underneath each picture it said, "What makes it go?"

I thought, "I know what it is: They're going to talk about mechanics, how the springs work inside the toy; about chemistry, how the engine of the automobile works; and biology, about how the muscles work." … The answer was, for the wind-up toy, "Energy makes it go." And for the boy on the bicycle, "Energy makes it go." For everything, "Energy makes it go."

Now that doesn't mean anything … It's also not even true that "energy makes it go," because if it stops, you could say, "energy makes it stop" just as well. … Energy is neither increased nor decreased in these examples; it's just changed from one form to another …

But that's the way all the books were: They said things that were useless, mixed-up, ambiguous, confusing, and partially incorrect. *How anybody can learn science from these books, I don't know, because it's not science.* "

This last decade, the state of California decided to try and include scientists a second time (THE MATH WARS - Implementing Standards: The California Mathematics Textbook Debacle, 2012). This experience is chronicled in the book (Wilson, 2003). She explains the tendencies for math educators to be biased toward the progressive school of mathematics education, and the working scientists to be biased towards a more traditional view of math education, clearly and impartially. The same problems arose, and the Nobel prize winners (there were more than one the second time) quit the commission in protest– as did Feynman – before the textbooks were adopted. When the scientists and the educators can't agree, we must not expect to succeed at educating scientists.

Discrete Subject Differences

To bring a math student to the level of understanding of the present topic necessary to advance to the follow-on abstraction, a rudimentary mastering of the previous concepts is necessary, but not sufficient. For example, counting comes before addition and addition before multiplication. For each new concept any deficiency in background knowledge makes it difficult for students to advance. Hence deficiencies must be reviewed at each step until the preliminary concepts are at least weakly present in their minds while they learn the more advanced topic. This is the nature of math and science and the fundamental reason why the subjects are presented as discrete topics.

Educational Psychology

A teacher who is also a competent mathematician understands the dependencies within the discrete subjects and can recognize where a student's misconceptions are, and begin to correct these misconceptions as they build towards the next topic. Relevant repetition problems assigned the night before a new topic also prepares the students to bridge over to the next abstraction. Further, when teaching an abstraction fails, you can retrench, correct their mental models of the task at hand, and then try the more abstract approach again.

Piaget proposed, without proof, that there is a maturity level, a threshold if you will, when the normative child is mentally capable of advancing beyond hands-on-learning to begin learning new concepts in a more formal manner. This maturity level is correlated to both age and IQ. Lower IQ individuals may be unable to master an abstract concept regardless of age, while higher IQ individuals may notice many abstract connections on their own. Indeed this is the germ of theory from which the Intelligence Quota was constructed.

In (Wikipedia, 2012), the developers of the IQ test were measuring ability to learn memory, attention and verbal skills by adulthood based on differential age acquisition in childhood. Only 6 out of the original set of 30 questions were mathematical in nature. However today's tests have an equal number of verbal and mathematical questions, and most questions require some logical thinking. An aggregate breakdown of abilities is given in Table 2.

Score	Original Name	Modern Name
>140	Genius	Near-Genius
120-139	Very Superior	Very Superior
110-119	Superior	Superior
90-109	Average	Normal
80-89	Dull	Dull
70-79	Borderline Deficient	Deficient
50-69	Moron	Moderate
20-49	Imbecile	Severe
0-19	Idiot	Profound

Table 2: IQ Chart.

Current IQ tests measure cognitive abilities as they relate to both qualitative and quantitative reasoning, problem solving and discovering existing relationships. These are the critical thinking skills that make a good Engineer (c.f. (National Association of Secondary School Principals, 1980)(Jones, 1998)).

IQ has been defined as

$$IQ = \left(\frac{Mental\ Age}{Actual\ Age}\right) * 100,$$

which centers the Gaussian distribution of both quantitative and qualitative skills about the mean at 100 (Current studies show a wide disparity across countries, however, that is unaccounted for in this theory (webpage)).

Constructivist Learning

Following the Constructivism learning theory, we can view teaching as passing your mental schemes onto others. The difference between passing on information (data) and schemes (knowledge) is profound. Teachers may focus on presenting the scheme itself, or on designing a path that others may follow to arrive at a scheme similar to the one they have constructed in their own mind. To teach STEM well, as Feynman noted, these mental schemes need to be valid (correct). STEM teachers need to understand the details of the scheme's mental model. Unfortunately, the educational reforms of the past half century focused on the path (ex. manipulatives), without realizing that the average class room teacher (with an IQ of 109) did not possess sufficient mental models. In this void, students are left to develop their own schemes. Working within a void, students with higher IQ's may construct a mixture of correct and incorrect mental models, leading to frustration and doubt, which reduces, rather than increases, the potential pool of Engineering students. This may explain why more than half of the gifted students in the US do not reach their full potential.

The law of large numbers (Tanis) argues that a Gaussian distribution applies to the four phases of Piaget's psychological development theory (c.f. (Han, 2001)) The four phases are shown in Table 3 with the positive standard deviation mental ages listed as well.

Stage	Physical Age or $\|\sigma\|<1$	$1<\sigma<2$	$2<\sigma<3$	$\sigma>3$
Sensorimotor	0-2	0-1.75	0-1.5	0-1.3
Preoperational	2-7	1.75-6	1.5-5.4	1.3-4.8
Concrete Op.	7-11	6-10	5.4-9	4.8-8
Formal Op.	11-adult	10-adult	9-adult	8-adult

Table 3: Piaget's Psychological Development Theory

Approximately 68% of individuals lie within these stages at the given ages.

The normative intelligence range is between 84-116. We would expect this cluster of individuals to track Piaget's phases more closely, and those outside this region to deviate from this structure as shown in Table 3.

Individual's two standard deviations above the norm, those 5% with an averaged IQ of over 130, are well studied. They are able to answer questions posed to test the higher phases of Piaget's mental development earlier than their peers by the definition of IQ.

Individuals above three standard deviations, above 148, are far from the average, and it is unclear whether the same developmental stages should apply to them since behavior above three standard deviations may well indicate different dynamics are dominating. Differentiated instruction (Differentiated Instruction, 2012) researchers make the case that students placed in academic settings based on their mental age (a concept introduced in 1912), rather than their physical age, perform better overall.

An optimal educational pedagogy, then, would include assessment feedback that informs the instructor as to when a student is transitioning to new levels of thought. Then, as appropriate, a switch can be made to a more formal method of instruction. Educational research efforts directed towards ways to identify these paradigm shifts, rather than studying the disparate pedagogies that have demonstrably failed, may prove useful. This is especially promising since educational research indicates that students learn best when placed by their mental rather than physical age.

Vertical Study

We present a vertical study of eight students who were in 1-5th grade from 2001-2006 along the Gulf of Mexico coast. These students shared the same teachers for five years, used the same textbooks, and had the same classes. The sample size is small as many students did not return after hurricane Katrina (Pat Smith).

From grades 1-4, the math courses utilized the Chicago math curriculum [10], however almost all of the student's parents complained that their children were not learning math well during the fourth grade year (interview with School Principal). This is backed up by the standardized test scores, which show that at the end of first grade six of the eight students scored at or above 98%, yet by third grade only one did. The average percentile fell from 92% to 72% - a full 20 percentage points in just two years. The Chicago math approach vertically integrates manipulatives, while eschewing practicing the fundamental tasks. This is analogous to teaching reading by spending most of their classroom and homework exploring all the words where the letter "A" makes a hard sound. Reading research shows [11, 12] that omitting the practice of studying words, in favor of theoretical foundational studies, does not produce good readers. But the opposite is also true. For reading, then, a combination of practice and phonemes (theoretical under pinning's) works remarkably well. For mathematics, an analogous blend of practice and abstraction was introduced during the students fifth grade year in order to focus on the transition between concrete and formal operations that typically occur near that age.

We include all data available from 1-5th grade assessments because it demonstrates that the overall downward trend in second through fourth grade was reversed when the new pedagogy was introduced. We include national standardized test results for verbal reasoning, reading comprehension, writing mechanics, writing concepts, and quantitative reasoning as well as math in this study.

We note that these students' fifth grade year was very challenging because most students lived in temporary cramped residences or in a neighbor's side yard after a catastrophic natural disaster destroyed their community.

Data Analysis

At the beginning of their 5th grade year, their school was heavily damaged in Hurricane Katrina, and 6 of the students lost their homes. Both resources and teachers were hard to find. For several months after the storm the class teacher emphasized writing mechanics, and the class wrote and published a book about the Hurricane [Vissar et al.]. Their fifth grade math teacher did not return after the storm, so a PhD Computer Scientist volunteered to help. The class did not include mathematics for two months after the storm. Both teachers were very enthusiastic about their subjects, and both were highly competent. Each had clear mental models of their subjects (Personal Interviews).

Six skill areas were measured using National Standardized testing at the end of the students first, third and fifth grades. Some areas were not tested all three years, and a few student reports were lost in the storm. The areas measured were

- Verbal Reasoning
- Reading Comprehension
- Writing Mechanics
- Writing Concepts
- Quantitative Reasoning
- Math

We discuss the trends in these test results focusing on the difference between their third and fifth year measures. In reading comprehension (Fig. 1) the overall trend was downwards. Four students decreased performance over 8 percentage points, while three increased an average of 6 percent.

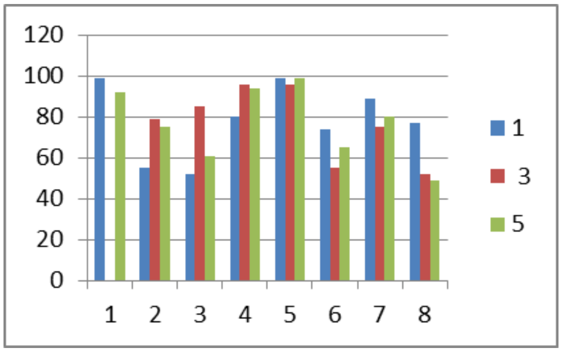

Figure 1: Overall downward trends in reading comprehension from 3rd to 5th grade, with first grade scores shown for reference (- -4 -24 -2 +3 +10 +5 -3). Increasing students added 18 points, while decreasing students lost 33 points.

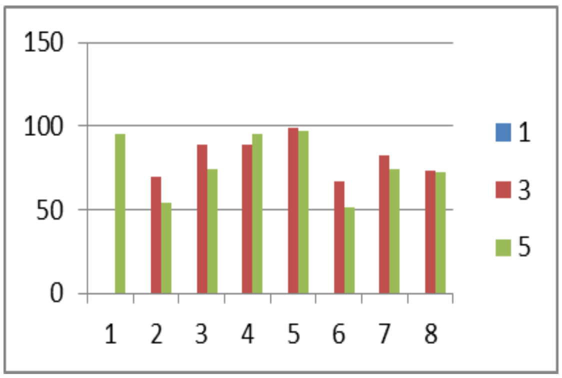

Figure 2: Nearly universal downward trend in writing concepts (3rd to 5th grades) (---16 -15 +6 -2 -16 -8 -1). Only one student improved, while six students lost ground.

The second measure, writing concepts, showed marked declines. Only one student improved, and the average decline was 6.5% (Fig. 2).

The third metric was the classroom teacher's passion (Fig. 3). A previous class of hers had won the annual national Scholastic book competition. So for the first two months after the hurricane, with no facilities available, the teacher met with the students in her own home, whenever they could, and they wrote a book about the storm and how it changed their lives (Vissar, 2006). Here 5 students improved an average of 22.8% while two students declined an average of 15%. Student 6 declined in four out of the six areas measured, showing significant declines in many areas. The student was homeless for a significant amount of time during the school year, and was strongly affected by the storm (interview with the principal).

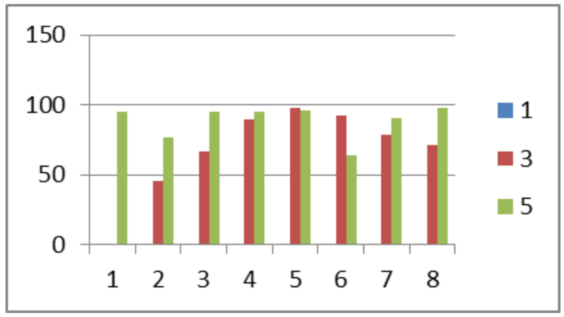

Figure 3: Trends in writing mechanics (3rd to 5th) (-- +31 +28 +5 -2 -28 +12 +27). Six of the eight students performed above the 90% even though only three had done so after third grade. All students performed above the 60%. Five students improved adding 103 percentage points total, while two decreased loosing 30 percentage points.

In Mathematics (Fig. 4) most students responded well to the scientist/teacher. Student three, however, showed no interest in the subject. She slept during class, did not turn in homework, etc… Overall she was an excellent student, and the teaching staff never gave up on her, but at the end of the year they concluded that she was electing not to focus on math. She showed the largest decline in Math. Of the remaining students, two thirds scored at or better than after their third grade.

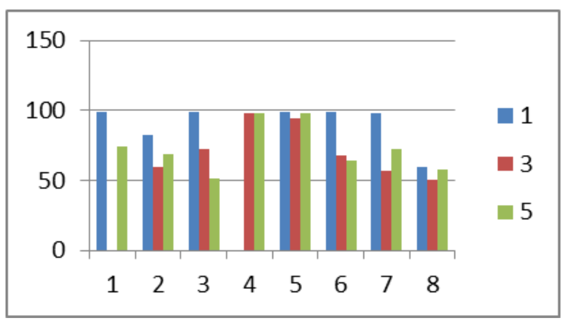

Figure 4: Math demonstrates an overall upward trend from third to fifth grade, (-- +9 -21 -- +4 -4 +15 +8). Because the overall trend from first grade to third was significantly downward, Data Imputation methods argue that student 1 probably improved from third grade as well, even though that data was not available. Four students improved for a total of 36 percentage points, while two students continued to lose ground with a total of 25 lost percentage points.

In the next metric, quantitative reasoning, students showed remarkable gains in critical thinking with numbers (Fig. 5). The Math teacher focused on how to approach problems using math to reason out a solution. Five students showed an average improvement of 13.6%, while two students declined an average of 8%.

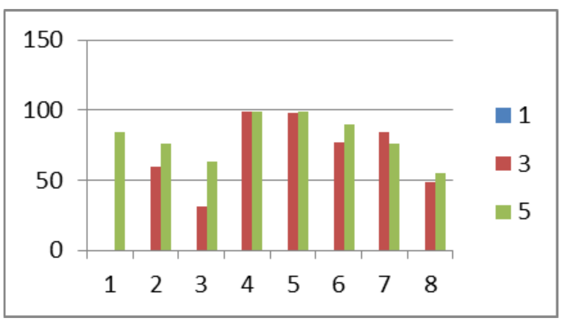

Figure 5. Quantitative reasoning includes the transition from hands on to abstract thought (-- +16 +32 -- +1 +13 -8 +6). Working explicitly on this transition helped students significantly improve.

Five students improved in their verbal reasoning skills as well (Fig. 6). The five students who increased, added 68 percentage points, while the one student who decreased dropped 8 points.

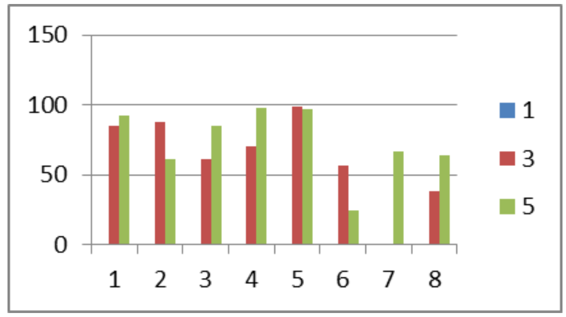

Figure 6: Trends in verbal reasoning (3rd to 5th) (+7 -27 +24 +28 -2 -32 -- +26). Four students increased a total of 85 points, while 3 students lost 61 percentage points.

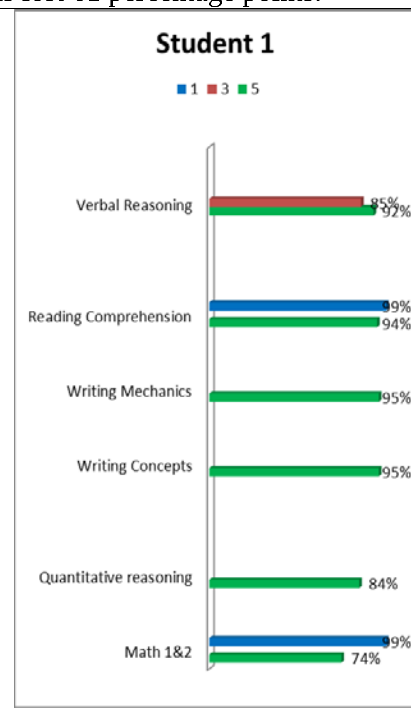

Figure 7: Student 1's standardized test scores.

Most of student 1's third grade scores were lost in the storm (Fig. 7). The student was very well prepared to enter first grade, and appears to have been about two standard deviations from the norm in verbal skills, and somewhat less in quantitative skills.

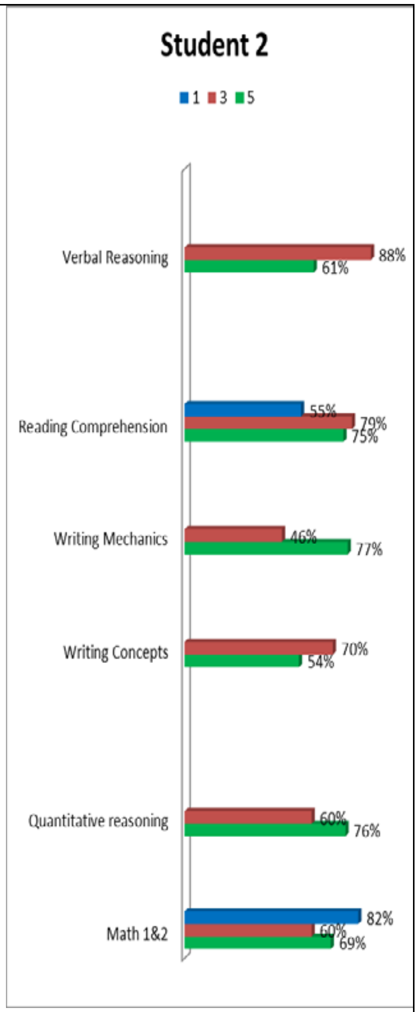

Figure 8: Student 2's standardized test scores.

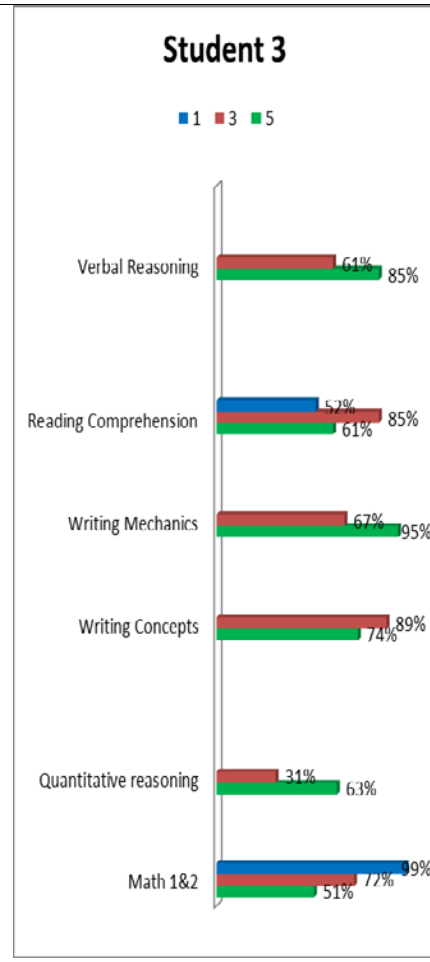

Figure 9: Student 3's national test scores

A normative student, S2 responded well to explicit connections towards abstract thought, but did not appear to have been able to create these connections on their own (Fig. 8).

S3 continued to decline relative to her peers in Math. But her quantitative and qualitative reasoning skills have been strengthened, as well as their writing mechanics scores (Fig. 9).

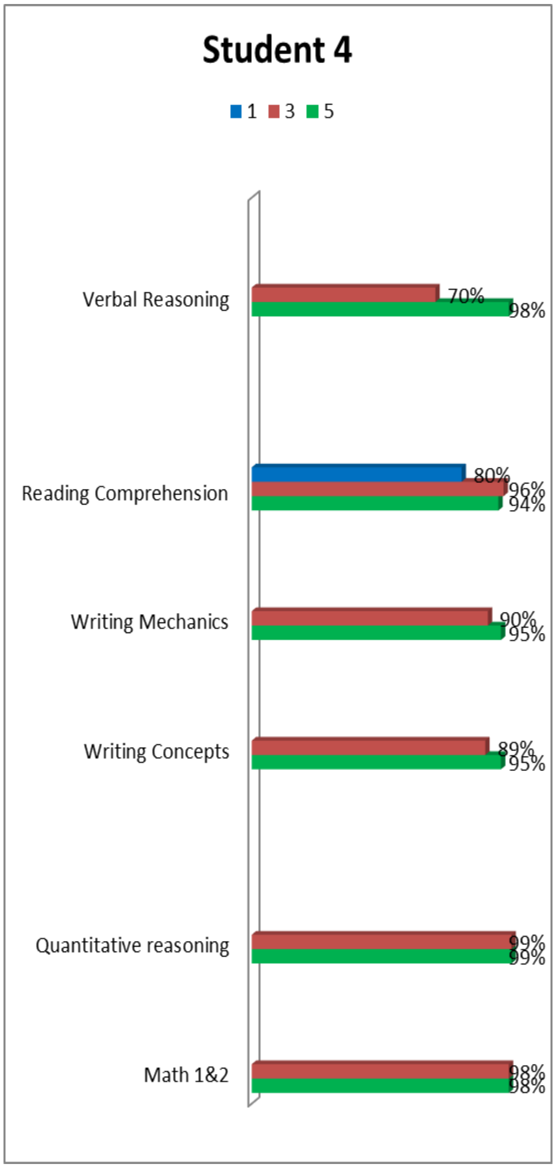

Figure 10: Student 4's standardized test scores.

By the end of the third grade S4 had only one weakness – verbal reasoning. Practicing reasoning skills seems to have rectified that weakness, and by the end of the fifth grade the student is performing well in all areas (Fig. 10).

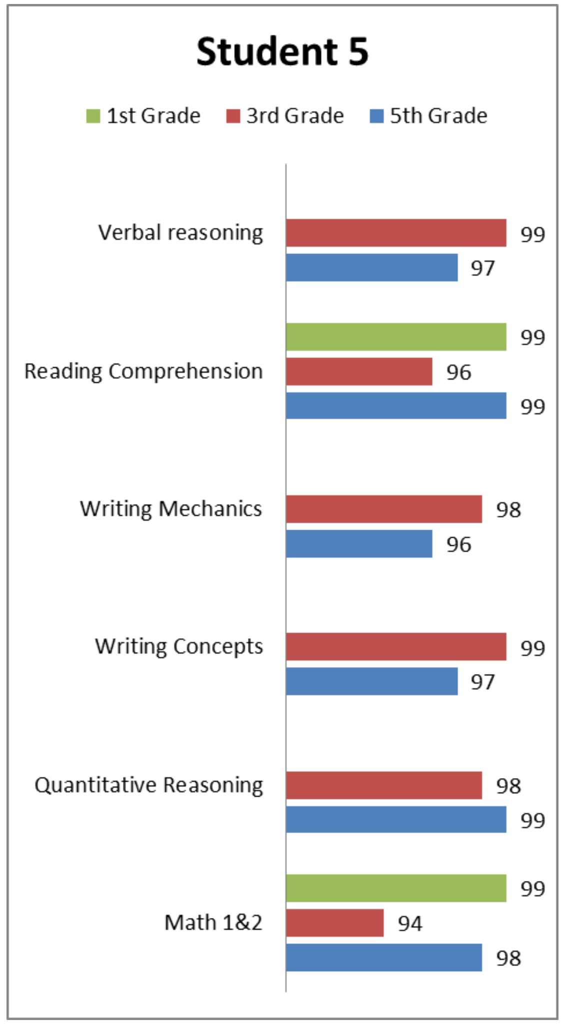

Figure 11: Student 5's standardized test scores.

Student 5 appears to be near three standard deviations above the norm and may be learning quite differently that his classmates. None-the-less he has also improved his math score (Fig. 11).

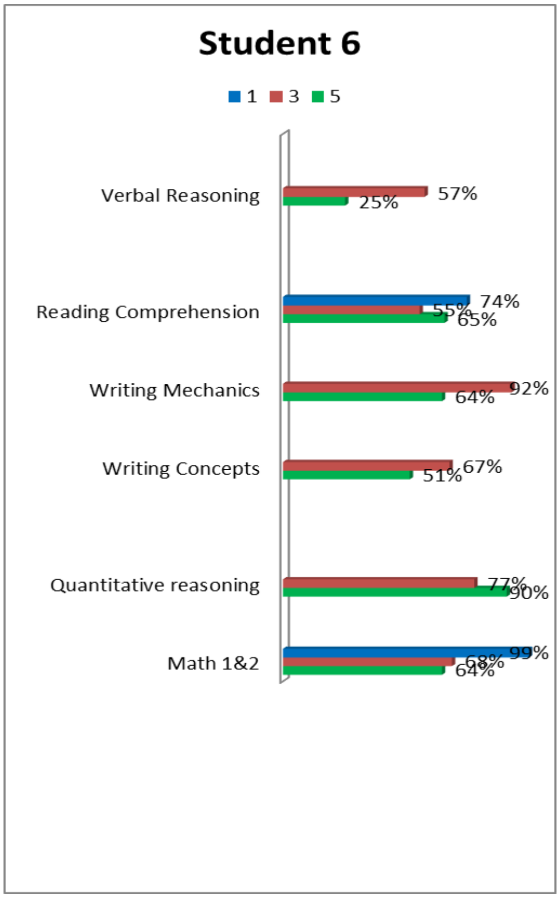

Figure 12: Student 6's standardized test scores.

Student 6 has continued an overall decline in performance since the first grade (Fig. 12).

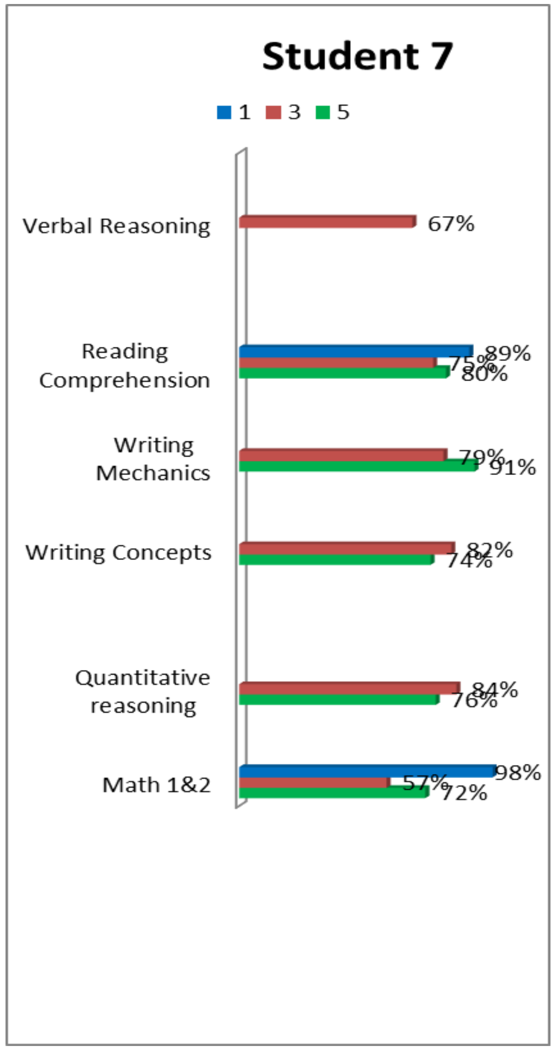

Figure 13: Student 7's standardized test scores.

Student 7 appears to be near one standard deviation from the norm, but stronger in verbal skills. They did not improve in either writing concepts or quantitative reasoning, but did improve in mathematics and reading and writing. In other words they appear to have learned exactly what was taught, but were not yet able to form abstractions to find other places where the acquired skill set applies (Fig. 13).

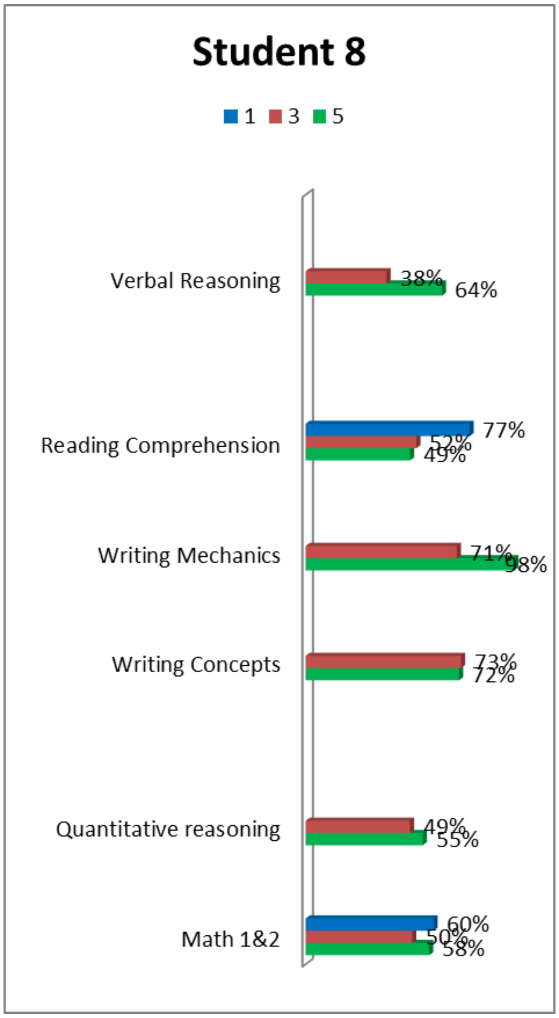

Figure 14: Student 8's standardized test scores.

Student 8 appears to be a normative student. Working on the book strengthened writing mechanics, while both qualitative and quantitative reasoning skills improved. Math also improved (Fig. 14).

Conclusions

We conclude that, by the 5th grade, the majority of these students were ready for a more formal treatment of mathematics, while a minority self-differentiated themselves by not fully participating. Further, explicit in-depth examples helped a significant number of students to improve their reasoning skills.

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