

Research Relating to Making the Transition from High School to College and the Workforce

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Research Relating to Making the Transition from High School to College and the Workforce Executive Summary

This report is an outgrowth of a Math and Science Partnership grant funded by the New Hampshire Department of Education and the U. S. Department of Education entitled “Making the Transition from High School to College (MaTHSC). The report examines national and local research pertaining to the preparation of students for college and the workforce.

Repeated US Department of Education studies over the last eight years demonstrate that the most important factor affecting college graduation is the number and level of mathematics courses taken in high school. This report details the implications of those studies for New Hampshire.

While 90% of all high school freshmen expect to complete college, only 44% take the college preparatory curriculum. The movement away from mathematics begins early in students’ careers. The U. S. Department of Education (1997, p. 31) reported 51% of the students surveyed planned to quit taking mathematics as soon as possible. In light of these statistics, the need for remediation by about 40% of all college students, except at the most selective colleges, and 60% of students at community colleges is not surprising (Conley, p. 37). One estimate of the economic cost of this remediation, to higher education, businesses, and families is 16.6 billion dollars. If remediation did, indeed, make students successful in college, it might be worth the expense. However, 63% of those requiring remediation in mathematics fail to earn either two- or four-year college degrees.

Achieve, Inc. was created by the nation’s governors and business leaders to help states “raise academic standards, improve assessments and strengthen accountability to prepare all young people for postsecondary education, work and citizenship.” Achieve, and others, have concluded that students need a minimum of four years of high school mathematics including Algebra I, Geometry, Algebra II, and a fourth course beyond Algebra II in order to be ready for college or the workforce. These are the requirements to prepare high school students to be ready for college or the workforce. When these requirements were first proposed, no state in the union required all students to take this kind of a rigorous curriculum. However, over the past three or four years, many states have moved towards these requirements, and additional states have legislation pending that will require all students to complete this series of courses. Over 80 % of both college and non-college students report that if their high school demanded more, they would have worked harder EVEN if it meant less time for non-academic pursuits. Apparently, if high schools increase the rigor of their programs/graduation requirements, then the students (for the most part).will rise to the challenge.

New Hampshire has recently raised its graduation requirements from two to three credits of mathematics, and specifies that **one** of those credits must be Algebra. It is generally understood that the algebra credit should be equivalent to what has been traditionally known as “Algebra I.” Although New Hampshire is to be commended for increasing its requirements, clearly New Hampshire is not a leader in requiring the “college- and work-ready” requirements that Achieve and the nation’s governors have suggested.

In 2000, the National Commission on Mathematics and Science Teaching for the 21st Century estimated that 60% of all new jobs in the early 21st century will require skills that are possessed by only 20% of the current workforce. Colleges and universities, as well as local and state business groups, have a clear responsibility to communicate the need for rigorous preparation to all students. A P-16 council has often been recommended to coordinate efforts between the K-12 community and the post-secondary community. Aligning state standards with post-secondary and workplace expectations requires the full participation of all stakeholders including elementary and secondary schools, colleges and universities, and business and industry. New Hampshire has recently established a P-16 Council.

Research Relating to Making the Transition from High School to College and the Workforce

This report is an outgrowth of a Math and Science Partnership grant funded by the New Hampshire Department of Education and the U.S. Department of Education entitled “Making the Transition from High School to College (MaTHSC). The report examines national and local research pertaining to the preparation of students for college and the workforce, and seeks to provide some insight into the following questions:

What can be done to help students make a successful transition from high school to college?
What can students do to help themselves to make the transition from high school to college?
Is this course of action different for students who transition directly from high school graduation to the workforce?

The report begins with a discussion of the factors that influence success, reviews national data and reports, and concludes with a discussion of the current situation in New Hampshire.

Factors Influencing Post High School Success

After correcting for socio-economic status, *Answers in the Toolbox: Academic Intensity, Attendance Patterns and Bachelor’s Degree Attainment* (US Department of Education report) concluded in 1999 that the most important factor affecting college graduation was the number and level of mathematics courses taken in high school. In 2006, Adelman replicated the analysis of data from the 1982-1993 cohort with a 1992-2000 cohort of students. Again, the data showed that “The academic intensity of the student’s high school curriculum still counts more than anything else in pre-collegiate history in providing momentum toward completing a bachelor’s degree” (Adelman, 1999, 2006).

The highest level of mathematics reached in high school continues to be a key marker in pre-collegiate momentum, with the tipping point of momentum toward a bachelor’s degree now firmly above Algebra2. (Emphasis added.) But in order for that momentum to pay off, earning credits in truly college-level mathematics on the postsecondary side is de rigeur. The world has gone quantitative: business, geography, criminal justice, history, allied health fields – a full range of disciplines and job tasks tells students why math requirements are not just some abstract school exercise. By the end of the second calendar year of enrollment [in college], the gap in credit generation in college-level mathematics between those who eventually earned bachelor’s degrees and those who didn’t is 71 to 38 percent. In a previous study, the author found the same magnitude of disparity among community college students in relation to earning a terminal associate degree... . The math gap is something we definitely have to fix (Emphasis added.) (Adelman, 2006, p. 20).

The National Commission on the High School Senior Year (2001, p. 1) reported that 90% of all high school freshmen expect to complete college, while only 44% take the college preparatory curriculum. Unfortunately, the movement away from mathematics begins early in students’ careers. The U. S. Department of Education (1997, p. 31) reported 51% of the students surveyed planned to quit taking mathematics as soon as possible. Yet, 89% of those students indicated that they would like to attend college. In light of these statistics, it is not surprising that remediation is needed by about 40% of all college students except at the most selective colleges, and 60% need remediation at community colleges (Conley, p. 37).

A similar survey by the NH Partnership for the Advancement of Postsecondary Research in 2005 found similar aspirations. In this survey, 79% of public and 96% of private high school seniors were planning to pursue a degree in higher education in the fall of 2005. Of those not intending to pursue a degree, 37% said they were going to do so in the future. Sixty percent of the students with a “C” average or less

indicated that they intended to go to either a 4-year college (26%) or a 2-year college (34%). Thus, nationally and within the State of New Hampshire a large number of students intend to pursue higher education, but many are only minimally prepared to do so. In addition, both nationally and within the State, women are planning to pursue higher education at a higher rate than men (GAO, 2000). The proportion of students planning to attend a 4-year college within the State has increased to 45%.

The Pew Charitable Trusts and the Association of American Universities came together on a project entitled “*Understanding University Success*” (Conley, 2003). They produced a booklet with the same title that lists Standards for Success (S4S) in six content areas: English, Mathematics, Natural Sciences, Social Sciences, Second Languages and The Arts. They have listed 84 Standards for Success in mathematics. In addition to the standards for each content area, the booklet identifies “cross-cutting habits of mind” that high school students should develop for success in college. These habits are considered to be “more important than specific content knowledge.” They include analytic thinking and problem solving, openness to failure, an inquisitive nature, perseverance, clarity in written and oral language, working collaboratively in a group, critical assessment of resources, and proceeding independently in drawing inferences. The emphasis of learning should be on the ability to use one’s knowledge to solve a problem, present one’s point of view, or obtain a reasonable conclusion based upon data given.

The S4S also indicate that in mathematics, problem solving is the focus of learning and teaching mathematics. Skills which are central to this issue are the ability to:

1. Converse fluently in the language of mathematics;
2. Think conceptually, not just procedurally (i.e. students understanding relationships among mathematical concepts);
3. Write with clarity and cohesiveness;
4. Construct convincing arguments;
5. Use investigative strategies and multiple approaches when exploring a problem; and
6. Persist in the face of failure.

Achieve, Inc. was created by the nation’s governors and business leaders to help states “raise academic standards, improve assessments and strengthen accountability to prepare all young people for postsecondary education, work and citizenship.” In 2004, the American Diploma Project (ADP) Network, a partnership of Achieve, The Education Trust, and the Thomas B. Fordham Foundation published a list of benchmarks in English and mathematics that high school graduates need for success in college or the workforce. These standards are significantly more rigorous than current high school standards. The ADP Network includes 26 states; New Hampshire is not one of them. The 26 states have agreed to align their high school standards with the ADP standards, require all high school students to take challenging courses to prepare them better for college or the workforce, have their state assessments serve as readiness tests for college or work, and hold high schools accountable for graduating students ready for college or work and hold postsecondary institutions accountable for student success once enrolled. As a result of this initiative, several states have moved to require high school students to take the equivalent of Algebra I, Algebra II, and Geometry. Some are moving to require a fourth year of mathematics (Achieve, 2006). [Appendix C is a compilation of high school mathematics graduation requirements from all states in the US. The information was gathered during February and March 2007, when several states said that their requirements were still being debated by their state legislators.]

As stated in the beginning of this section, the highest level of mathematics one studies in secondary school appears to have the strongest continuing influence on bachelor’s degree completion. For example, if students finish a course like trigonometry or pre-calculus, they more than double their chance to complete a bachelor’s degree (Lundin et. al. quoting Adelman (1999), p. 19). Lundin et. al. report that it is the rigor involved in solving complex problems and communicating solutions logically within the high

school mathematics courses which leads to a student's success. This observation is important and needs to be examined in the context of Stigler and Hiebert's (2004) conclusion that U.S. teachers tend to undermine students' learning of problem solving by reducing the thinking process to rote procedures, rather than having them work hard to make connections.

Mounting evidence indicates that not only do college bound students need to take a minimum of Algebra I, Algebra II, and Geometry, but that students who plan to enter workforce training programs after they graduate need the same kind of preparation (ACT, 2006). The ACT report emphasizes that the context in which these skills are taught may differ for students, but the expectations for all students should be the same. In addition, a 2003 report from the Educational Testing Service indicates that more than two-thirds of the new jobs in the future will require some postsecondary education. Minnesota Governor Tim Pawlenty, Chair of the National Governors Association Education, Early Childhood, and Workforce Committee stated, "This landmark report [ACT, *Ready for College and Ready for Work: Same or Different?*] makes it clear that we must ensure that high school is relevant and rigorous for all students" (Education Research Report, 2006). Many or, perhaps, most students will at some time enroll in post-secondary education. Occupations such as electricians, plumbers, upholsterers, construction workers, usually require vocational training and on-the-job experience or an associate's degree.

Expectations of our High School Students: Are They High Enough?

The Council of Chief State School Officers (2005) reported on the enrollment in mathematics and science courses among high school students in 30 different states (New Hampshire was among the non-reporting states). The CCSSO found that 50% of high school students took four years of mathematics, while 17 of the states reported most students (70%) take Algebra II or Integrated Math 3 before graduating from high school. The report stated that over the last eight years, the number of students taking three or four years of high school mathematics had significantly increased. It also reported that 27% of the students in the U.S. had taken Algebra I in the eighth grade.

"[New Hampshire] Eighth grade students perform very well on national assessments in math, science and reading, indicating that they are well prepared to succeed in challenging high school courses" (The National Center for Public Policy and Higher Education, p. 5, 2006). Unfortunately, very small proportions of 11th and 12th graders score well on Advanced Placement tests, but very large proportions score well on college entrance exams" (p. 5). However, "New Hampshire continues to struggle in enrolling students in higher education" (p. 7). New Hampshire does have a high enrollment in college for students by the age of 19, but "A very small percentage of working-age adults (ages 25 – 49) are enrolled part-time in college-level education or training" (p. 7).

While some of the information in the above paragraphs may sound good, these expectations may not be high enough. A recent report from the National Governors Association (see Achieve, *Closing the Expectations Gap*: 2006, p.30) stated that, of all U.S. students entering the ninth grade, 68 percent complete high school on schedule and immediately enter higher education. However, of those same ninth grade students, only 18 percent will complete a two-year or four-year college degree on time. A report from Achieve, Inc., found that only 24% of recent high school students felt that they faced high expectations. An Indiana study of 900,000 students found that most U.S. students spent three hours or less a week studying for classes, yet were able to receive good grades. So, while students may be completing more and more courses, if they are not challenged, they may struggle in the college or university classroom (Hart, 2005). In a summary report of "Getting Students Ready for College: What Student Engagement Data Can Tell Us," Kansky notes that 'on average (across the four grades), only 52% of respondents agreed that schools challenged them to do their best work.' (Kansky, 2006)

Many of today's high school students are counseled to complete three years of mathematics, especially if they are planning to attend a 4-year college. Many are told that two years will be sufficient for admission to a community college. Few believe that 4 years of high school mathematics will be needed if their intended major is history, art, or automotive repair. These latter students are often surprised when they learn that the statistics needed for the study of history in college will challenge them since they have typically not studied any mathematics since their junior (or sometimes sophomore) year in high school. Art students may discover they need trigonometry and geometry to calculate the spatial relationships of a sculpture. Automotive repair students will need algebra and trigonometry to understand physics and the laws of mechanics that are central to the discipline – and may even be required to take an applied calculus course.

The current New Hampshire state requirements for graduation from high school include three years of mathematics, and specify that **one** of those credits must be Algebra. It is generally understood that the algebra credit should be equivalent to what has been traditionally known as “Algebra I.” Yet, most 4-year colleges in New Hampshire specify that the student should have completed three years of mathematics: Algebra I, Geometry, and Algebra II. The NHCTC requirements vary from program to program, but contrary to popular belief, most require a significant amount of high school mathematics.

The present study being conducted by the NH-IMPACT Center at Plymouth State University is uncovering a need for mathematics beyond Algebra II, and this conclusion applies to all students who plan to study in our NH colleges and NH Community and Technical College network. Four- and two-year colleges in NH - and throughout the nation - report far too many freshmen enrolled in remedial, non-credit mathematics courses. At the NHCTC campuses, as many as 72% of students fail to meet the minimum mathematics requirements and are placed in remedial courses – delaying completion of their degrees and costing them additional tuition expense. Approximately one-third of all the mathematics courses taught on NHCTC campuses are remedial, non-credit courses.

So, a student entering high school in New Hampshire is thus faced with a quandary.

The State requires me to take three years of mathematics, only one of which needs to be Algebra; the colleges and universities recommend three years of mathematics including Algebra I, Geometry, and Algebra II, and the Community Colleges/Technical Schools vary their suggestions, based on the program that I would complete. What do I do? And what should I do if I don't intend to go to college? Will the State requirement suffice for me to enter the workforce here in NH?

Several different organizations have been asking themselves the very same questions as our hypothetical New Hampshire student. The reports from these groups are summarized in the following paragraphs, but they all come to the same general conclusion: **students in high school should complete four years of mathematics at a minimum; further, three of those years should be Algebra I, Geometry, and Algebra II (or their equivalents)**. Whether students plan to attend a two- or four-year college, or go directly to the workforce is immaterial – they may well change their minds and thus are better poised to achieve their goals with four years of mathematics in their background. (Note: The “Toolbox” report cited above also recommends 3.75 units of English, 2.5 units of science, 2.0 units of which are in a laboratory science, 2.0 units of history and social studies and 1.0 or more units of computer science.)

An ACT (2004) report, *Crisis at the Core: Preparing All Students for College and Work*, showed that a majority of students are not ready for college level work, with only 40 percent meeting the benchmark for the study of College Algebra, a common credit-bearing first-course at the collegiate level. They further report that when one pools readiness for college algebra, college biology, and college English composition, then “a mere 22 percent of the 1.2 million students tested in 2004” (p. 3) met or exceeded

the College Readiness Benchmarks established by ACT. The suggested requirement of four years of high school mathematics doesn't change just because a student intends to enter the workplace. According to the report, "No longer do students planning to go to work after high school need a different and less rigorous curriculum than those planning to go to college" (ACT, (2004), p. iii). The report notes that 70 percent of the fastest-growing jobs will require an education beyond high school and that 40 percent of all new jobs will require at least an associate's degree (p. iii).

All schools and colleges should study the findings and recommendations of *Crisis at the Core* (ACT, 2004). Special attention should be given to the "College Readiness Benchmarks for [College] Algebra, found on pages 38 and 39 of the report. The message in *Crisis at the Core* is that the traditional mathematics core of Algebra I, Geometry, and Algebra II is no longer sufficient. Students and their advisers – counselors, teachers, and parents - must understand that more is required for both college and the world of work. Students today need more than the 3-course traditional mathematics core. They must be encouraged and guided to complete a fourth course of mathematics, a course that, at a minimum, includes trigonometry and some upper-level mathematics. Other studies, such as the NCTM's *Principals and Standards for School Mathematics* (2000) and Washington State's Transition Mathematics Project (2006), recommend the inclusion of probability and statistics in the mathematics preparation of high school students.

Schools should also embark on a detailed study of the NCTM's *Principles and Standards for School Mathematics*, PSSM, (NCTM, 2000), guided by Mirra's "Administrator's Guide: How to Support and Improve Mathematics Education in Your School" (Mirra, 2003). The PSSM should be compared to the New Hampshire State GSEs for grades 9-10 and 11-12 (NH State Department of Education, 2006), to the school's curriculum, and to the college expectations identified elsewhere in this report.

Additionally, the College Board has recently issued *College Board Standards for College Success: Mathematics and Statistics* (College Board, 2006). These guidelines are different from other reports in that they address the need to start the planning in middle school and address the need for statistics, an area of growing importance in many careers and occupations. The Board notes: "Mathematical thinking and statistical thinking both involve logical reasoning and recognizing patterns, but mathematical thinking is more deterministic and statistical thinking is usually probabilistic in nature. Students need to learn both ways of thinking" (p. xiii).

In February, 2006, Achieve, Inc, released a report entitled "Closing the Expectations Gap – 2006." The report is "an annual 50-state progress report on the alignment of high school policies with the demands of college and work." (Note the dual reference to **college and work**.) Commenting on New Hampshire's effort in this regard, the report notes that New Hampshire (as well as several other states) "raised requirements in past year [recently], but not to college- and work-ready levels" (p.14). Other parts of the report reinforce the need for more and more rigorous study of mathematics by all students and urge states to move to P-16 planning. [Note: "A P-16 system integrates a student's education beginning in preschool (as early as 3 years old) through a four-year college degree." ECS (2007)]. Aligning state standards with post-secondary and workplace expectations requires the full participation of all stakeholders including elementary and secondary schools, colleges and universities, and business and industry. New Hampshire has established a P-16 Council, and we praise the State for doing so.

Another point made in "Closing the Expectations Gap 2006" is that when schools raise graduation requirements (and the rigor of the required courses), they must also work to raise graduation rates. The report suggests **that middle school programs be strengthened to better prepare students for a rigorous high school curriculum**. This link to middle school programs is found in other reports as well. For example, *Bridging the K-12/Postsecondary Divide with a Coherent K-16 System* (CPRE, 2000) suggests that college-admission counseling should begin in middle school. In the middle school years,

academic advisors should make students and parents aware of the consequences of course selection in high school, and the need for a course of study that includes four years of mathematics as defined above.

What's Happening in College Today: What High Schools Need to Know

A Fresh Start for Collegiate Mathematics: Rethinking the Courses below Calculus (Hastings, 2006), is a collection of papers that were the core of a conference held in Washington, DC in October of 2001. Among the several papers, this committee recommends three in particular for review by school administrators and teachers: Don Small's "College Algebra: A Course in Crisis;" Zalman Usiskin's "High School Overview and the Transition to College;" and Al Cuoco's "Preparing for Calculus and Beyond: Some Curriculum Design Issues".

In the first, Small reports that "college algebra has the largest enrollment (approximately 400,000 in fall 2000) of any college credit-bearing mathematics course" (p. 83). Yet, Small notes, that the traditional college algebra course is a boring, archaic, torturous course that does not help students solve problems or become better citizens (p.85). He then outlines his suggestions for change, including real-world problems, modeling, data analysis, and small group projects. Such reforms would have serious implications for the courses taught in high school, yet mirror what some of the new standards-based programs reviewed by the Curriculum Committee incorporate in their materials.

In his article, Usiskin notes that many students are required to take remedial courses in college while the data show that mean mathematics scores on tests such as the NAEP, SAT, and ACT have risen. This seems to be a contradiction, but he conjectures that among the reasons is the fact that "college mathematics requirements have themselves increased." He writes: "Some institutions require a certain competence in mathematics of all their students, and almost all institutions have seen mathematics requirements increase in fields such as psychology, business, the biological sciences and the social sciences where requirements were once minimal." Usiskin further notes that there is often a "mismatch between the mathematics taught in high school and the mathematics tested on college placement exams..." He goes on to point out that the college placement exams receive little publicity and "are accountable to no one." He concludes that a national effort is needed to bring these placement tests in line with high school curricula and teaching practices. Such might be addressed in New Hampshire by the formation of a P-16 Council, alluded to earlier (Hastings, 2006, pp. 111-120).

In his paper, Al Cuoco suggests a new pre-calculus course be created that focuses on matters such as finding and analyzing patterns, designing and conducting experiments, describing and communicating, and "tinkering and inventing" (Hastings, 2006, p. 236). This article is recommended for high school teachers, since the materials described will soon be available commercially and represent a radically different view of a 'senior-level' course for high school. Field tests of the materials have shown that students can do this work:

"Students at all levels can do this kind of work. Much of the field test of [Mathematical Methods] was done in senior topics classes; my students were the weakest students in their school taking a fourth year of mathematics. Poor performance in mathematics courses has many causes, but lack of ability to think in a characteristically mathematical way is, for the vast majority of students, not one of them" (Cuoco, p. 247).

Each mathematics teacher should review his/her own beliefs about the ability of students to pursue mathematics and convince more of our students that they can succeed, if they only apply themselves. Of course, creative teaching and genuine belief in their ability is necessary as well.

In addition to the reports summarized here, other reports (cited in the bibliography) reinforce the contention that today's student should take four years of mathematics, that the 'core' (Algebra I-Geometry-Algebra II) is no longer sufficient and that a greater and greater proportion of professions and/or work opportunities require mathematical thinking and mathematical skills such as: problem solving, pattern recognition, conjecturing, and making connections, as well as the ability to solve equations, use polynomials to represent functions, apply trigonometric relations, and use permutations and combinations in statistics and probability.

Communication Between High Schools and Colleges/Universities: What is Needed

Seldom is the information presented in the previous section communicated to our high school students, and therefore, students fail to study as much mathematics as they will need to be successful in beginning mathematics courses in college or in the world of work. A very recent report from ACT, "Ready for College and Ready for Work: Same or Different," (ACT, 2006) states: "Results of a new ACT study provide empirical evidence that, whether planning to enter college or workforce training programs after graduation, high school students need to be educated to a **comparable level of readiness in reading and mathematics.**" (Emphasis added.) The research committee highly recommends this 10-page report to all counselors, teachers, and parents.

Similarly, the National Science Board (2006) in a companion report to the Board's 2006 report "Science and Engineering Indicators – 2006" stated that it is necessary to prepare guidance counselors to provide quality STEM (Science, Technology, Engineering, Mathematics) career guidance. Counselors must be able to access – readily – the necessary information about STEM careers to guide students' choices of pre-college courses. Similarly, the counselors must be aware of the growing need for mathematics for those students who plan to enter the work place directly.

Colleges and universities, as well as local and state business groups, have a clear responsibility to communicate the need for rigorous preparation to all students. The suggestion of the need for a "coherent P-16 system" referenced above (p. 5 of this document) is timely and needed if we are to best serve the students with a clear, accurate, and consistent set of data on which to act. For example, such a group might maintain a website which clearly identifies the mathematics admission standards for all New Hampshire colleges and community colleges – not merely generally, but specifically by intended major. The data and information contained in the Southern Regional Education Board (2007) website for that consortium might serve as a model for New Hampshire.

Schools must also work to align the **espoused** curriculum with the **enacted** curriculum. The first step, collecting information, is not as straightforward as it may seem. "Many high school courses do not clearly document in writing what they are attempting to accomplish, or what knowledge and skills students need coming in or will master by the end" (Conley, p. 63). It is necessary, according to Conley, that schools look to develop a 'common template' for writing course outlines and syllabi where the knowledge and skills coming in and mastered at the end are clearly identified. Only then, writes Conley, can schools

make recommendations for curricular and instructional changes ...so that all students receive an appropriately challenging education that prepares them for post secondary education and lifelong learning. (p. 64)

He further notes that the work must continue with annual revisions and monitoring to assure that these syllabi are truly meeting the needs of the students and producing the outcomes that are intended. The MaTHSC Survey Committee found a lack of a coherent, consistent Algebra I curriculum among the high schools surveyed in New Hampshire. The names for these courses also varied considerably, making it difficult to know what the student actually studied.

At the August 2006 Math Fest, Vélez concluded: “The transition from high school to university is brutal.” We need to examine ways to ease the transition. Part of that ‘easing’ should be clear and specific guidance on the importance of studying mathematics and the role of mathematics in today’s world-of-work – be that the immediate work after high school or the later work following further study.

Before It’s Too Late reports that 60% of all new jobs in the early 21st century will require skills that are possessed by only 20% of the current workforce (National Commission on Mathematics and Science Teaching for the 21st Century, 2000). Our students must be made aware of this conclusion and be guided to prepare themselves for the future. In addition to the transition from high school to college the high school dropout rate leaves students unprepared for the 21st century. New Hampshire is presently seeking to lower the high school dropout rate and to raise the age at which one can leave high school to 18. [See Appendix D for more information on high school dropout rates.] The work that must be done to assure that students no longer receive mixed messages requires the involvement of many – teachers, guidance counselors, college admissions directors, professors, business leaders, and parents. Part of this work must include changes in our perceptions of what students can do, our beliefs about having all students studying a strong curriculum, and our communication among the several partners that must be involved in P-16 planning. In all of this, we must also commit ourselves to the notion that better teaching is the single, best lever for change – teaching that builds on the student’s knowledge and is grounded in the belief that ALL students can and must learn mathematics. (Note: *Before It’s Too Late*, beginning on p. 32, has a list of recommendations for administrators, teachers, parents, etc., which the reader may wish to review.)

In summary, the importance of communication between institutions of higher education and secondary schools can not be over-emphasized. An ancient Chinese proverb says, “The best time to plant a tree is twenty years ago; the second best time is today.” If we are to help ALL students prepare for the world of work and/or higher education, we must ‘plant the tree’ of clear, accurate, information about the importance of mathematics now.

Issues of Teacher Preparation

If we truly commit ourselves to four years of mathematics for the great majority of our students, then we are faced with the need for far more teachers who are adequately prepared to meet this challenge. In a 2000 report (*In Pursuit of Quality Teaching*) by the Education Commission of the States (ECS), teaching quality is listed as the key factor to student learning. The report goes on to state that teachers need a strong initial preparation with effective professional development throughout their careers, and teachers need a working environment that promotes student learning and professional satisfaction. Unfortunately today, one in four teachers enters the profession with a temporary or emergency license or no license at all. One in three teachers is teaching at least one class outside of the teacher’s certified content area. There continues to be teacher shortages in mathematics, science, special education and bilingual education. The National Science Teachers Association reports, “Based on data from the Teacher Follow-up Survey, it is estimated that after just five years, between 40 and 50 percent of all beginning teachers have left teaching altogether” (Ingersoll, 2006). In another report, published by ECS, Allen (2003) examined issues affecting teacher preparation. The report states that there is limited evidence that content knowledge, pedagogical course work, or a high-quality field experience leads to effective teaching. Similarly, there is limited support that alternative programs produce teachers as effective as traditionally trained teachers.

According to the National Center for Education Information (2005) the public school teaching force in the United States is getting more female and older. Currently, 82% of the public school teachers are female. While 28% of teachers with 30 or more years experience are male, only 16% of those with five or fewer years of teaching experience are male. Forty percent of current public school teachers expect not to be

teaching in K-12 schools five years from now. Half of the current high school teachers do not expect to be teaching in K-12 schools in 2010 with one-third of high school teachers expecting to be retired.

In a Summary Report of *Mathematics & Science Teachers: Understanding Factors Affecting Supply & Demand* written by Bob Kansky (2006), he states that teacher retirement is not the primary reason for the shortage of mathematics teachers. Kansky states that teacher retention is the primary cause and that schools need to improve the conditions of the teacher's work environment and professional development. He suggests induction programs for new teachers, providing salaries for mathematics teachers that are commensurable with other careers in mathematics, providing more support for teachers with regard to student discipline, and giving teachers more input into school/district decision-making.

Disconnect Between High School and College

Now, consider the disconnect or "gap" between high school and college mathematics. Initially, in preparing this report, the word "gap" was defined solely on the content: there existed a gap between the content of the mathematics being taught in the high school and the content of the mathematics taught in entry-level college mathematics courses. However, clearly gap could mean many things. In addition to the above, there seems to be a gap in the mathematics being taught in the high school when compared to the mathematics necessary to be successful at even the most basic skilled job in the workforce. There also appears to be a gap between the mathematics being tested in the high schools (on statewide assessments) and the mathematics necessary to succeed in an entry-level mathematics course in college. Finally there exists a gap in the perception of high school students concerning college level mathematics; what they believe to be true, and what really is true, are often two completely different things. [Also see Appendix E: Student Misconceptions for a discussion of student errors and misconceptions in mathematics that could influence their success in college level mathematics.]

Researchers have documented several reasons for why there is a disconnect between high school and college. The Bridge Project at Stanford University collected data in six states (California, Georgia, Illinois, Maryland, Oregon, and Texas) to identify the source of the high school and college disconnection. The researchers report the following:

- a. Students take multiple and confusing assessments. High school students take national tests (SAT, ACT, NAEP, etc.), district tests, and tests in their high school courses. The formats of these tests vary widely. Some are strictly multiple choice, while others focus on more open-ended responses.
- b. There is a disconnection between high school graduation standards and the demands required by college entrance or placement requirements. An example of this is the difference in mathematics courses required for graduation and mathematics courses required to enter a college.
- c. There is a lack of longitudinal K-16 data that would help bridge the disconnectedness between high schools and colleges. If more data were collected and shared at all levels, more could be done about the problem.
- d. There are few K-16 accountability mechanisms. The researchers acknowledge that K-12 education is being held accountable but postsecondary education is not.
- e. There are insufficient K-16 governance mechanisms. Hence, no one is held responsible for K-16 reform and the education sectors often act independently without regard to each other's reform needs.
- f. Students' knowledge about college is filled with myths. Appendix A lists the top ten myths that students believe about college, as articulated in Venezia (2003). Not all these myths contribute to the gap between high school and college, but many do.

The Stanford Bridge Project (2006) researchers recommend the following three actions be taken immediately to bridge the gap between high school and college:

- Provide all students, parents, counselors, and teachers with accurate information about college admissions, coursework requirements, and prerequisites.
- Focus on all colleges, not just the highly selective ones.
- Expand the focus from getting into college to successfully completing college.

The researchers also suggest the following steps to improve the transition from high school to college:

- Colleges need to publicize their requirements and standards clearly.
- Compare K-12 exit-level standards and assessments and college placement exams. Then determine if more compatibility is necessary or possible.
- Review college placement exams for reliability, validity, efficacy, and the extent to which they promote teaching for understanding.
- Allow students to take placement exams in high school to prepare for college.
- Link senior high school courses to entry-level general education courses at the college level to make the transition smoother.
- Expand the enrollment of high school students in college courses.
- Collect and connect data from all education sectors.
- Provide the technical support necessary for each state to collect and analyze these data.
- Expand the federal grants available for states to work on bridging the gap between high school and college.

The researchers believe that the creation of an effective P-16 council is key to the successful completion of all of these recommendations.

The problem of the disconnection in mathematics between high school and college is being addressed in different ways. The following are three examples at various levels of intervention:

(1) Solutions at the College Level: The Early Outreach/Urban Health Program at the University of Illinois at Chicago is the umbrella organization for seventeen pre-college programs, which operate during the school year (Saturday programs) and summer. These programs promote science, mathematics, and language literacy and proficiency for students in grades four through twelve. They offer a variety of programs, including programs in mathematics that ensure students' success pre-college and in college. The results indicate that these programs are helping students perform better in their high school classes (80.6% reported grades B and higher in science, mathematics, and language arts), and 100% of the Saturday program students go on to college (University of Illinois at Chicago, 2006).

(2) Solutions at the High School Level: Many community colleges, colleges and universities in the United States administer mathematics placement tests to place incoming students in appropriate mathematics courses. Some states (ex. Maryland, Ohio, and Wisconsin) administer an early placement test— usually in the junior year of high school. This early placement test is modeled after a college mathematics placement exam. This test is purely diagnostic with the results released only to the student and the high school. Although no research has been published on the effectiveness of taking this early placement test in high school, it does give the high school students an idea of what they are expected to know before enrolling in a college mathematics course. The students might be able to practice and memorize the mathematics needed to be successful on the college placement test, but there is no guarantee that this student will then be successful in college mathematics courses. However, Hart (2005) reports, “Virtually all (94 percent) employers and the vast majority of college instructors (85 percent) say that giving students college placement tests when they are juniors to find out whether they are ready for college-level work or where they need to fill gaps in their learning would improve students’ chances of success.” For several years in the late 1990s New Hampshire had a similar program called NH-MAJIC: Mathematics Advice to Juniors for Informed Choices.

(3) High School and College Partnership Solutions: In Washington State nearly one-third of students graduating from high school begin their higher education in a two-year college, and of those students, one-half take remedial mathematics courses. The Transition Mathematics Project (TMP) in Washington State is designed to reverse this trend by helping students successfully progress from high school mathematics courses to college mathematics courses. The Project received funding from both the private and public sectors to improve student performance in mathematics and foster successful student transitions from high school to college and the workforce. With the participation of high school and college mathematics educators, TMP helped identify the mathematics skills and knowledge high school graduates need to be successful in college mathematics courses, meet minimum admission requirements, and avoid remediation upon enrolling in college. TMP now has defined clear and consistent expectations in mathematics so high school teachers can effectively prepare their students for success after high school. They have developed practical communications materials so students and parents understand what it takes to be prepared for college-level mathematics and quantitative reasoning. They have also promoted local and regional partnerships to support teachers and improve student preparation for college-level mathematics through professional development and sharing of best practices. Finally, TMP has created system-wide support and a process for aligning higher education mathematics placement testing and college readiness expectations. They are still planning to:

- Increase the use of mathematics standards and expectations in designing classroom tasks, assignments and assessments.
- Reach more students, especially students under-served by higher education, with clear messages on the importance of mathematics for post-secondary success.
- Improve the mathematics course placement process at Washington's colleges and universities by evaluating mathematics placement tests and informing students about mathematics expectations.
- Implement College Readiness Math Expectations across Washington by supporting local faculty and teacher partnerships.
- Demonstrate the impact of project activities on student course-taking and performance in high school and college math courses.

[Washington State Board for Community and Technical Colleges, (2004)]

In *Rising to the Challenge: Are High School Grads Prepared for College and Work?*, Hart (2005) reported that a large group of college students felt that they left high school unprepared or under-prepared for college. Thirty-nine percent of students replied that they felt that they had some gaps in their high school education; of these, seven percent believed they had large gaps in their preparation. Almost half (46%) of the students in this group took at least one remedial course in college. Concerning the subject of mathematics, 42% believed they had some gaps in their mathematics preparation, with 13% of those believing they had large gaps. When asked to choose one or two areas they wished their high schools had done a better job preparing them, the four-year college student's first choice was work and study habits (25% of respondents), while the two-year college students number one choice was the subject of mathematics (30% of respondents).

The numbers for those high school graduates who entered the work force were similar. Thirty-nine percent of the employed interviewees believed they had gaps in their preparation for what is expected of them in their current job. The number rises to 49% for those high school graduates who were currently unemployed; they stated that the gaps in their preparation were limiting their ability to get the type of job that they hoped to have. When asked to choose one or two areas in which they wished their high schools had done a better job preparing them, the number one choice for this group was the same as the two-year college students: the subject of mathematics (22%).

College instructors and employers were also surveyed in the Hart study; their responses basically reflected the self-reporting of the students and employees. The college instructors (on average) estimated

that 42% of the students in their entry-level mathematics courses were not sufficiently prepared to succeed in college-level classes. The employers estimated that roughly 39% of recent high school graduates were unprepared for the expectations they faced in entry level jobs, with 45% not prepared with the skills necessary to advance beyond the entry-level job.

These numbers can be interpreted in at least two different ways. One such interpretation could be positive, noting that a majority of all high school graduates (roughly 61% in both subgroups) did report feeling sufficiently prepared by their high schools for college-level classes and/or for their work. Employers and college instructors also support this data in their reporting, although their percentages aren't quite as high as the students self-report. However, the alternative interpretation would suggest that a serious problem exists. When approximately four in ten high school graduates are reporting gaps in their high school preparation, and this data is echoed by their college teachers and employers, there is a serious reason for concern. **Furthermore, even among those who believed that they were extremely well prepared or well prepared for college level work, 31% of them took a remedial course in college.** By any method of measurement, these students were not well prepared for college level work.

When it comes to academic preparation, only 24% of all high school graduates (26% of college students, 20% of non-college students) thought they faced high academic expectations and were significantly challenged in high school. However, those that faced high expectations and were challenged were much more likely to believe they were well prepared for college (80%) than those who faced moderate expectations (58%) or low expectations (13%). Also, those who faced high expectations were more likely to be getting mostly A's in college (28% compared to 13% of low expectation students) and were less likely to have taken a remedial college class (27% compared to 50% of low expectation students). The numbers for non-college high school graduates were similar. About 72% of those who faced high expectations in high school felt well prepared for their job, compared to 36% of those who faced low expectations. These data seem to suggest that the more rigor put into a high school academic program, the better the chances of success in both college and the workplace for the high school graduates.

Other interesting findings from the Hart report include:

- Only 14% of the employers reported being “very satisfied” with the overall job that high schools were doing in preparing graduates for the work world.
- 7% of college instructors at two-year colleges, and 22% of college instructors at four year colleges believed that most of their students come to college extremely well prepared or well prepared.
- College instructors estimate that 50% of the students at their schools are not adequately prepared to do college-level mathematics. The number rises to 60% when only instructors who teach mathematics, science, or engineering are considered.
- The two biggest areas that college instructors wished high schools would do a better job at preparing students are quality writing (37%) and mathematics (34%).
- Algebra II seems to be a crucial course; of those students who completed it, 60% felt they were well prepared for college; of those who did not, only 28% believed they were well prepared. For the non-college students, 68% of those who completed Algebra II felt well prepared to succeed at work, while 46% of those who didn't complete it felt the same way.
- Based on what they know now, 65% of college students and 77% of non-college students now say they would have worked harder in high school. Of those who took a remedial college course, 74% said they would have worked harder in high school, knowing what they know now. College

students at two-year colleges (76%) were more likely than students at four year colleges (60%) to say they would have worked harder.

- 82% of college students and 80% of non-students report that, had their high school demanded more, they would have worked harder EVEN if it meant less time for non-academic pursuits.
- 34% of the college students and 48% of the non-students report that they would have taken more challenging mathematics courses when in high school (knowing what they know now about college and work). This compares with 32% and 41% for science, and 29% and 38% for English.
- 84% of the high school graduates not in college believed that they would need more education to achieve what they hope for in life. 52% of them planned to attend college within the next year, while another 26% planned to attend college at some point in their lives.
- Over one-third (35%) of those interviewees who left college said they did so because of the challenges of the academic workload.

These last few points imply what was mentioned earlier; if high schools increase the rigor of their programs/graduation requirements, then the students (for the most part) will rise to the challenge. If schools continue to let students “slide by”, then a majority will usually choose that path; and, as a result, students will regret that decision later. Interestingly, once students have left high school for college or the workforce, they develop the insight to wish they had taken harder, more rigorous courses in high school. They needed this insight when in high school; but since they cannot obtain that insight without experience, schools must insure they complete the rigorous courses that their later lives will demand.

Some of the remedies that the interviewees suggested:

- 94% of college students believed that high schools need to provide the opportunity to take more challenging courses, such as advanced placement (AP) or international baccalaureate (IB) courses; 85% of college instructors echo this sentiment.
- 97% of non-college students believed that high schools should provide opportunities for real-world learning, and should make coursework more relevant; 95% of employers echo this sentiment.
- 81% of recent high school graduates interviewed believed that students should be required to pass exams to graduate from high school, and 74% thought all students should be required to take four years of mathematics. College instructors and employers agreed that requiring an exit exam (79% and 89%, respectively) and a more rigorous curriculum (81%, 83%) would improve the situation.
- 95% of employers and 85% of college instructors believe that college placement exams should be made available to high school juniors to take, to determine if they are ready for college level work.
- 90% of college instructors believe that guidance counselors need to start early in high school giving students better advice concerning the courses they should be taking.

Current Exit Exams

Achieve, Inc. (2004b) looked at six states that require exams in mathematics for graduating students. They examined the tests for academic rigor, determining what the tests actually measured and if the tests were reasonable. The six states (Florida, Maryland, Massachusetts, New Jersey, Ohio, and Texas) combined enroll nearly 25% of the nation's high school students. The data showed that the tests were not very demanding. Most of the mathematics questions placed an emphasis on pre-algebra skills, rather than algebra, and on basic geometry and measurement concepts, rather than on the concepts of a typical high school geometry class. In short, the tests seem to demand more mathematics from middle school than high school. Also, the scores needed to pass the tests were extremely modest, and the skills measured in these tests were rudimentary at best. In short, they were minimal competency skills, not skills that measured preparedness for either college-level work or realistic workforce demands.

The general public assumes that, by passing these exit exams, a student is ready for college-level work. Although states never make this claim on their tests, the assumption by the general public is that the student is now ready for college entrance. This misconception about the efficacy of exit exams is accompanied by another false assumption: that by earning a high school diploma, a student is ready for college level work. Both are misleading, and both contribute to the "gap" that exists between high school students' work, and expectations of college level instructors in entry-level college courses. Unless changes are made, taking (and passing) these tests, like graduating from high school with a diploma, reflects a **minimum**, not a maximum, amount of knowledge about a subject area.

Achieve (2004b) recommends that states begin to test on more challenging content in their exit exams. They recommend that more algebra and high school level geometry be present on these tests, and that the questions should measure higher-level thinking skills, not just the basic, low-level procedural skills that essentially require little or no understanding of the underlying concepts. They also recommend that the "cut" scores be (gradually) raised over time, providing that the tests either are maintained or increased in rigor; raising scores, then lowering the rigor of the tests, does not really help.

Achieve also recommends an exit exam (which could be different from the required graduation exam) that would concentrate on skills and knowledge more aligned with what colleges expect in their entry-level courses. They recommend that these exams not be "high stakes" exams, but rather simply a tool to inform teachers, parents, and the students about how much more work the student may have to do to succeed in college or in the workplace.

What Mathematics is Required: A National Perspective

In 2004, thirteen states required exactly two years of mathematics, twenty four states required three years, and just five states – Alabama, Arkansas, Mississippi, South Carolina, and West Virginia – required four years of mathematics. (Note – eight states leave graduation requirements up to the local school boards). Twenty-two states did not specify any courses in mathematics that are needed. Of those that do, twenty require Algebra I. (As of 2004, New Hampshire wasn't one of these states). Thirteen states require Geometry. Only three (Arkansas, Indiana and Texas) required Algebra I, Geometry, and Algebra II. In the last three years many states have drastically increased their mathematics requirements for high school graduation. Appendix C summarizes the recent data. Although New Hampshire is to be commended for recently raising the number of credits required in mathematics from two to three and now requiring algebra (usually interpreted to be the equivalent of Algebra I), the table in Appendix C clearly shows that several other states are ahead of New Hampshire in adopting the four year "college- and work-ready" standards articulated by the nation's governors at the Achieve meeting in 2004.

The weakness of the requirements inevitably leads to students taking remedial courses in mathematics. According to *The Expectations Gap*, 22% of students in their first year of college are placed into a remedial mathematics course, and 40% of postsecondary students will take at least one remedial course over the course of their college careers (Achieve, 2004a). Greene (2000) estimates that, across the U.S., the cost of this remediation, to higher education, businesses, students, and families, is 16.6 billion dollars.

The idea behind remedial courses in college is to help get the remedial student “up to speed” so they can handle “normal” college work. In fact, 76% of students who require remediation in reading and 63% who require remediation in mathematics fail to earn college degrees of any kind (two- or four-year degrees). In contrast, 65% of students who do not require remediation earn college degrees. The reasons for this failure can only be speculated upon. Perhaps the student is so distraught at being placed in remedial courses that they drop out of school. Perhaps, if the student’s skills are sufficiently deficient in one area to demand a remedial course, his/her skills may be deficient in other areas as well; the combination of the effect of being academically challenged in all areas is enough to doom the student to failure. A third possibility is that these students may choose a major that doesn’t fit their high school preparation; so, besides being doomed to take remedial coursework, their other courses require too much of them to succeed.

As important as reading and grammatical skills are to the successful adult, it appears that mathematics may be even more so. A report by ETS found that 84% of those people who currently hold highly paid professional jobs had taken Algebra II or higher as their last high school mathematics course. Among people who held well paid, white collar skilled jobs, 67 percent had taken Algebra II or higher in high school; and 84% had taken at least Geometry. This seems to echo data mentioned earlier in *The Expectations Gap* (Achieve, 2004a).

Once again, more and more rigorous mathematics seems to be the gatekeeper for success. Unfortunately, this caveat seems to hit minority groups the hardest. In a study conducted by the National Center for Education Statistics (2004), for the high school graduating class of 2000, only 29 percent of American Indian, 31% of Latino, and 32% of African American students took a mathematics course beyond Algebra II. This data compares rather unfavorably with white (47%) and Asian students (69%) who did the same.

In this context, Achieve made the following recommendation concerning mathematics: to be prepared for the challenges students will face after graduation, be it in the workplace or in college, every high school student should take four years of **rigorous** (emphasis added) math, including Algebra I, Geometry, Algebra II, (or their equivalents) and a course in data analysis and statistics. It should be pointed out that, in 2004 at the time of publication, no state had these standards (Achieve, Inc, 2004a, p. 16).

Achieve also makes the following recommendations:

- 1) Require all students to take a common college and work preparatory curriculum in mathematics and English. Translated, this means the following: make the graduation requirement (the default curricula) across the state reflect what is necessary to get into postsecondary education or the skilled workforce.

Texas, Arkansas, and Indiana have all adopted these requirements. All students, beginning in 9th grade, are required to take Algebra I, Geometry, and Algebra II (or their equivalents). Arkansas also requires a fourth year class in mathematics, which could be a Precalculus or Calculus course, or a course in data analysis and statistics. They have similar rigorous requirements in English. [See also Appendix C for additional states that have recently adopted similar expectations.] This is the default curricular requirements for getting a high school diploma in these states. Students may “opt out” of

this course of study, but they need permission from both their parents/guardians and from the school administration.

- 2) Pay attention to course content, not course titles. Just because a course is called Algebra I or Geometry throughout a state doesn't guarantee uniformity of content. The content in the courses must reflect high standards; state standards should be written (or re-written) to reflect what is essential for each student to learn in order to succeed in college or in the workforce. States need to articulate what is most important for students to learn in each course
- 3) Allow flexibility for instructional approaches. Even though the **content** should be (relatively) uniform in these courses, the **method** of presentation need not be. Educators should be allowed to teach in ways that best reflect their students, and should be allowed to make their own decisions when it comes to content delivery.
- 4) Encourage students to go beyond the core. Even if the State decides to make its default graduation requirements "college prep," remind students that it is still a **minimum** college prep...students can, and should, go beyond the requirements, especially in the technical fields of mathematics, science and engineering, (especially more so if they plan on pursuing a career that involves these fields even tangentially).
- 5) Monitor the results. States should track student achievement from K-12 at a minimum. It would be more useful to track student achievement (at least in state) from K-16.

To close this section, we quote from page 15 of *The Expectations Gap*. This passage succinctly states the problem.

*There is ample evidence that there is a performance gap in American education – too many young people graduate from high school poorly prepared for college and work. Achieve's review of high school graduation requirements makes clear that there is also an expectations gap. **Because state expectations, as defined by high school graduation requirements reflect an economy and society that no longer exist, students who do precisely what is expected of them are not likely to be prepared for college and work.** (emphasis added) Today's students deserve much better than that.*

In February 2005, governors from 45 states, business leaders, and education leaders met at the National Education Summit on High Schools. Following that meeting, Achieve (2007) reported momentum from many states, raising graduation requirements to include required courses that lead to a "college and work-ready diploma," which is defined as including four years of mathematics, including Algebra I, Geometry, Algebra II, and beyond. Many states are presently in a dialogue that will lead to these requirements; twelve states have already established the requirements that the American Diploma Project recommends. In other states, communities, including Los Angeles and San Jose in California, Boston, and Chicago have set standards higher than the state standards and are (or will be) requiring the more challenging curriculum for all their students. Appendix C lists the high school graduation requirements or pending graduation requirements for many of the nation's states. Students who do not meet these challenging requirements will be put at a disadvantage in the competitive global economy. States who do not require their students to leave high school "college and work-ready" are doing their students a disservice.

New Hampshire's Expectations and Recent Changes

Appendix B provides an analysis of possible “gaps” due to inconsistency between New Hampshire high school and national college standards. A member of the research committee compared the State of New Hampshire draft High School Mathematics Grade-Span Expectations (GSEs, 6/14/2006) to the National Council of Teachers of “Mathematics Principles and Standards for School Mathematics” (NCTM, 2000), and found them to be in good agreement across content areas. The GSEs were then compared to “Crossroads in Mathematics, Standards for Introductory College Mathematics before Calculus,” produced by the American Mathematical Association of Two-Year Colleges (AMATYC, 1995) and “Understanding University Success,” a report from Standards for Success, a project of the Association of American Universities and the Pew Charitable Trusts (Conley, 2003). While the standards outlined in the AMATYC document represent mathematical standards suggested for students **while in college**, the Standards for Success outline those standards that students need to have proficiency in **before entering college** to ensure success at the university level, and thus offers a better benchmark for the comparison between the draft GSEs and what is expected by post secondary educations of incoming college freshmen.

The State of New Hampshire Mathematics GSEs are a collection of expectations; some of those expectations are assessed on the State level, while others are not. Those that are not assessed at the State level are considered “local” GSEs, written to provide guidance to local districts developing mathematics curricula for college bound students, and assessed at the local (school) level. The State level assessment, the New England Common Assessment Program (NECAP), is common to the states of New Hampshire, Rhode Island, and Vermont. The NECAP assessment items within the GSEs are expectations for students at the end of grade 10, or the beginning of grade 11. There is currently no required assessment for graduating seniors, and until recently, many students in New Hampshire finished their high school mathematics “career” in their sophomore year. Such a student would undoubtedly inherit a “gap” with the Standards for Success, which assumes a student will begin the study of algebra in the 7th or 8th grade, and will continue with progressively higher levels of mathematics each year until graduation (i.e., a minimum of 4 **years**, not credits, of high school mathematics). Students finishing their State mathematics requirement in the sophomore year will face difficulty retaining what they have learned for the next two years of high school, and will often have an inadequate concrete understanding of the curricula presented in traditional Algebra I, Algebra II and Geometry levels, which universities often require as the minimum for college entrance requirement.

In an attempt to address such concerns, the State of New Hampshire adopted new standards, effective in the summer of 2005 with regard to high school mathematics programs and their associated requirements. High schools are required to offer a minimum of 6 credits of mathematics that are sequential, integrated, or applied, or a combination of the 3, with at least one credit to be offered in each of the following areas:

- a. Introduction to high school mathematics and applications;
- b. Elementary Algebra;
- c. Geometry;
- d. Intermediate algebra; and
- e. Advanced mathematics (Ed 306.43 (c) (10)).

In addition to outlining which courses a district needs to offer, the number of mathematics credits required to be completed by each student was increased from 2 “units of credit” to 3 “credits.” The new language, which went through rigorous debate during the draft stages concerning the inclusion or exclusion of an “Algebra I” requirement, states that each student must complete “3 credits, including algebra credit that can be earned through a sequential, integrated, or applied program (Ed 306.27 (m)).” The definition of “credit” in the new rule differs slightly from the prior definition of “units of credit,” used in the old rule. The credit definition now includes an option employing a competency assessment to demonstrate mastery of the required competencies for the course. These competency assessments are to

be locally developed for each course by the 2008-2009 school year. Until the 2008-2009 school year, credit can be earned by attending a class scheduled to meet for no less than 135 hours of instructional time if the school operates on an 8-period schedule, for no less than 150 hours if the school operates on a 7-period schedule, or by using the aforementioned competency assessment, if the school district has adopted one. Initial information attained from educators within NH high schools indicates the new language will provide little to no change regarding when students are capable of completing their high school mathematics course work. One southern NH high school which uses the “block scheduling” format for classroom instruction indicated that their students are capable of satisfying the 3 credits by January of their sophomore year, leaving a “time gap” of 2 ½ years between the last mathematics class taken and entrance to college. Law makers were clearly trying to send a message to NH students that they would like to see high school students take a minimum of three years of mathematics, but the administrative rule, as passed, does nothing to require a student to do so.

The Standards for Success, a nationally recognized list of standards compiled by a group of more than 400 faculty from 20 research universities, are broken down into six categories: Computation, Algebra, Trigonometry, Geometry, Mathematical Reasoning, and Statistics (Conley, 2003). Each category is broken into sub-categories which explain the content areas students need to have mastered to be successful in college. By titles alone, the categories indicate that students need more than basic algebra credit to be successful in college. Almost all of the subcategories are met if a student follows the State GSEs through the “Advanced Mathematics” section of the standards. However, several of the Standards for Success are not met if a student merely completes coursework up to and including those topics that will be covered in the high school NECAP assessment. Students who perform well on the NECAP assessment and complete the 3 credits of required mathematics are not necessarily prepared for success in college. In fact, high school graduation requirements are a common misconception as an indicator of adequate college preparation (Kendall & Williams, 2004). Yet, with increasing numbers of high school students expecting to go on to college, this misconception is affecting more and more graduating high school seniors.

The draft State GSEs and the proposed 11th grade NECAP assessment improve the status of mathematics education by providing a benchmark for schools to measure 10th grade achievement where one previously did not exist. The results of the assessment for each individual student come early in the high school experience to allow time to address deficiencies by allowing further coursework. However, the GSEs and the State administrative rules do not address students’ furthering their mathematics education beyond 10th grade, if the student shows proficiency on the NECAP assessment. These students will still fall short of the standards necessary for college success. In an attempt to outline standards that will be assessed on the State GSEs, and the potential gaps that a student may have if they conclude their mathematics exposure at the end of grade 10, the Standards for Success were compared with the State GSEs. Appendix B outlines standards from the Standards for Success that will not be assessed by the NECAP exam, as well as those standards not present in the draft GSEs at all.

In order to identify possible gaps between what colleges expect of their incoming freshmen and what standards high school students are required to meet, the State of NH Grade-Span Expectations were compared with the Standards for Success. (See Appendix B.) While the overall content of the State GSEs (through the High School and Advanced Mathematics levels) meet the Standards for Success relatively well, there are many standards that will not be met by students who merely meet the standards that will be assessed by the proposed 11th grade New England Common Assessment Program (NECAP). During local standards-based reform, school districts must set their requirements high in order to properly prepare their students for post secondary education. It also will be crucial for local mathematics personnel developing new curriculum to communicate with post-secondary mathematics professors during the reform, to discuss their proposals and to examine whether their curricula will meet college expectations. The GSEs and support documents will undoubtedly be interpreted differently by different school districts.

These different interpretations by themselves may result in further standards gaps (Sandholtz, Ogawa, Scribner, 2004). It is important that the overall goal of improving student academic performance not be overlooked. As New Hampshire moves forward with developing the content, all stakeholders must be mindful of improving student academic performance and reducing the gap between high school and later expectations.

Conclusion

The State of New Hampshire is at a crossroads with regards to mathematics readiness. With the proposed standards-based reform, high school educators and administrators have the opportunity to reverse the disturbing trend of increasing numbers of students leaving high school unprepared for college or work. The numbers of students graduating NH high schools with insufficient mathematics backgrounds is reaching unsustainable levels. To date, the “standards gap” that exists for these students has resulted in the necessary remediation at the college level, often at the pre-algebra and algebra I levels. This remediation costs students a significant amount of money, and costs institutions a significant amount of money and resources to implement the remedial program. In the Fall of 2006, remedial (not for credit) mathematics courses at the State’s largest community college constituted 52% of all offered mathematics courses, including 4 sections of pre-algebra and 16 sections of algebra I (roughly 500 students). The number of sections at these levels has risen in each of the last 5 years. A reform at the high school level can help reverse this trend, but not by itself. Post-secondary educators and high school teachers must communicate closely to adopt standards that will bridge the gap between high school and college, and make the transition from high school to college less of a challenge and more of a rewarding experience.

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Appendix A

Students' misconceptions about preparing for and attending college	
Many students believe:	In truth:
I can't afford college.	Students and parents regularly overestimate the cost of college.
I have to be a stellar athlete or student to get financial aid.	Most students receive some form of financial aid.
Meeting high school graduation requirements will prepare me for college.	Adequate preparation for college usually requires a more demanding curriculum than is reflected in minimum requirements for high school graduation, sometimes even if that curriculum is termed "college prep."
Getting into college is the hardest part.	For the majority of students, the hardest part is completing college.
Community colleges don't have academic standards.	Students usually must take placement tests at community colleges in order to qualify for college-level work.
It's better to take easier classes in high school and get better grades.	One of the best predictors of college success is taking rigorous high school classes. Getting good grades in lower-level classes will not prepare students for college-level work.
My senior year in high school doesn't matter.	The classes students take in their senior year will often determine the classes they are able to take in college and how well-prepared they are for those classes.
I don't have to worry about my grades, or the kind of classes I take, until my sophomore year.	Many colleges look at sophomore year grades, and, in order to enroll in college-level courses, students need to prepare well for college. This means taking a well-thought out series of courses starting no later than 9 th or 10 th grade.
I can't start thinking about financial aid until I know where I'm going to college.	Students need to file a federal aid form prior to when most colleges send out their acceptance letters. This applies to students who attend community colleges too; even though they can apply and enroll in the fall of the year they wish to attend.
I can take whatever classes I want when I get to college.	Most colleges and universities require entering students to take placement exams in core subject areas. Those tests will determine the classes students can take.

Source: Betraying the college dream: How disconnected K-12 and Postsecondary Education Systems Undermine Student Aspirations. Venezia A., Kirst, M. W., Antonio A. L.

Appendix B

Table 1: What is missing? NH State GSEs versus Standards for Success

Standards for Success	Assessed by 11 th Grade NECAP?	In the NH GSEs?	Notes
know terminology for complex numbers, integers, rational numbers, irrational numbers and complex numbers.	No	Yes	See note 1
perform appropriate basic operations on sets (e.g., union, intersection, elements of, subsets and complement).	No	No	
know how to compose and decompose functions and how to find inverses of basic functions.	No	Yes	
know basic theorems of exponents and roots.	No	Yes*	*May be contained within problems using exponents and roots.
understand logarithms (to bases 2, 10 and e) and their properties. know basic theorems of logarithms.	No	Yes*	See note 1 *Not explicitly listed - assumption is that if a student can solve an equation containing a log expression, they must need to understand the properties of logs.
divide low degree polynomials (e.g., long division).	No	Yes	See note 1
factor polynomials (e.g., difference of squares, perfect square trinomials, difference of two cubes and trinomials such as $x^2 + 3x + 2$).	No	Yes	See note 1
solve quadratic equations using various appropriate methods while recognizing real solutions. This includes: factoring. completing the square. the quadratic formula.	No	Yes	
understand a variety of functions (e.g., polynomial, rational, exponential, logarithmic and trigonometric) and properties of each.	Yes *	Yes	* conceptual understanding only
understand the basic shape of a quadratic function and the relationships between the roots of the quadratic and zeroes of the function.	No	Yes	
know formal notation (e.g., sigma notation and factorial notation).	No	Yes*	See Note 1 * Not explicitly stated, assumed to be contained in the Data, Statistics and Probability strand
know arithmetic and geometric progressions and series.	No	Yes	See Note 1

Appendix B, cont.

Table 1 (cont.): What is missing? NH State GSEs versus Standards for Success

Standards for Success	Assessed by 11 th Grade NECAP?	In the NH GSEs?	Notes
understand the relationship between a trigonometric function in standard form and its corresponding graph (e.g., domain, range, amplitude, period, phase shift and vertical shift).	No	Yes	
understand periodicity and recognize graphs of periodic functions, especially the trigonometric functions.	No	Yes	
know and use identities for sum and difference of angles [e.g., $\sin(x \pm y)$, $\cos(x \pm y)$] and use double and half angle formulas.	No	Yes	See Note 1
understand the ideas behind simple geometric proofs and are able to develop and write simple geometric proofs (e.g., the Pythagorean theorem; that there are 180 degrees in a triangle; and that the area of a triangle is half the base times the height).	No	Yes	GSEs mention making and defending conjectures and arguments only as part of NECAP assessment item
solve problems involving proofs through the use of geometric constructions.	No	Yes	
recognize geometric translations and transformations algebraically.	No	No	See Note 1
know the algebra and geometry of parabolas and ellipses as a prerequisite to the study of calculus.	No	Yes	See Note 1
use trigonometry for examples of the algebraic/geometric relationship, including Law of Sines/Cosines.	No	Yes	See Note 1

Conley, David (2003b) Standards for Success (S4S) for mathematics found on pages 29-37 *Understanding University Success*, Center for Educational Policy Research, University of Oregon, Eugene, OR., http://www.s4s.org/Understanding_Success.pdf

Note 1: S4S notes that these expectations are suggested for those who plan to major in mathematics, computer science, or statistics. These skills are also important for scientific or technical disciplines such as chemistry, physics, engineering, pre-med or other majors/goals that require calculus.

Appendix C

State Requirements in Mathematics for Graduation from High School

Compiled February, 2007

States Shown in Bold Face Type Require (or will require in future)

Algebra I, Geometry, and Algebra II, or equivalent as the “default” diploma for all students

State	# of Math Courses	Alg I	Geometry	Alg II	Additional Courses	Source#	Notes
AL	4	Yes	Yes	Yes*		1	*Diploma+ requires Alg II with trig
AK	3	Yes	Yes		“1 higher level math course”	1	
AZ	2	*	*			4	*Within the two years of required mathematics in AZ, all five strands of the Mathematics Standard must be addressed. Two of the five strands are: Strand 3 - Patterns, Algebra, & Functions and Strand 4 - Geometry & Measurement.
AR	4	Yes	Yes	Yes*	“1 higher level math course”*	4	*Most Students graduate from Smart Core curriculum Core curriculum does not require Alg II – but students must have parental permission – and Core Curriculum is not college prep.
CA	2	Yes				5	
CO	*					4	*CO allows school districts to determine which courses are required for graduation from high school.
CT	3					4	A proposal to move to a 4-year requirement will be decided upon in the upcoming legislative session in CT
DE	4			Yes		1	Starting with graduating class of 2011
DC	3	Yes				5	
FL	3 present 4 starting with graduating class of 2011	Yes				1	3 different diplomas; all require Alg I; 3-year college prep diploma requires “Algebra I and above”
GA	3 for tech-career prep 4 for college prep (CP)	Yes	*	*	*	1	*CP diplomas require “Algebra I and above”

State	# of Math Courses	Alg I	Geometry	Alg II	Additional Courses	Source#	Notes
HI	3	Yes*	No*	No*	No*	4	*General Math courses will sunset this SY: Pre-Algebra course will sunset in SY2010-2011; No math course requirements but highly recommended that Algebra I be taken by ALL students.
ID							
IL	3	Yes	*			4	*one year must contain geometry content
IN	3	Yes	Yes	Yes		3	Presently recommended to all students; will be required for all students starting with class of 2011
IA	3*						*IA is a local control state. The requirement for 3 years of math was enacted during 2006 and takes effect for the 2011 graduating class. Districts decide about which courses.
KS	3					4	“3 units including algebraic and geometric concepts”
KY	3 – Core 40 *Core 40 w/ Academic Honors	Yes	Yes	Yes*	*Honors addl. course	1	*added for the 2008 freshman class. Also required to take mathematics every year.
LA	3	Yes					The High School Redesign Commission will formally issue recommendations on March 2, 2007 to increase these requirements to 4 units, including Algebra I, Geometry, and Algebra II -- called LA Core 4.
ME	2	No	No	No		4	A proposal for 4 years of mathematics including one year beyond Algebra II is currently under consideration.
MD	3	Yes	Yes		Data analysis	1	
MA	*					5	*MA allows school districts to determine which courses are required for graduation from high school.
MI	4	Yes	Yes	Yes		3	Take affect with 9th graders entering high school in fall 2008 – math course required in senior year

State	# of Math Courses	Alg I	Geometry	Alg II	Additional Courses	Source#	Notes
MN	Presently no years specified	Yes	Yes		Data analysis	4	Standards being revised and scheduled to be adopted by the legislature in Spring 2007 and implemented in 2010-11. New standards will require Algebra II.
MS	3 presently 4 for students graduating in 2009*	Yes				1	*starting in 2009 at least one course must be higher than Alg. I Drafting I & II can count as one mathematics credit
MO	2 present 3 *	No Yes				4	*Beginning with the class of 2010 students must have 3 math credits Algebra I and above.
MT	2					5	
NE	*					4	*NE allows school districts to determine which courses are required for graduation from high school.
NV	3					4	3 Bills presently in legislature to require 4 years of math incl. certain courses. Two largest districts in NV already have the requirement of 4 years of math and required Alg I, Alg II and Geom, with a 4 th course of choice.
NH	3	Yes				4	
NJ	3					4	
NM	3	Yes				4	Legislation pending to require 4 years of high school math, one being Algebra II and the parents can opt out of this requirement for their student.
NY	3	*				5	*at a more advanced level than grade eight
NC	3 CP 3 CTP 4UNIV 3 OCCUP	Yes Yes Yes Yes	No Yes Yes	No Yes Yes	No No Yes	1	3 diploma tracks: OCCUP is listed for students with disabilities who have IEPs CP Career Preparation CTP College Technical Prep UNIV College/Univ. Prep
ND	*					4	*ND allows school districts to determine which courses are required for graduation from high school.

State	# of Math Courses	Alg I	Geometry	Alg II	Additional Courses	Source#	Notes
OH	4*	Yes	Yes	Yes		2	* requirements passed Dec 2006 – take affect with graduating class of 2014
OK	3	Yes	*	*		1	*Alg I and “2 higher-level units”
OR	3					5	
PA	*					4	*PA allows school districts to determine which courses are required for graduation from high school.
RI	4*						*4 th course can be “math-related” (computer science, physics, accounting)
SC	4*	Yes	*	*	*	1	*Only College-Prep requirements listed by SREB. The 4 units are listed as “Algebra I and above.”
SD	3 Standard 3 Advanced* 4 Distinguished	Yes Yes Yes	No Yes Yes	No Yes Yes	No No Yes	4	These requirements go into effect with the graduating class of 2010. All students must complete Advanced or Distinguished Level unless specifically excused by signed consent with parent and school counselor.
TN	3	Yes	Yes-UP	Yes-UP		1	Two diplomas: University Prep (UP) and Tech Prep (TP). Starting with students graduating in 2009 all will be required to complete at least one course from Algebra II, geometry, Integrated Math II, or technical geometry.
TX	3	Yes	Yes	Yes*	Yes* Starting with 9 th grade class entering in fall 2007	1	*3 diplomas: Minimum(M), Recommended (R), and Distinguished(D). All require Alg I and Geom. Students graduating in 2008 and beyond must complete the R or D curriculum. Currently R and D require Alg I, Alg II and geometry – and will require a fourth unit of math for ninth graders entering in fall 2007
UT	2 presently 3 starting with graduating class of 2011	*	**			4	*Elem Alg or Applied Math I ** Geom or Applied Math II or other course beyond these courses

State	# of Math Courses	Alg I	Geometry	Alg II	Additional Courses	Source#	Notes
VT	3					5	
VA	3 Standard 4 Advanced Studies	Yes	Yes	Yes		1	
WA	4					5	WA had legislation pending in March when State Department of Education was consulted.
WV	3 presently 4 starting with graduating class of 2010	Yes	*	*		1	* Algebra I and one "higher course"
WI	2					4	
WY	3					4	

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2. Amos, Denise Smith (2006, Dec.). "Ohio toughens high school: Today's 5th-graders face Core standards." *The Cincinnati Inquirer* <http://news.enquirer.com/apps/pbcs.dll/article?AID=/20061221/NEWS0102/612210351>
3. Achieve, Inc. (2007) *Raise High School Graduation Requirements* <http://www.achieve.org/node/332>
4. Direct communication from ASSM member or representative of the Department of Education within the state. Listed below are e-mail addresses from these people or from those who corroborated other sources of information for their state
5. Reys, B.J., Dingman, S., Nevels, N., Teuscher, D. (April, 2007) *High School Mathematics: State-Level Curriculum Standards and Graduation Requirements*, Center for the Study of Mathematics Curriculum, An NSF Center for Learning and Teaching. <http://mathcurriculumcenter.org> [Note: This document reports on information gathered from State Department of Education websites, gathered September 1, 2006.]

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Appendix D

Dropping Out: Falling Even Further Behind

According to the Bill and Melinda Gates Foundation (2006) and Barton (2005), approximately one-third of our students nationally do not graduate from high school. The Gates Foundation determined that although some dropouts had faced academic problems, the overwhelming majority possessed the potential to graduate. Many factors contribute to this dropout rate, including socioeconomic status, single parent homes, changing schools, and a lack of guidance; e.g., nationally there is only one counselor for every 500 students.

The cost of dropping out of school is great. In 2003, 3.5 million 16-to-25-year-olds did not have a high school diploma and were not enrolled in school. If all youth chose to complete schooling, the cost to the nation would be billions of dollars. However, those billions and more now are being spent in dealing with the economic and social costs of youth who have not completed school. Only 40% of dropouts aged 16 to 19 in that group are employed; under 60% of dropouts aged 20-25 are employed. While 39% of Hispanic dropouts and 43% of White dropouts aged 16 to 24 are unemployed, 65% of Black dropouts in that age group are unemployed. For those who are employed, the wage prospect is grim. The average earning power of male dropouts in constant 2002 dollars declined 32% between 1971 and 2002 (from \$35,087 to \$23,903); for female dropouts, the comparable decline was 14%, but the total wages were much smaller than for males (from \$19,888 to \$17,114). To put these wages in perspective, the report notes that the \$22,903 average salary of male dropouts in 2002 is about \$4,240 above the poverty threshold for a couple with two children; the \$17,114 average salary of female dropouts would barely keep a three-person household out of poverty.

Appendix E

Student Misconceptions

It is an empirical fact that students make errors in solving mathematical problems. Much research has been conducted over the past several decades on the nature of these errors. Faculty at institutions of higher education lament the lack of algebraic preparation of incoming students. Placement tests are given at many institutions and students who have had precalculus and even calculus at the high school level are often not successful on those tests. A review of the literature suggests that this frustration with the performance of incoming students is not a new phenomenon. For example, an article in the 1931 issue of *Mathematics News Letter* discusses the struggles of freshmen algebra students with signs (Murray, 1931). A 1949 article in *The American Mathematical Monthly* states that fewer than half the freshmen at a particular college were able to properly define *polynomial* or demonstrate an understanding of the difference between *factor* and *term* (Ogilvy, 1949). A 1970 article in *The Two-Year College Mathematics Journal* states that recent research indicates 80% of incoming junior college freshmen were “inadequately prepared for college algebra” (Wood, 1970, p.9). Many of these statements could be said about students entering college today. So, what are the common errors or misconceptions held by students as they make the transition from high school to college? What assumptions can be made about the nature of these errors or misconceptions? What resources are available to high school teachers and college faculty?

We will begin with an assumption about the nature of these errors and misconceptions. The constructivist perspective has led researchers to hypothesize that the majority of errors made by students in solving mathematical problems are systematic and the result of definite processes that are considered rational by the students who possess them. As such they can serve as sources of valuable insights into students’ difficulties. Misconceptions describe an internalization and associated meaning of a concept that is at variance with the accepted view. They are often resistant to instruction (Confrey, 1980; Geuther, 1986; Ginsburg, 1977; Matz, 1982).

Much has been written about the common errors and misconceptions held by students as they make the transition from high school to college. Matz (1982) in her development of a process model for analyzing high school algebra errors, was struck by the uniformity of both the correct and the incorrect answers given by high school students. She supports the view that errors are reasonable and the result of the student making inappropriate connections. Matz proposes that the problem solving process has two components: a set of base rules and a set of extrapolation techniques. The extrapolation techniques assist the individual in making the connections that allow him/her either to view an unfamiliar problem as a familiar one, or to revise a known rule so it is applicable to a new problem. Matz claims that errors commonly occur when either the student inappropriately uses a known rule in a new situation or incorrectly adapts the known rule to a new problem. The errors that result are viewed as rational because the techniques are valid, but the student processes a misguided belief as to when the techniques apply. Misconceptions might arise in a variety of situations when students over generalize and are not given the opportunity to investigate new situations (Evans, XXXX). For example, when exploring multiplication of two whole numbers, students learn that the result greater than either factor. This may lead to an overgeneralization (misconception) that multiplying any two numbers yields a result that is greater than the original numbers. Language can also lead to misconceptions and errors. As Evans points out in his paper on student misconceptions “teachers and students often indicate that $\frac{4}{8}$ ‘reduces’ to $\frac{1}{2}$. Reduces in an everyday context means to get smaller, but $\frac{4}{8} = \frac{1}{2}$ ” (Evans, XXXX, p.2). Regardless of the cause, research suggests that misconceptions have the potential to interfere with a student’s ability to learn new information, and misconceptions are very resilient.

Several researchers have developed error classification schemes or lists of common misconceptions that contain categories describing the errors that occur while students are completing a variety of mathematical tasks (Confrey & Lipton, 1985; Geuther, 1986; Newman, 1977; Orton, 1983; Radatz, 1979; Vinner, et. al., 1981). These schemes can be grouped by the content area investigated, e.g. arithmetic, algebra, calculus, by the age level of the subjects, e.g. elementary, college; or by the type of information reflected in the category

descriptions. In most cases the schemes are based on results from assessing a specific set of students and do not claim to be comprehensive. The value of the schemes is that they provide a way to describe a set of errors, as such they can serve as a focus for hypothesis generation and student questioning; a potential window into student thinking that can be used when designing curriculum and course expectations. What follows are several examples of such schemes or lists of misconceptions. Further information on these and others is provided in the resource/reference list at the end of this appendix.

Example 1: A list of 10 common misconceptions related to number, operations, and algebra (Evans, XXXX).

1. The sum of two non-zero numbers is greater than either addend.
2. Any number divided by itself equals one.
3. The product of two non-zero numbers is greater than either factor.
4. When dividing two numbers, the divisor is the smaller number.
5. The quotient when dividing two numbers is less than the dividend.
6. $(a + b) / b = a$
7. Two negatives make a positive.
8. $X^2 > X$
9. $\sqrt{X} < X$
10. $-X < 0$

Example 2: Research suggests that students may have the following understandings related to the concept of function (Ferrini-Mundy and Lauten, 1993; Geuther Graham, and Ferrini-Mundy, 1990; Swan, 1987)

1. The working definition of function held by most students is that a function is a rule or correspondence that can always be represented by a single symbolic formula.
2. Algebraic and graphical data for particular functions are viewed as independent.
3. Students interpret function in a point-by-point (local) way rather than globally.
4. There is an excessive adherence to linearity.
5. Many students have an iconic confusion, e.g. students interpret the graph of height versus time for a particular object to actually represent the path that the object travels.

Example 3: The following is a list of general categories and descriptions based on the analysis of a set of student written solutions and the use of student interviews to investigate hypotheses raised from this analysis. The categories describe the nature of the connections which result when a student relates any given problem to his/her prior knowledge and experience. The categories are not tied to any specific skill but apply in a wide variety of problem situations (Geuther, 1986). The specific errors/misconceptions mentioned above could be thought of as specific examples of these more general categories.

Wrong analogy type: Describes situations in which the student generalizes inappropriately from a previous content area or a previous example. A “student-invented algorithm” is the result. This algorithm is based on the student having changed a rule to fit a new situation. Typical of invented algorithms that occur are “the square root of a sum is equal to the sum of square roots” in algebra or “the derivative of a product is the product of the derivatives” in calculus. What is hypothesized to happen is that a student misinterprets or does not analyze how the algorithm works in a particular example and uses this misinterpretation to solve any problem that has a similar form.

Misidentification: Describes situations in which the student ignores the constraints imposed on an algorithm and applies the algorithm in an inappropriate situation. An inappropriate connection (identification) has been made between a problem and a procedure. The procedure applied is

appropriate only under certain conditions which the student has either forgotten or chosen to ignore. Typical constraints ignored include: this procedure is true for any non-zero integer or this procedure is true provided $f(x)$ does not equal zero.

Misinterpretation of symbols: Describes a situation in which the student gives a symbol a different meaning from the conventional one. For example, the student in a given problem situation treats the radical index as an exponent. (Note: The variety of notational schemes employed by students is often astounding.)

Many examples of common errors and misconceptions that first semester college students exhibit appear on the placement tests that are typically given to incoming students. For example, at the University of New Hampshire (UNH) a calculus placement test is administered to all incoming first year students who are majors in the College of Engineering and Physical Sciences (CEPS) and more recently to students who are majors in the College of Life Science and Agriculture (COLSA). The test is a 40-question (CEPS)/20-question (COLSA) multiple choice test that covers topics from algebra and precalculus such as algebraic fractions, functions, logarithms and their properties, and trigonometry (Please see <http://www.math.unh.edu/cgi-bin/generatePage.cgi?/math418/pl> for a description of the process and some practice questions). Similar placement tests are given to students at Plymouth State University (PSU) seeking to take calculus and to the general population of incoming students at Keene State College (KSC) and the New Hampshire Community and Technical Colleges (NHCTC). Results of the test given at UNH suggest that students have difficulty with a variety of algebraic and precalculus concepts similar to those mentioned in the schemes above. Research would suggest that these identified issues are not unique to UNH. Below is an example of several key results from the UNH placement test given to entering COLSA students in Summer 2006. (These preliminary results were compiled by Dr. Gertrud Kraut, Lecturer and Math 418 Coordinator, Department of Mathematics and Statistics, UNH, Durham NH. The test was administered to 359 incoming COLSA students). The results appear to be related to the common misconceptions described in the literature but without additional information it is difficult to determine a cause.

- 47% of the students could NOT correctly simplify: If $x \neq 0$, then $\frac{24x^2 + 6x}{6x} =$. The number one error (24.7% or 89 students) was incorrect division $\frac{24x^2 + 6x}{6x} = \frac{24x^2 + \cancel{6x}}{\cancel{6x}} = 24x^2$
- Only 39% could correctly answer the problem: Solve the equation: $t^2 = -2t + 3$. Almost half the students just took the square root of both sides of the equation obtaining $t^2 = -2t + 3 \Rightarrow t = \pm\sqrt{-2t + 3}$ or $t^2 = -2t + 3 \Rightarrow t = \sqrt{-2t + 3}$.
- Only 60% of the students could simplify this expression $\frac{E}{2r} + \frac{E}{7r} =$ and 29.5% of the students added the numerators and denominators to get $\frac{2E}{9r}$.

As noted in the beginning of this section, student errors and misconceptions and the low performance of entering students on mathematics placement tests is not a new phenomenon. In addition, there does not appear to be any “miracle cure” on the horizon. However, research would suggest that there are a variety of strategies that can be used to help students come to terms with the issues. Although the activities may vary, the major focus of the instruction in each case should be to develop activities in which the students have a

need to make their conceptual models explicit in order to construct more powerful, appropriate, and useful strategies or procedures. In most cases, such instruction will rely heavily on the student being engaged in some reflective thought about the concept or procedure under consideration. Swedosh and Clark (1997) suggest that Piaget's notion of "cognitive conflict" could be the focus of instruction. Gruenwald and Klymchuk (2002) suggest that having students find counterexamples to incorrect mathematical statements might be an effective strategy (Evans, XXXX). The success of any strategy would appear to rely on the teacher's understanding of the students' viewpoints and strategies. The first step is to be aware of the research that has been conducted on student understanding of particular mathematics concepts. In addition, it is important to collect multiple pieces of student evidence. Several researchers caution against basing an error or misconception classification scheme solely on the students' written responses. In particular, Radatz (1979) states that there tends to be a close interaction between causes; the same problem can produce different errors and the same error can originate from different problems. By examining only a student's written response, one is in danger of classifying an error into an inappropriate category that does not reflect the student's thinking. Interview-based methods might be helpful in this situation (Ginsburg et. al., 1983). The following is a list of resources and references that might be helpful to teachers and schools as they seek to identify student misconceptions and errors and implement related instructional practices.

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Appendix F: How does New Hampshire compare?

Item:	New Hampshire	National Average	Top State(s)
4 th grade math achievement – proficient or advanced (NAEP, 2005)	47%	35%	49%
4 th grade math achievement – proficient or advanced (NAEP, 1992)	26%	18%	28%
4 th grade math achievement – basic or above (NAEP, 2005)	89%	79%	91%
4 th grade math achievement – basic or above (NAEP, 1992)	74%	59%	76%
4 th grade math achievement – proficient or above (state test – NECAP, 2005)	65%		
8 th grade math achievement – proficient or advanced (NAEP, 2005)	35%	30%	43%
8 th grade math achievement – proficient or advanced (NAEP, 1992)	30%	23%	37%
8 th grade math achievement – basic or above (NAEP, 2005)	77%	69%	81%
8 th grade math achievement – basic or above (NAEP, 1992)	77%	61%	82%
8 th grade math achievement – proficient or above (state test – NECAP, 2005)	56%		
8 th graders taking algebra or above, 2005	32%	41%	56% *
8 th graders taking algebra or above, 1992	18%	19%	
11 th and 12 th graders taking AP exams (2004)	9%	12%	18% *
11 th and 12 th graders taking AP exams (1997)	6%	8%	
10 th grade math achievement – proficient or above (NECAP, 2005)	39%		
Freshman graduating on time with a Regular Diploma (2003)	79%	70%	85% *
High School Graduates Immediately Enrolling in College (2002)	56%	57%	65% *
High School Graduates Immediately Enrolling in College (1992)	56%	54%	
Freshmen returning for Sophomore year at four year colleges (Fall, 2001)	80%	74%	84% *
Freshmen returning for Sophomore year at four year colleges (Fall, 1988)	85%	75%	
Freshmen returning for Sophomore year at two year colleges (Fall, 2001)	63%	55%	61% *
Freshmen at four year colleges earning degree within six years (2004)	67%	56%	67% *

* - median average of top five states

Sources: Achieve Data Profile: New Hampshire (April, 2006) American Diploma Project Network, <http://www.achieve.org/files/Data%20Prfile%202006%20-%20New%20Hampshire.ppt>

National Association of Educational Progress, <http://nces.ed.gov/nationsreportcard/>
NAEP 1992 Mathematics Report Card for the Nation and the States, Ina V. S. Mullis and others.