ALIGNING STEM EDUCATION TO 21st CENTURY KNOWLEDGE AND SKILLS

The preceding section looked at the traditional metrics of measuring student achievement such as academic performance, graduation rates, and matriculation into college. According to the Partnership for 21st Century Schools, "Even if every student in the country satisfied traditional metrics, they still would remain woefully under-prepared for 21st Century success beyond high school."[147] As described in Chapter II, workers and citizens in the 21st Century need to be proficient in the traditional core subjects as well possess higher-level thinking skills, interpersonal skills, various meta-cognitive skills related to learning how to learn, employability skills, and technology skills.

Keeping Illinois competitive requires that high school and postsecondary instructional programs prepare students for 21st Century jobs.

Chapter VI examines the current alignment of curricula, state assessments, and secondary and postsecondary instruction to the 21st Century needs of business and industry in Illinois. An underlying assumption is that the updated core of 21st Century knowledge and skills for Illinois are similar to those identified by national projects such as the *American Diploma Project* and *Standards for Success*.

VI. STANDARDS, ASSESSMENT, AND INSTRUCTION

STANDARDS, ASSESSMENT, AND INSTRUCTION

State standards, instructional methods, and high school graduation requirements should reflect the 21st Century knowledge and skills students need to be ready for college and the workplace. Given this focus, this chapter examines

- *Illinois Learning Standards* and state assessments
- Instructional approaches to engage students
- Alignment of high school requirements to college and workplace readiness
- Alignment of STEM education to Illinois' economic development

The Illinois Learning Standards, including its "Applications of Learning" and the workforce and career competencies, represent the knowledge and skills needed by students in the 21st Century.

Illinois Learning Standards and State Assessments

The *Illinois Learning Standards*[148] provide the framework for K-12 education by outlining the essential knowledge and skills students need to learn. The state assessments measure the degree to which students are progressing in meeting the standards. Taken together, the state standards and assessments are seminal factors in determining the quality of pre-college STEM education in Illinois.

Seven learning areas are detailed in the Illinois standards: English language arts, mathematics, science, social science, physical development and health, fine arts, and foreign languages. For each area, specific standards are given for early elementary, late elementary, middle/junior high school, early high school, and late high school levels.

Illinois' standards are considered to be above average by several rating studies. *The State of State Science Standards 2005,*[149] produced by the Fordham Foundation, gave Illinois a rating of B, the same rating it received in 2000. Nineteen states received either an A or B rating in 2005. Fordham reviewers attributed the high grade to the more detailed expectations indicated by "Performance Indicators" created by the Illinois State Board of Education and Illinois teachers. To increase its rating, Illinois needs to improve the "science content and instructional approach" of the science standards.

The State of State Math Standards 2005[150] graded Illinois standards as a C, higher than the D received in 1998 and 2000. To put this grade in perspective, the U.S. average was a high D, and only 6 states received a rating of A or B. The Fordham grades of mathematics standards are based on controversial assumptions, as national debates on mathematics content continue.

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In addition to the student goals by level in school, each of the seven subject areas of the *Illinois Learning Standards* contains a section called "Applications for Learning," which describes how students should apply the knowledge and skills in solving problems, communicating, using technology, working on teams, and making connections with other learning areas. (See Appendix A for more information on the Applications for Learning.)

As described in Chapter II, these "Applications of Learning" are similar in approach to that expounded by the Partnership for 21st Century Schools; e.g., the integration of content areas, the application of knowledge and skills in new ways, and the importance placed on interpersonal skills and communication. In Illinois there are no specific student indicators for the "Applications of Learning," only general descriptions of the intended student outcomes for the subject area as a whole are given.

Are the standards aligned with workplace expectations? The Illinois standards development team recognized this need and included business and industry representatives on the group who drafted the standards. According to Harry Litchfield, co-chair of the standards project team and then an executive at Deere and Company, they were supportive of the process and product.[151] They were instrumental in drafting the appendix of the *Illinois Learning Standards* which aligns the learning standards in each content area to a list of workplace skills and career development competencies (Appendix A). This appendix has been used extensively by educators in career and technical education to raise the level of rigor in their courses.

There is a growing national consensus that the 21st Century basic core is different than the traditional core, as discussed in Chapter II. Since content from Algebra II is included on the PSAE, the Illinois mathematics standards may be close to the 21st Century basic core. Nevertheless, neither science nor mathematics standards have been analyzed for their relationship to 21st Century expectations exemplified in the work of the *American Diploma Project* and the AAU/Pew "Standards for Success."

Furthermore, rapid technological change and the blurring of the traditional disciplines require state-level processes to regularly critique and update the learning standards and assessments. For example, the *Illinois Survey of Critical Technologies* identified cutting-edge topics important for STEM education; e.g. artificial intelligence, alternative fuels, green technology, and fuel cells that cross traditional departmental lines.[152] According to an Illinois State Board of Education science consultant, "There are so many new and important areas of knowledge, but Illinois lacks a system for deciding when new concepts should be added and where to focus scarce training resources."[153]

Even when the standards are aligned to the 21st Century basic core, as they obviously are in high-performing districts, curricula based on the standards must be enacted; that is, classroom instruction must reflect the standards. Several Illinois schools have addressed the alignment of instruction to the Illinois standards as part of their Comprehensive School Reform projects,[154] their Mathematics and Science Partnership grants, or their

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school improvement planning. Currently, a pilot project is using the *Surveys of Enacted Curriculum*[155] to determine the usefulness of that tool in assessing the alignment of classroom instruction to the *Illinois Learning Standards* in mathematics, science, and career and technical education.

Because "what is tested" is often "what is taught," it is important to align state assessments with the most important knowledge and skills. The "Applications of Learning" and the list of workplace skills and career development competencies are not reflected in the state assessments except for the use of WorkKeys as part of the 11th grade assessment. Since state assessments are developed years in advance of actual administration, the critical technologies that will drive the Illinois economy for the future do not appear on the PSAE. If any of the "Applications of Learning" are to be assessed, local districts must take the initiative.

Instructional Approaches to Engage Students

Beyond alignment studies and the assessments that tend to direct instruction, practical applications of knowledge, such as those encouraged by the Applications of Learning, can help to engage students in learning science and mathematics. A common sense approach, perhaps, but one supported by research. In the last few decades, much has been learned on how we learn and the impact of different pedagogies on learning.[156] Unfortunately, it appears the research has not been widely implemented:

- The Bayer Survey of parents of under-represented students indicated that one of the challenges for their students is that science classes are boring or uninteresting (58% daughters, 51% sons).[157]
- The Gates foundation found 88% of high school dropouts have passing grades and many dropouts list "boredom" as the reason for leaving school.

In the past ten years, national studies focused on how to improve STEM education and have offered recommendations ranging from a total reorganization of the educational system to less comprehensive approaches such as changing how mathematics and science content is taught. Some, such as Bill Gates, have argued for a new concept of high school:

> When we looked at the millions of students our high schools are not preparing for higher education—we look at the damaging impact that has on their lives—we came to a painful conclusion: America's high schools are obsolete…By obsolete, I don't just mean that our high schools are broken, flawed, and under-funded—though a case could be made for every one of those points. By obsolete, I mean that our high schools—even when they're working exactly as designed—cannot teach our kids what they need to know today. Training the workforce of tomorrow with the high schools of today is like trying to teach kids about tomorrow's computers on a 50-year-old mainframe. It's the wrong tool for the times.[158]

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Although a full study of instructional alternatives is beyond the scope of this paper, several basic themes recur frequently in analyses of mathematics and science instruction at both school and college levels:

- Increased use of relevant, practical, application-based approaches
- Integration of content across disciplines from the early grades
- A focus on depth of learning and thinking as opposed to rote memorization

For example, college students have limited opportunities to participate in authentic situations they might encounter in the workplace. Experiential learning projects are most likely to be found in colleges of business, engineering, and health sciences; and in homeland security courses. These projects may include cross-functional teams with students from engineering, marketing, financial investment, and psychology working together on a real-world task to identify what consumers need and to develop and market a product using "consumer to market" strategies. This teamwork exercise differs from a group project of like majors who may know and process information similarly. The experiential approach allows the college major to understand his role in the larger picture of an organization, hone teamwork skills, apply the abstract knowledge acquired in the classroom, and develop an understanding of the need for an interdisciplinary perspective. Authentic, experiential learning projects are also being used in some middle schools and high schools.

At the school level, another approach is the integration of mathematics and science with a focus on critical thinking beginning in the early grades. Such an approach is hands-on and accommodating to a wider range of student abilities.[159] An integrated curriculum is being implemented in a small number of schools around the country.

A related instructional methodology is "problem-based learning." The Illinois Math and Science Academy and some of the Illinois teacher preparation programs train teachers and preservice teachers to use "problem-based learning," which emphasizes multi-disciplinary approaches to solving complex problems. They are part of national and international efforts to replace formulaic methods of teaching math and science with more engaging instructional activities.[160]

Research on high-scoring countries in international competitions shows that the instructional materials of these countries build deeper levels of understanding, whereas the pervasive U.S. approach is one more attuned to definitions and formulae.[161] The U.S. approach is to show students an example of a problem which represents the material to be covered in the standards and then have the student do multiple problems of the same type. A perusal of Japanese instructional materials shows a focus on applying concepts, where problems build on previous ones, and students are encouraged to solve unrehearsed, dissimilar problems.[162] Related research has shown that students given such challenging work in a highly varied curriculum are more successful on standardized tests than those who have undergone narrowly focused test prepping.[163]

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Perhaps the U.S. Department of Education Secretary's Summit on Science Education summarized the concerns with science education the best:[164]

- At all grade levels we try to teach too many disconnected concepts and less may be more.
- In current classrooms, many topics are covered superficially.
- There are too few student investigations of real and simulated systems.
- There is no systematic way to fundamentally change instructional practice in response to science advances.
- Science standards are a decade old and need to be revised to be based on a few core areas, incorporate current advances, and make better use of technology.
- Increase the number of qualified teachers for science and provide professional development, especially for those in urban and rural schools.
- Increase the use of better and more sophisticated online, simulation, and real-time data acquisition probeware.

In summary, *Illinois Learning Standards* present a traditional discipline-focused approach to student learning and the state assessments are aligned to these standards. Two sections of the standards—the "Applications of Learning" and an appendix on workplace skills and career competencies—provide a glimpse of the knowledge and skills needed by students in the 21st Century. At this time, the state assessments are not overtly aligned to these two sections of the standards, nor are there systematic processes in place to address new and emerging fields of study or to measure the alignment of classroom instruction to the standards.

Alignment of High School Requirements to College and Workplace Readiness

Several major national projects, such as the *American Diploma Project* and *High Schools That Work*, offer methods of improving high school education that promise to improve the level of STEM education performance. These projects are important, especially in light of data presented by the 2005 National Education Summit on High Schools: 40% of high school students say they are just going through motions and one-third did not try hard.[165]

On the other hand, no matter what the curricula is for high school or how rigorous the graduation requirements, if only slightly more than half of all 8th grade students are meeting the Illinois mathematics and science standards, they are not "high-school ready." For high schools, the challenges seem conflicting – how can they remediate nearly half of the students while trying to make the high school curriculum more rigorous and aligned to the expectations of postsecondary institutions and the workplace?

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The Illinois State Board of Education is convening a meeting in June 2006 intended to forge consensus that raising the quality of Illinois high schools should move to the front burner.[166] As part of the efforts to improve high schools, ISBE joined the *High Schools That Work* consortium several years ago. Twenty of Illinois' 668 high schools participate in this nationally-regarded program. The state also participates in nationally researched programs that bring engineering curriculum modules to middle schools and high schools. Multiple projects in Chicago support the Mayor's and Chicago Public Schools' efforts to improve high school, including the development and implementation of mathematics and science instructional support programs, the creation of smaller high schools, and other initiatives funded by the Bill & Melinda Gates Foundation.

Among national reports on high school reform and improving STEM education, a prominent agenda item is alignment of high school graduation, college admissions, and workplace expectations. As noted on the chart below, Illinois took a small step in that direction last year in increasing the graduation requirements, but our state's requirements are still well below University of Illinois admissions standards and recommendations of national groups such as the *American Diploma Project* and ACT.

Table 13 Comparison of Illinois Graduation Requirements to ACT and UIUC

Discipline	Illinois Graduation Requirements (2005 Legislation)[167]	University of Illinois Admission Requirements	ACT Recommendation[168]
English/ Writing	4 years, with at least 2 in writing intensive courses	4 years	4 years
Mathematics	3 years, including Algebra I and 1 year with a course that includes geometry content	3 – 3.5 years	3 or more years including Algebra I, Algebra II, Geometry and at least one other advanced course beyond Algebra II
Science	2 years	2 years laboratory	Biology, chemistry, physics
Social Sciences	2 years, one to be U.S. history or combination of U.S. history and American government	2 years	--
Electives	1 year, includes art, music, foreign language, or vocational education	2 years foreign language and 2 years fine arts	1-2 years of foreign language

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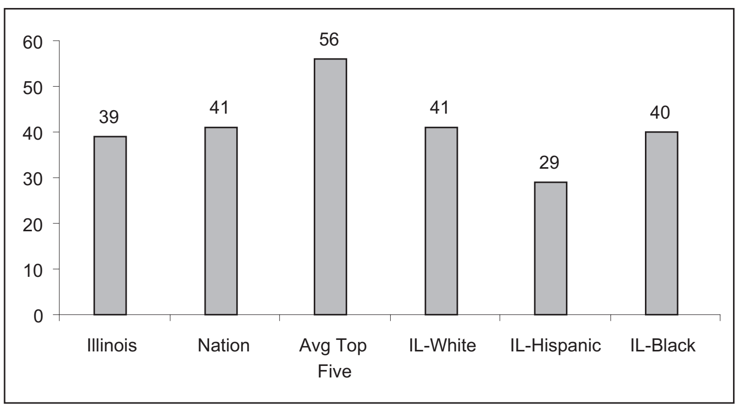
Debate over the numbers and titles of courses tends to obscure the most critical issue, which is the actual content of the courses. Unless courses are rigorous enough to enable students to meet the Learning Standards, the requirements are simply a game of numbers. The next section of this report looks at the controversy around courses for just one subject – mathematics.

To meet the mathematics requirements set forth by ACT, *American Diploma Project*, and others, some Illinois schools would need to reorganize mathematics curriculum so that students could complete Algebra I in middle school and find qualified teachers to teach higher levels of mathematics in high school.

There is increasing debate over the appropriate mathematics courses for all students to complete in high school. At the low end, Algebra I appears to be the mandatory gateway course. In 2005, 39% of the Illinois 8th graders took algebra, as compared to 41% nation-wide, and an average of 56% in the five top-performing states.

Figure 35 Percentages of Eighth Grade Students Taking Algebra in 2005[169]



Several research studies correlated college success with courses taken in high school and concluded that Algebra II is important to student success in college.[170 171 172 173] Other researchers and practitioners are questioning the usefulness of Algebra II for all students, especially if taught in traditional ways. A first point of contention is that the research that led to the recommendation only showed a relationship between students' success and taking Algebra II, and correlation does not mean causation. Other factors related to taking Algebra II could be playing a larger role in the students' success. In fact, research has found that just taking the mathematics courses does not automatically lead to college readiness, and the outcomes are much weaker for black and Hispanic students.[174] Other possible factors contributing to the increased white students' success could be that they have more rich, varied background experiences and higher quality teachers.

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A second point of contention is that "more of the same" of an old model is not the answer. Algebra II is the next step in the traditional sequence leading to calculus. Few occupations require a knowledge of calculus, but many do require other topics such as data analysis, statistics, discrete mathematics, and mathematical modeling. Some mathematics educators contend that rather than abstract mathematics, such as calculus, greater numbers of students need more applied mathematics such as statistics.[175]

In the same line of reasoning, there are advocates to less mathematical and more applied approaches to science, such as in Physics First. The traditional sequence of science courses is biology, chemistry, and physics. Physics First, as the name implies, would put physics in the high school curriculum first, because biology requires an understanding of chemistry which requires physics knowledge.[176] Advocates of Physics First say that the course content is simpler than biology and can be learned by younger students. Opponents of alternative science models usually prefer the traditional, calculus-based, college prep curriculum now expected by higher education. The pervasiveness of the 19th and 20th Century college prep programs is evident in both the American Diploma Project and ACT's new core.

As the debate continues between the traditional and pedagogical newer models and content, it will be important to ensure that graduation requirements meet the expectations of postsecondary institutions. For Illinois, aligning the state standards to college expectations is difficult because each institution of higher education has its own unique requirements, placement testing, and criteria for remediation. Other states such as "California, Kentucky, and Oklahoma have established 'remediation-free' standards to clarify what incoming students need to know to place into credit-bearing courses,…[and] Oregon has identified the level of knowledge and skills needed for college entry and aligned this with the state's high school standards."[177]

Illinois has some under-utilized mechanisms in place which could help with the alignment of high school, community college, and university standards. Public colleges and universities provide feedback reports to high schools on the success of students who matriculated to their institutions from the high school. Universities provide similar feedback information to community colleges. The Illinois Public Community College Act describes a college-ready background for students but it is not universally implemented. Perhaps a coordinated P-20 approach to improving high schools (and mathematics and science also) would initiate conversations between institutions that would put available tools to work.

In summary, Illinois raised high school graduation requirements in 2005, but not to a level expected by the state's own public universities. High school reform faces a dual challenge of trying to remediate students while increasing the rigor of instruction. Further work is needed to ensure the level of rigor truly matches the expectations of colleges and the workplace.

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Alignment of STEM Education to Illinois' Economic Development

Chapter I pointed out some potential areas of concern for Illinois: the decline in the middle class, the need to create higher paying jobs, and a projected shortage of skilled workers in the future. If these predictions hold true, it will be important for the educational institutions to work closely with the business sector to create the skilled workforce needed for Illinois' economic vitality. Currently, according to Illinois Community College Board standards, all public community college career and technical programs are required to have advisory councils. Many other programs in community colleges and universities have such committees, but there is little evidence to show the extent to which advisors influence curriculum content. Influence seems most likely in professional training and programs such as business, technology, engineering, and health sciences.

There are many indications that the alignment of educational expectations and business needs could be stronger. In *Closing the Expectations Gap 2006,* Illinois was reported as one of fifteen states that has not aligned high school requirements to college and workforce standards and has no current plans in place to do so.[178] Only five states had completed the alignment process with the remaining states in progress.

Nearly one-third of the currently unemployed Illinois workers for whom their educational level is known, had some postsecondary education.[179] In addition, increasing numbers of college graduates are under employed. Earning a postsecondary degree or certificate does not automatically lead to employment. Increasing numbers of graduates are finding that there is an over supply of potential workers with credentials similar to theirs or that the certificates or degrees they completed do not align with what employers are seeking.

Illinois is actively pursuing ways to alleviate the shortages in the healthcare workforce; however, bolstering the middle class may need more alignment of education and industry, especially for the skilled trades, manufacturing, engineering, and emerging technologies.

The challenge for Illinois, as for every state, is to align programs of study to result in

- Students completing with the skills needed by current business and industry
- Sufficient numbers of graduates to fill critical shortages
- Skilled workers to support the economic development initiatives of the state

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Nationally, there has been a renewed interest in career and technical education programs and more internship and work-study programs:

> The key to our nation's success won't come from channeling an indiscriminate mass of students along one track toward college, especially when we lose 30 percent of them along the way. It will come by combining demanding academics with other educational opportunities, and by creating a class of high school graduates who leave with skills to succeed both in a technical job and in the realm of higher education. It will come by graduating classes of students who have something invested in their own success, and who arrive in the world with a vision and the know-how to achieve it." [180]

State leaders in Kentucky believe that rigorous career/technical courses—ones that integrate academic skills and industry-developed end-of-program exams—have improved the academic achievement of students. Since the courses were redesigned, Kentucky's career and technical students have improved more than other students on the state accountability test.[181] Some states, following the Kentucky pattern, maintain multiple tracks, some headed for the workplace, some headed toward high education, and some preparing for both. Other states are attempting to integrate more career and technical education into traditional academic coursework. Regardless of the instructional approach, all students must complete a rigorous curriculum.

Whether students enter the workplace from high school or from postsecondary education, their individual instructional programs should be closely tied to the theoretical and practical knowledge and skills needed to be successful in the workforce. Emphasis on real world applications of curriculum content does not diminish the critical importance of mastery of core academic subjects. This is not about "dumbing down" traditional curriculum, as has been charged by the critics of Physics First. It does suggest a need for reevaluating curriculum content and establishing a balance appropriate for our times.

Chapter Summary

Keeping Illinois competitive requires the learning standards and graduation requirements to be aligned with the needs of the economic infrastructure of the state. Even though the traditional aspects of the *Illinois Learning Standards* have received above average national ratings, the "Applications of Learning" sections of the standards, which reflect the additional 21st Century skills and knowledge, and the alignment of the standards to workplace expectations are not assessed at the state level. Little is known about the extent to which the Applications are implemented in the classrooms. In fact, assessment of the Applications at the local level may be more appropriate and more practical.

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National research on instructional practices advocates a rethinking of the traditional U.S. organization and delivery of instruction. The major focus at this time is on redesigning high schools to be more engaging for students; to use more authentic, problem-solving and hands-on approaches; and to be aligned with the expectations of postsecondary education and the workplace. Illinois has made some headway in addressing the high school problems, most notably with the Chicago initiatives and through isolated projects receiving Comprehensive School Reform grants and *High Schools That Work*.

For all levels of education, research indicates that cross-disciplinary approaches focused on deep levels of understanding and the opportunity to solve new problems result in higher levels of student academic performance. There are isolated projects across Illinois implementing this type of approach.

Illinois has several underutilized mechanisms in place that could be useful in aligning the standards and instructional programming across high school and postsecondary education and to the needs of business and industry. The current high school graduation requirements, which are comparatively low and are focused on "seat time" not alignment with standards, need to be the subject of ongoing discussion.

The success of graduation standards is necessarily tied to the ways in which instructional programming is structured. Nationally, there is a renewed interest in career and technical education as a way to provide multiple pathways for students to achieve the same rigorous preparation for postsecondary education and the workplace. At the college level, increased emphasis is being placed on ensuring the instructional programs provide students with practical, applied knowledge and skills as well as theoretical knowledge. These approaches require collaborative relationships among education, economic development, and business and industry professionals.

No matter what the curricula is for high school or how rigorous the graduation requirements, if only slightly more than half of all 8th grade students are meeting the Illinois mathematics and science standards, they are not "high-school ready."

CHAPTER VII

Essential elements of support include making parents aware of the need for their children to succeed in mathematics and science, providing qualified educators, providing financial aid to support promising students, and creating a rich environment for research activities.

RESOURCES FOR STEM EDUCATION

Keeping Illinois competitive requires that there is support for STEM education within the state. Essential elements of support include making parents aware of the need for their children to succeed in mathematics and science, providing qualified educators, providing financial aid to support promising students, and creating a rich environment for research activities.

This chapter includes sections on

- Student and parent awareness of the need for STEM education
- Preparation and professional development of educators
- Support for innovative research and development

Student and Parent Awareness of the Need for STEM Education

To increase student achievement in all grades, parents and students need to value strong mathematics and science skills. Research indicates there is a need for greater awareness of the importance of STEM Education:

- On a *Bayer Facts of Science Survey* in 2003, nearly 90% of the general public felt the low international mathematics and science ratings of the U.S. students could negatively affect the U.S. security and economy.[182] On the other hand, *Reality Check 2006: Are American Parents and Students Ready for More Math and Science* reported that 57% of the parents say the amount of current mathematics and science their child studies is about right.[183]
- A national survey of parents concluded that even though attitudes and interest in mathematics—particularly among minority students—have increased, "half of all students still plan to take mathematics only as long as they are required to do so."[184]
- In a national survey, nearly two-thirds of the college students and over three-fourths of the non-college students surveyed reported they would have worked harder and taken more rigorous courses in high school if they knew then what they know now.[185]
- The *Bayer Facts of Science Survey XI - 2005* asked parents of under-represented students about their children and science and engineering. Over 95% of the parents are confident that their children have the ability to succeed in science and engineering careers and see these careers valuable for their child. At the same time, 88% of the parents indicated that the science and engineering communities need to do a better job of telling today's students about these job opportunities and providing role models or mentors for their children (56% daughters, 45% sons).[186]

RESOURCES FOR STEM EDUCATION

- An ACT study found that over 90% of all surveyed students indicated that their mother or other female guardian was helpful in selecting their high school courses, whereas tenth-grade students reported that about 70% of their counselors were helpful.[187]
- Success in STEM college programs is related to the courses completed in high school,[188] which in turn is highly related to courses taken in middlle school.

Whether students are relying more on their mothers or their guidance counselors, data supplied by ACT makes clear that students are not choosing enough of the rigorous courses that will help them succeed in college and the workplace.[189] Instead, far too many of them are enrolling in middle school and high school courses that will lead them to years of remediation at the community college and/or university.

No comprehensive data was found on how well Illinois is meeting the challenge of providing accurate and timely career planning information to parents and students in elementary, middle, and high schools, as well as postsecondary institutions. However, the Illinois Department of Employment Security provides a comprehensive one-stop information center for workforce and career education at http://www.ilworkinfo.com/.

Preparation and Professional Development of Educators

In the 2005 debate over raising high school graduation requirements, local education leaders protested that qualified teachers were simply not available for more advanced science and mathematics courses. Research has supported their contention, placing the supply of qualified teachers as a central challenge for upgrading STEM education.

Illinois has a multiple-assessment qualification process for teachers: a passing performance on the *Basic Skills Test* before entrance into a teacher education program, a passing performance on *Content Tests,* and a passing performance on the *Assessment of Professional Teaching (APT),* an assessment of general knowledge of the teaching profession and pedagogical methodologies. In addition, Illinois has three-tiered licensing: initial, standard, and master, with specific requirements for advancing in level and remaining current in licensure. According to the *Illinois Teacher Salary Study 2003-2004,* the median schedules salary was $53,820, ranking the state 8th in the nation and 1st in the Midwest.[190]

That said, Illinois teachers for mathematics and science are consistently listed as critical shortages. In 2005, 225 school districts reported shortages of physics and chemistry teachers, up 8% and 9% respectively.[191] The future need for STEM teachers may be great: about 30% of the math and science teachers for grades 9-12 are over the age of 50.[192]

Illinois high school teachers of science and mathematics are required either to major in their subjects or take 24 academic credits in the subject and pass a test of content knowledge.

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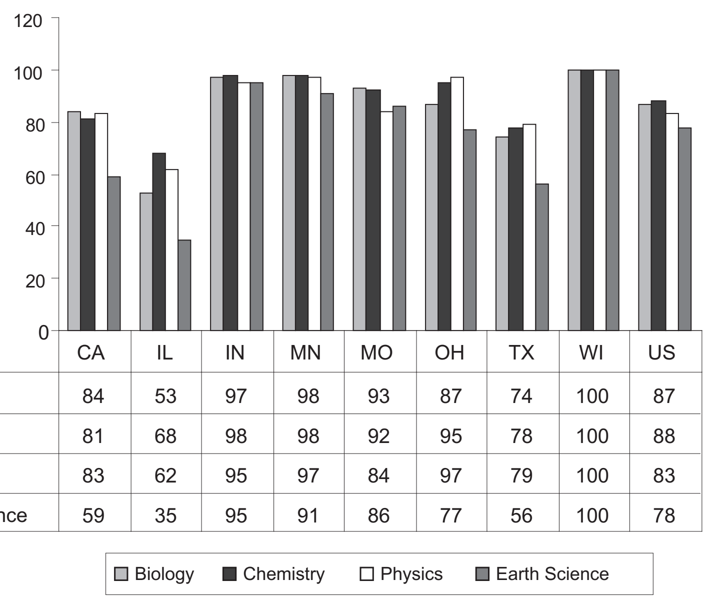
Currently, slightly more than 50% of 8th grade mathematics teachers in Illinois are certified to teach mathematics, compared to 61% nationally.[193] An additional 26% of Illinois 8th grade mathematics teachers hold an elementary certificate, and nearly one-fourth hold neither an elementary nor mathematics certificate. This means that significant numbers of 8th grade students are being taught by teachers who do not hold the proper certification. The same is true for high school; compared to the U.S. averages and other large industrial states and neighboring state, fewer high school science teachers are certified in the high school subjects they teach. In fact, one-third of chemistry teachers, two-fifths of physics teachers, about one-half of biology teachers, and nearly three-fourths of earth science teachers do not hold the proper certifications to teach in their content area.

Figure 36 Percentages of *High School Science Teachers Certified in the Subject in Grades 9-12, 2004*[194]



	CA	IL	IN	MN	MO	OH	TX	WI	US
Biology	84	53	97	98	93	87	74	100	87
Chemistry	81	68	98	98	92	95	78	100	88
Physics	83	62	95	97	84	97	79	100	83
Earth Science	59	35	95	91	86	77	56	100	78

A 2004 *Bayer Facts of Science Survey* pointed out a national problem with the preparation of teachers: only 18% of the K-5 teachers with three to five years experience graded their science preparation as an "A". When asked which subject they wished had been emphasized more in their pre-service training, nearly two-thirds of the teachers cited science. The deans of colleges of education (84%) and the teachers (72%) agreed that elementary preservice teachers should be required to take more coursework in science and science teaching methods. Over one-third of the teachers indicated that they use their knowledge of science more from what they learned in high school than in what they learned in college to teach science. Nearly 95% of the K-5 teachers reported teaching reading and mathematics everyday; only 35% teach science everyday, and 29% teach it two or fewer days a week [195]

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Illinois has taken steps to improve the quality of mathematics and science teachers. New Associates of Arts in Teaching (AAT) in science and mathematics have been approved for Illinois community colleges for the purpose of increasing the numbers and quality of mathematics and science teachers. Various scholarships and tuition waiver programs are available for those pursuing an education major.[196]

Ongoing professional development for the existing cohort of teachers adds another challenge. The *Illinois Survey of Critical Technologies* identified the barriers current teachers face in trying to complete professional development in cutting-edge mathematics and science topics. Illinois needs to find ways to overcome the barriers of lack of time, financial resources, and professional development opportunities.

Support for Innovative Research and Development and STEM Education

Keeping Illinois competitive requires innovative research and development and a highly-skilled STEM workforce. A couple of examples will suffice as a reminder of the competition in this environment. "Of 120 *new* chemical plants being build around the world with price tags of $1 billion or more, one is in the U.S. Fifty are in China."[197] Also "in 2003 only three American companies ranked among the top ten recipients of patents granted by the U.S. Patent Office."[198]

Developing innovations that will succeed in the global economy requires significant resources for the recruitment and retention of the best STEM workforce and for innovative research. The following section assesses Illinois' capacity for innovation in terms of

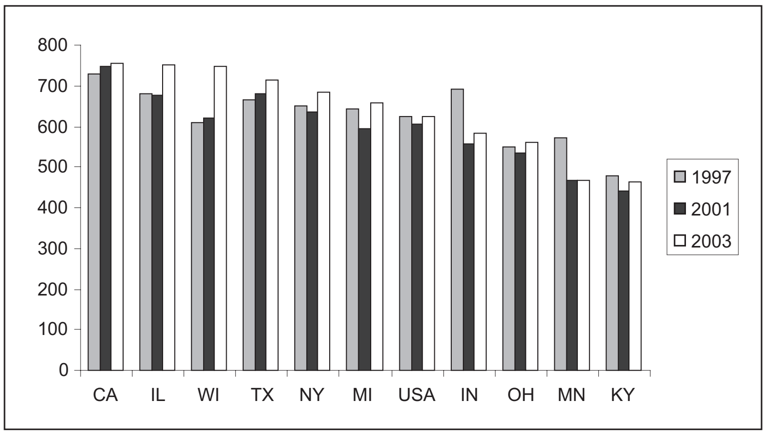
- Scholarly articles and patents
- Financial support for STEM students and STEM education
- Investment in research and development

CHAPTER VII

Scholarly Articles and Patents

Historically, institutions of higher education have provided a cadre of STEM researchers. The number of articles written is a traditional academic measure of research. As shown below, Illinois is one of the higher volume publishing states in terms of the number of academic articles per science and engineering doctorate.

Figure 37 Academic Article Output per 1,000 Science and Engineering Doctorate Holders in Academia 1997-2003[199]



In addition, academic institutions play major roles in the innovative endeavors to create new products, processes, services, and programs. The number of academic patents relative to 1,000 science and engineering doctorate holders provides a measure of the degree to which results with economic value are generated by the doctoral academic workforce. From 1997 to 2003, the number of academic patents per 1,000 academic doctorate holders

- increased from 10.5 to 13.0 in the United States
- Increased from 7.7 to 10.5 in Illinois

Compared to other states, Illinois fell into the second quartile. The highest patent rates was 27.5 for California. Other states with rates greater than 15 include Alabama, Florida, Iowa, Maryland, Massachusetts, New York, and North Carolina.[200]

When the patent rate is defined as the number of patents awarded per 1,000 individuals in science and engineering occupations, Illinois is slightly below average (18.8, compared to U.S. rate of 19.9).

RESOURCES FOR STEM EDUCATION

Financial Support for STEM Students and STEM Education

Financial aid is often a deciding factor for whether a student will enroll in postsecondary education. The costs of higher education can be prohibitive, especially for low-income and middle-income students. In addition, students may shy away from "high cost" degrees, such as those in engineering and science which have large laboratory costs.

The amount of financial support from state grants which goes directly to undergraduate students varies widely by state. Some states subsidize tuition at the state level for all students; other states provide student aid directly to students. From 1995 to 2002, Illinois increased the state expenditure per full time undergraduate student from $1,040 to $1,447, a direct student funding level surpassed only by Georgia.[201] The most recent 2007 budget for higher education increased MAP (financial aid) funding $34.4 million or about 10%. Illinois public universities were cut in 2003 and again in 2004 and remained flat through 2006. During this period, universities increased tuition and fees to meet increasing enrollments and expenses. The 2007 budget has a 2% increase for public universities.

The Illinois Student Assistance Commission offers three programs for prospective teachers:

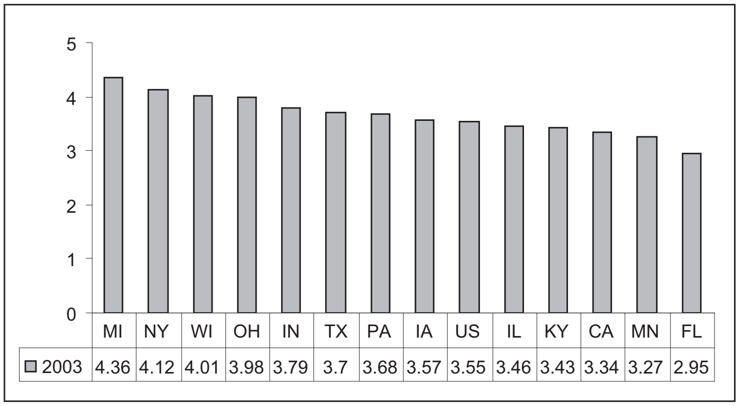
- Illinois Future Teacher Corps (IFTC) for those committing to teach in hard-to-staff schools or in critical shortage disciplines
- Minority Teachers of Illinois (MTI) for minority students wishing to teach in schools with 30% or more minority populations
- Illinois Special Education Teacher Tuition Waiver (SISTTW) for students in 4-year Illinois public universities studying to be a special education teacher

Other financial assistance programs available to education majors include the Golden Apple Scholars of Illinois, Federal Perkins Loan Cancellation for Teachers, Stafford Loan Cancellation for Teachers, and the Illinois Teacher Loan Repayment Program (see www.collegezone.com for more information).

Another measure of the priority placed on education is the percentage of the state's wealth expended on education. Based on data from the U.S. Department of Education, the *Science and Engineering Indicators 2006* computed the state expenditures as a share of the gross domestic product. From 1994 to 2003, the national average for spending on elementary and secondary education increased from 3.37% to 3.55%. In Illinois, the percentage increased from 2.93% in 1994 to 3.46% in 2003.[202]

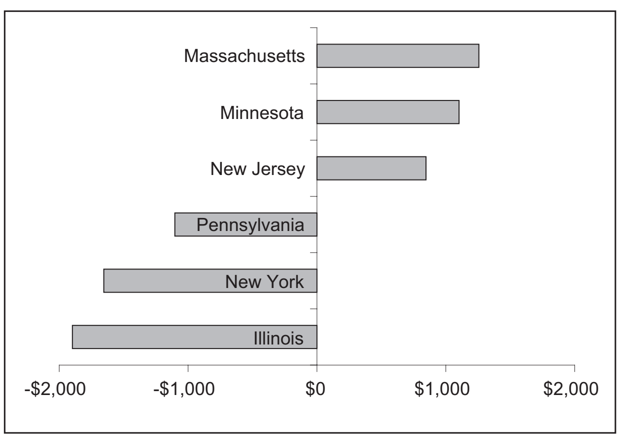
CHAPTER VII

Figure 38 Elementary and Secondary Public School Expenditures as Share of Gross State Product: 2003



Another measure of educational expenditures is the gap in expenditure per student between the highest and lowest poverty districts. The average revenues per student were compared for the 25% of schools with the highest low-income students and the 25% of schools with the lowest percentages of low-income students. Illinois has a nearly $2,000 gap, one of the largest in the U.S. Other states expend more resources on high-poverty districts. The Illinois expenditure gap mirrors the achievement gap of low-income students and the fact that wealthier districts use local property taxes as a source of increased revenue.

Figure 39 Absolute Dollar Gaps in Expenditure Per Student for Highest and Lowest Poverty Districts



RESOURCES FOR STEM EDUCATION

The appropriations of state tax funds for higher education operating expenses in Illinois increased 10.1% from 1990 to 2005. During the same period, the aggregate funding for states in the Midwest increased 8.7% and national funding for higher education increased 19.2%. The decline in the manufacturing industry was particularly severe in the Midwest, taking a toll on tax revenues.

Investment in Research and Development

Research and development activities (R & D) are necessary to support a strong STEM infrastructure. Globally, the top five countries with R & D as a percentage of the gross domestic product are Israel, Sweden, Finland, Japan, and Iceland. The U.S. leads in per capita spending on information and communication technology, followed by Switzerland, Denmark, Sweden, and Norway. The top producers of innovations in genetically modified crops are the U.S., Argentina, Canada, Brazil, and China.[203]

The ratio of the amount of academic spending relative to the gross state product is a measure used in the *Science and Engineering Indicators 2006*. The U.S. average ratio of academic R & D spending to $1,000 GSP increased from 3.01 in 1993 to 3.60 in 2003, and in Illinois, the ratio increased from 2.45 to 3.23 during the same period. [204]

From 1998 to 2002, the U.S. average percent of the gross state product attributed to R & D remained stable (2.48%, 2.46% respectively). Similar conclusions can be made for Illinois, with the percentage of the gross state product attributed to R & D going from 2.14% to 2.10%. Over 3.5% of the gross state product was attributed to R & D in states such as California, Massachusetts, Michigan, New Mexico, Rhode Island, and Washington.[205]

Another measure of R & D funding is the amount of federal R & D obligations per civilian worker in a state. From 1992 to 2002, federal R & D obligations rose from $64 billion to $84 billion. The per civilian expenditure in the U.S. increased from $536 to $612. In Illinois, the per civilian rate increased $166 to $284. As pointed out in the *Science and Engineering Indicators 2006,* federal R & D obligations varied greatly. For instance, some sparsely populated states host national laboratories, and a number of R & D institutes surround the District of Columbia.[206]

The federal Small Business Innovation Research (SBIR) program supports companies with 500 or fewer employees with awards for planning and commercialization. *Science and Engineering Indicators 2006* examined the three-year total of SBIR awards relative to $1 million in the gross state product. For 2001 to 2003, the U.S. ratio of SBIR to $1 million gross state product was 141, compared to Illinois' ratio of 43. States with the highest rankings tended to have federal laboratories or well-recognized academic research institutions from which small businesses have emerged.[207]

CHAPTER VII

Private industry is another source of R & D funding. From 1998 to 2003, private industry funding increased from $164 billion to $198 billion, an increase of 21% unadjusted for inflation. The percentage of R & D conducted by industry in the private sector decreased in the United States from 2.14% to 2.06% in 1998 to 2003. In Illinois, the percentage of industry-performed R & D increased from 1.90% in 1998 to 2.00% in 2000 but decreased to 0.85% in 2003.[208]

The expansion and emergence of companies can also be funded via venture capital. In 2003, the ratio of venture capital expansion to the gross state product was 0.76 in Illinois compared to the national average of 1.73. California and Massachusetts received the majority of the total venture capital dispersed in the U.S. in 2003.

Lastly, the amount of resources expended in ongoing training of employees is essential to the currency of workers' knowledge and skills. Increasing the educational level of employees by approximately one year can result in a 12.7% increase in productivity in the non-manufacturing sector.[209]

RESOURCES FOR STEM EDUCATION

Chapter Summary

Keeping Illinois competitive requires that resources be provided for STEM education. In addition to funding, other resources include staffing of the schools with qualified teachers and providing the most current instructional approaches and information to parents and students.

One of the greater challenges for Illinois is the need to increase the mathematics and science skills of all students, and this requires students in middle and junior high school to select more rigorous courses. Nationally, the role of the guidance counselor has become that of a career specialist, even in the elementary grades.

The quality of education provided is directly related to the qualifications of teachers in the classroom. Since Illinois ranks far below other states in the percentages of mathematics and science teachers who have the appropriate teaching credentials, the quality of STEM educators needs attention. Several steps have been taken. Illinois implemented the A.A.S. degree in community colleges to try to increase the number of mathematics and science teachers. Some school districts report success in their partnerships with universities to provide alternative certification programs for technically-proficient career changers. Illinois offers scholarships for students preparing to teach in areas where it is difficult to place teachers. Several states offer scholarships for students preparing for careers in STEM education and STEM professions, a mechanism supported by several of the national STEM reports.

In terms of fiscal resources, Illinois appeared average in the federal and state aggregate expenditures on education. However, the state has one of the largest gaps between student expenditures in the lowest- and the highest-poverty districts. Because of the large discrepancy among states in the amount of federal research funding, it is difficult to compare Illinois to other states. In the past few years, Illinois has received additional federal funds for R & D activities.

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