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Mathematics Preparation for College:
Some Things We Learned the Hard Way, and What We Do About Them

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…it was the colleges and collegiate aspects of higher education that were visible and attractive…many colleges survived only by offering secondary education…frequently [secondary students] outnumbered collegians. (W. Bruce Weslie, 1997, p. 333, characterizing college student populations in the 1870s)

Our story evolved from a case study born out of frustration with students' poor mathematics performance at our university. Nearly half of our students, just out of high school, took remedial mathematics or no mathematics at all during their freshman year. The situation was not unique to our institution; voices from the other universities in our state and elsewhere echoed a similar concern: too many freshmen come to college deficient in mathematics. Our state universities required three years of math to enter, but students could graduate with only two. Compounding the problem was an open door policy of our well-developed community college network. That policy guarantees transfer to a four-year institution after completing a two-year degree. Nearly 30% of our state's students enter community colleges right out of high school, with another 20% following within 3 years. Such a policy seemed to permit an "end run" around college entrance requirements, particularly in mathematics. Furthermore, our statewide university mathematics placement test and our state standards (Essential Academic Learning Requirements) were not in alignment, partially because state standards for high school juniors and seniors did not exist.

In response to mounting concerns over these issues, higher education policy makers favored requiring a fourth year of secondary mathematics to enter state universities. Policy makers were not, however, adequately considering the rigor of the newly proposed senior course, nor were they considering raising high school graduation requirements in mathematics from the current two Carnegie credits. As researchers, we saw multiple disconnections in expectations, requirements, alignment, and articulation. Our case study addressed many of these issues, and we include, here, findings, interventions, and suggestions under two main headings: (1) We Don't Agree on What is Important, and (2) Students Get Mixed Messages.

PROBLEM: We Don't Agree On What Is Important

While raising critical issues, the National Council of Teachers of Mathematics [NCTM] standards (NCTM, 1989; 2000) movement and the calculus reform movement are not without a cadre of traditionalist detractors. "Math Wars" (Schoenfeld, 2003; Lundin, 2001, p. 197) between traditionalists and reformers continue to emphasize conflicting belief/value systems with respect to content, pedagogy, and assessment. Both sides have valid points, but a lack of coherence has led to confusion about what is important at many levels. The consequences for incoming freshmen college students, we think, are dire; they no longer know what to expect!

SOLUTION: Agree on Curriculum Intensity and Rigor Readiness

In an effort to cope with the polemic of the Math Wars and in the interest of conciliation, we have become believers in Clifford Adelman's (1999) notion of curriculum intensity and our own definition of rigor readiness.

Adelman, after examining high school curricula for content, scope, and sequence, graded the curricula on a scale of 1-40, from least to most academically intense. He then analyzed 13 years of data from the NCES High School and Beyond Study (U. S. Department of Education. National Center for Educational Statistics [NCES], 2004). In this comprehensive study, his academic intensity scale better predicted graduation from college by age 30 than did other more traditional variables, including college entrance exam scores or high school GPA/rank (Adelman, 1999, Executive summary, p. 2).

Of all pre-college curricula, the highest level of mathematics one studies in secondary school has the strongest continuing influence on bachelor's degree completion. Finishing a course beyond the level of Algebra 2 (for example, trigonometry or pre-calculus) more than doubles the odds that a student who enters post-secondary education will complete a bachelor's degree. (Executive Summary, p. 2)

Rigor Readiness is the level of preparedness to solve complex problems and logically communicate solutions or arguments. Isn't this what we mean when we plead, "I just wish my students would think?" We believe Rigor Readiness has been well conceived in the NCTM Principles and Standards for School Mathematics (NCTM, 2000). The concept of rigor is embodied in the Problem Solving and Connections standards, as well as in the Reasoning and Proof standard. Historically, Schoenfeld (1994, p. 55) elevated problem solving, or "doing mathematics," above the level of importance of curricular content. He gave (and we still give) thanks to George Polya for pioneering How to Solve It (Polya, 1957). More recently, Stigler and Hiebert (2004, p. 15) exposed the absence of making connections as detrimental to the performance of U.S. students in the Third International Mathematics and Science Study (TIMMS). Those authors concluded that our teachers tended to undermine students' learning of problem solving by reducing the process to procedures, rather than allowing students to construct connections. In any case, a rigorous argument must include constructing connections; the ability to communicate that argument is also critical.

If we want incoming students to do mathematics, to construct connections, to solve problems and to communicate solutions, there is not better framework is to guide them (and us) than the NCTM Standards. We readily acknowledge that symbolic manipulation and computation, often the mainstays of traditionalists, are tremendously important to mathematics and science. They are of particular importance in passing gateway tests in college. Incoming college students need both rigor readiness and computational and algebraic skills; but what messages do they get?

PROBLEM: Students Get Mixed Messages

High school graduation requirements are not equivalent to college entrance requirements. In 17 states, including ours, two credits of mathematics suffice to graduate from high school, even though three credits suffice in 28 states, and 4 credits, in 4 states. The remaining states had local laws governing requirements. (US Department of Education, National Center for Educational Statistics, 2001a, Table 153). Community colleges generally leave doors open, so, despite their own requirements, transferees often have deficiencies.

It is both permissible and popular for high school students to avoid rigorous senior courses. While 90 percent of high school freshmen expect to complete college, only about 44 percent take the college preparatory curriculum that equips them for high achievement (National Commission on the High School Senior Year, 2001a, p.1). While about two-thirds of all high school students complete a half-year of Algebra II, less than half take a fourth year of rigorous mathematics (The U.S. Department of Education, National Center for Education Statistics, 2002, Chapter 2). Overall, 27% of American high school students complete Math Analysis or Pre-Calculus, 12% complete calculus, and about 6% take statistics. We remark here that 22% of entering college freshmen, nationally, take remedial mathematics (Parsad, Lewis, & Greene, 2003, p. 18). Lest the reader attribute all of this remediation to non-traditional students, we remark that 18% of the 17-19 year olds entering our institution place into developmental mathematics courses. In the three-year sample of our case study, 44% of our students took no senior mathematics class, while about 30% took a full rigorous class (pre-calculus, calculus, or statistics).

Surprisingly, math avoidance begins even earlier in middle school. Results from the National Longitudinal Study of 1988 (U.S. Department of Education, 1997, p. 31) indicated that 51% of the students surveyed (n = 28,000), grades five through eleven, planned to quit taking mathematics as soon as possible. However, 89% of those students reported having college ambitions, and 91% of their parents harbored

that dream for them (U.S. Department of Education, 1997, p. 18). More positively, eighth graders taking algebra tend to take advanced mathematics courses in high school, and taking advanced courses in high school can mitigate culturally linked deleterious effects in college performance. (Horn, Carol, & Kojaku, 2001, p. 38; U. S. Department of Education, 1997, p. 11).

In our case study, we sampled GPAs of traditional-aged freshman in the years 2001-2002 (n = 856). We disaggregated the data into two factor variables. The first factor, 1st High School Math Course, had three levels, (1) Pre-Algebra, (2) Algebra 1 or Integrated Math 1, and (3) Algebra 2, Geometry, or Integrated Math 2. The second factor, High School Senior Math Course Rigor, had five levels, (1) No Course, (2) Partial Course, (3) Non-Rigorous Course, (4) Rigorous Course, and (5) Advanced Course. Note that "Rigorous Course" here meant Math Analysis, Pre-Calculus, or Statistics, while "Advanced Course" meant Calculus or above. *See Table 1.*

TABLE 1:

Cross-Tabulation of First HS Math Course Rigor Level and Senior High School Math Course Rigor Level

			HIGH SCHOOL SENIOR MATH COURSE RIGOR LEVEL					
			No Course	Partial Course	Non-Rigorous Course	Rigorous Course	Advanced Course	Total
FIRST HIGH SCHOOL MATH COURSE RIGOR LEVEL	Pre-Algebra	Count	**23**	**4**	**69**	**10**	**0**	**106**
		% within First HS Course Vigor Level	21.7%	3.8%	65.1%	9.4%	.0%	100%
		% within Senior HS Course Rigor Level	6.1%	6.6%	42.3%	5.8%	.0%	12.4%
		% of Total	2.7%	.5%	8.1%	1.2%	.0%	12.4%
	Algebra or Int. Math 1	Count	**229**	**43**	**85**	**124**	**12**	**493**
		% within First HS Course Vigor Level	46.5%	8.7%	17.2%	25.2%	2.4%	100%
		% within Senior HS Course Rigor Level	60.4%	70.5%	52.1%	71.7%	15.8%	57.9%
		% of Total	26.9%	5.0%	10.0%	14.6%	1.4%	57.9%
	Algebra 2, Geometry, or Int. Math 2	Count	**127**	**14**	**9**	**39**	**64**	**253**
		% within First HS Course Vigor Level	50.2%	5.5%	3.6%	15.4%	25.3%	100%
		% within Senior HS Course Rigor Level	33.5%	23%	5.5%	22.5%	84.2%	29.7%
		% of Total	14.9%	1.6%	1.1%	4.6%	7.5%	29.7%
Total		Count	**379**	**61**	**163**	**173**	**76**	**852**
		% within First HS Course Vigor Level	44.5%	7.2%	19.1%	20.3%	8.9%	100%
		% within Senior HS Course Rigor Level	100%	100%	100%	100%	100%	100%
		% of Total	44.5%	7.2%	19.1%	20.3%	8.9%	100%

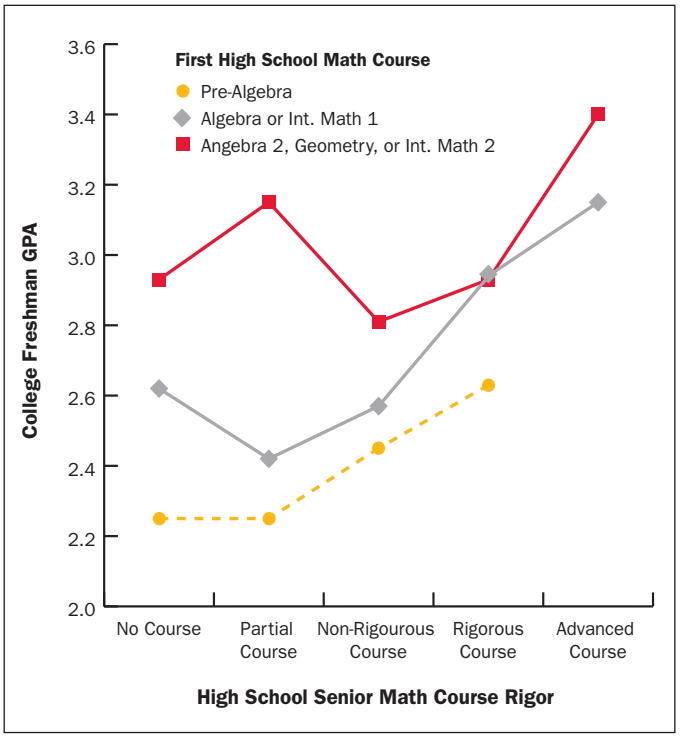

Figure 1

Students who took Algebra I or Integrated Mathematics as high school freshmen had a significantly higher mean college freshman GPA than those who began high school with a lower math course. Also, those taking Algebra II, Geometry, or Integrated Math II had significantly higher mean GPA than those taking Algebra I or IM 1. Furthermore, students who, as high school seniors, took No Course, a Partial Course, or a Non-rigorous Course had a mean freshman GPA significantly lower than those taking a Rigorous Course, and those taking an Advanced Course, had a mean GPA significantly higher than those taking a Rigorous Course. *See Figure 1.* Our research design did not control for cause; association, rather than cause-effect, is evident between the two factor variables and the independent variable.

SOLUTION: Intervene in Multiple Ways

1. Our university participates in Gear Up, an acronym for Gaining Early Awareness and Readiness. The Gear Up Program is funded by the Department of Education with the goal of enabling middle school students, especially those from low-income families, to choose a college path. The program focuses on sustaining achievement and interest in math, technology, science, and reading. Early reports of achievement gains are encouraging, and on-campus programs for middle school students and their teachers seem to produce the desired results. See more, including brief progress reports by state at www.ed.gov/gearup.

2. Algebra is important because of its connections to so many other areas. Research clearly shows that those who successfully experience it, perform better scholastically. We concede, however, that too much emphasis has been, and still is, placed on certain elements of symbol manipulation, even as the mathematics community continues to argue on import. In the interest of preparing students for college, where tradition reigns, we support the early introduction of algebraic concepts in middle school. Although we favor an integrated mathematics approach—see *Navigating Through Algebra* (Burke, Erickson, Lott, & Obert, 2001) for a compelling argument—we caution that manipulating symbols in a traditional sense is still important. It is a high stakes skill required for college admissions, placement, and in college mathematics and science courses.

3. To keep high school seniors interested in academics, the National Commission on the High School Senior Year recommended a "Triple A" solution: Align senior courses with college, raise the standard of Achievement, and provide course Alternatives, including those that are more rigorous (National Commission on the High School Year, 2001b, p. 19). We support dual enrollment programs that provide qualified high school students opportunities to take college courses either on campus or in their schools. Our Cornerstone Program (http://www.cwuce.org/cornerstone/) is becoming especially popular with high school students, teachers, and administrators, since students remain at school, but still earn college credit for taking pre-calculus or calculus. This program has strengthened the bond between our university, our mathematics department, and schools hosting Cornerstone courses. As an example, Mathematics teachers, wishing to qualify as Cornerstone Adjunct Instructors, have sought out our masters degree program.

Other options include our statewide Running Start Program, sponsoring high school students to attend regular college mathematics courses. Readers can compare the two programs at http://www.cwuce.org/cornerstone/cornerstone_vs_rs.asp. Finally, some schools in our area have had remarkable success preparing a majority of their students for college with AP mathematics. See for example, Bellevue High School's success story at http://www.bsd405.org/ap.html.

4. Our state does not have learning outcomes in mathematics for high school juniors and seniors. With a Bill and Melinda Gates Foundation grant and funding from the state legislature, members of the Transition Math Project [TMP] are now writing them. The grassroots committee, well-represented by key players in secondary and higher education policy, will take their completed recommendations to state agencies soon. Drafts of the new standards show innovative ideas, including a "student attribute" standard. The implementation of these state standards will, no doubt, smooth the transition to college. Readers may visit the TMP web site for more information at http://www.transitionmathproject.org/.

5. Finally James Rosenbaum (2004) recommended something we originally thought was a hard line approach to keeping standards high. He listed "New Rules of the Game" for college preparation: passing extra costs for college remediation down to students; increasing awareness in the high schools of the rigor of college coursework; retaining the burden of remediation at the high school level; and informing unprepared students of options other than immediate entry to higher education. We are no longer shocked by these suggestions. This year, our institution's doors closed early to new admissions; furthermore, some of our state's universities are already passing remediation service charges back to students, and the registrar just raised the admissions bar.

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