1. Introduction

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"Strategic Alliance to Advance Technological Education through Enhanced Mathematics, Science, Technology, and English Education at the Secondary Level" was designed to motivate and prepare students for technical careers requiring a solid foundation in secondary mathematics, sciences, technology, and English (MSTE). We were especially concerned to reach out to nonmajority students and young women. The initiative involved a collaborative partnership between the Rockford Public Schools (RPS) in Illinois, Rock Valley College (RVC), and Northern Illinois University (NIU). The project began as an alliance of the Rockford Public School District, Northern Illinois University, and 300 local business, industry, and community (BIC) organizations. Rock Valley College, a community college, became a partner after the pilot years.

Objectives

"Strategic Alliance" had eight objectives:

1. Provide in-service education, training, and technical assistance to secondary teachers.
2. Provide in-service education to district school administrators and counselors on change, reform leadership, and strategic planning, as well as exposure to the teacher development program.
3. Partner with local BIC organizations to provide teachers (and ultimately students) with exposure to the real world of MSTE problems and applications, authentic contexts, careers requiring MSTE foundations, and information about higher-education pathways and MSTE requirements to realize career access.
4. Evaluate all project activities, monitor progress, and determine the merit and broader impact of the initiative.
5. Produce a systemic reform model for improving MSTE education at the secondary level through business, industry, educational, and community partnerships.
6. Develop teacher knowledge and skills in the use of computer technology for teaching and learning.
7. Develop teacher and counselor knowledge and skills in strategies to assist students to develop postsecondary educational and career plans.
8. Develop a plan for long-term sustainability and continuous improvement.

Participants included all middle and high school teachers in the Rockford Public Schools who taught mathematics, the sciences, technology, and English. The results of a concurrent regional initiative pilot are also mentioned in this review.

Rationale

The initiative addressed fundamental issues of workforce preparation raised by various researchers on the basis of numerous national indicators, such as the Science and Engineering (S&E) Indicators (National Science Board, 2002). These indicators suggest that the U.S. workforce needs more people with appropriate degrees as retirements increase. Figures noting the high percentages of foreign-born science and engineering degree-holders – a result of little or no growth in domestic Ph.D. production – provide an incentive to increase the number of students following through to higher degrees in S&E.

The National Science Foundation (NSF) provides much evidence of learning gaps, which can be closed only by establishing stronger mathematics and science (MS) preparation at all levels of education. For example, at the secondary level, females score more than one year higher in reading, but boys continue to score higher in mathematics and science by approximately one year's difference. The gaps among whites, African Americans, and Hispanics remain significant and widen between entering school and high school. African Americans learn less in high school than whites and Hispanics.

Furthermore, although NSF data reveal that mathematics scores have increased and some progress is being made toward achievement of the National Council for Teaching Mathematics (NCTM) standards, few students scored as proficient or advanced, and more than 30% scored below the basic level. Again, boys outscored girls, and whites and Asians outscored African Americans, Native Americans, and Hispanics. The 1996 Third International Mathematics Science Study (TIMSS) study (Johnson, 1998) revealed that U.S. students score lower than those from other nations in mathematics at the eighth-grade level. For science, the U.S. students score lower at the fourth-grade level. And finally, students in the United States seem to decrease in mathematics and science competence as they progress to the secondary level.

Concerns remain about the lack of focus and depth of MS coursework. Standards and assessments have been implemented by most states, which now often require more courses for graduation, and there seems to be an indication that more students are enrolling in more courses (National Education Commission on Time and Learning, 1994). Females have course-taking patterns similar to males, with some differences (e.g., less likely to take physics), and their achievement is similar. However, the percentage of females is lower in the science, technology, engineering, and mathematics (STEM) pipeline. Nonmajority students also take more advanced courses, although African Americans and Hispanics lag behind whites and Asians. Lower socioeconomic students are more likely to be assigned to lower-level curricula, even though their ability may be the same.

There is insufficient evidence to determine if increased course requirements, quality of courses, standards, and assessments have improved student learning. Some studies suggest that requiring more courses has resulted in more failures, especially for non-majority students. Additionally, opinions differ about course quality, especially for lower-achieving students; some feel the courses lack integrity (National Science Board, 2002).

There is also the question of whether the state standards and assessments are closely linked. Do the measures have integrity? Or do they focus too much on facts rather than complex inquiry? Are the standards too vague to provide guidance? There is clearly a need for "a fully developed standards-based system that links quality standards to tests, curriculum, and accountability measures," given that tests are often based upon weak standards or not directly aligned with standards (National Science Board, 2002, pp. 1-29). Additionally, the curriculum is not adequate, and beyond that, tests for promotion are not always aligned with standards.

Enrollment in higher education for S&E degrees is also an issue of focus by the National Science Board (2002). In 1997, Johnson reported that by seventh grade, only 11% of a pool of 7 million students will express an interest in MS or technical fields, dropping to 5% by college age. Also in 1997, Hendley reported that 50% of all college freshmen, and even higher proportions of women and minorities, begin their college careers at community colleges, untapped sources of student recruits for technical degrees at the bachelor's level. Therefore, universities, especially those offering bachelor's degrees, should articulate more closely and work together to move students into bachelor's programs.

To tie that to the improvement of teaching, Wenglinski (2000) identifies the overwhelming importance of teacher development in student achievement in science, technology, engineering, mathematics, and English (STEME), the foundations for S&E. He found achievement to be higher when teachers receive professional development in different disciplines (107% ahead of grade level), higher-order skills (40% ahead of grade level), lab skills (44% ahead of grade level), and classroom management (37% ahead of grade level). When students are exposed to hands-on learning weekly rather than monthly, they are 72% ahead of grade level in mathematics and 40% ahead in science. When frequently exposed to critical thinking, they are 39% ahead of grade level in mathematics, and when exposed to ongoing, authentic assessment, they achieve ahead of those less frequently exposed to point-in-time tests.

Overall, Wenglinksi reveals the importance of teacher development on teaching and learning strategies, student achievement, and success in mathematics and science. Lynch (2000) reports on common denominators across outstanding high schools, including high standards, rigorous core curriculum, authentic assessment, and work-based learning – all foci of the work reported here.

The failure to take teacher development seriously is closely linked to professionalism (Bracey, 1997; Stigler, 2001). Good teaching matters. Students who have good teachers make dramatic gains (Traiman, 2000). Research indicates that one of the most important factors for student achievement is the teacher's disciplinary expertise (Darling-Hammond, 2000). Strong verbal and mathematical skills are essential for teaching lower-performing students. Ambach (2000), Chase (2000), and Feldman (2000) advocate the need to increase funding for effective professional development, employ a peer evaluation process, and professionalize the teaching and learning environment. Houston (2000) suggests that a university-school partnership can improve teaching and learning in schools. Bryant (2000) comments that these types of programs need to be increased, enhanced, and held to high standards. Langenberg (2000) praises the reform movements occurring through school, university, and industry partnerships, stressing that student learning improves when more attention is paid to the teacher's professional development.

Dozier (2000) supports results-driven professional development and rigorous evaluation of its effectiveness. Thurston (1999) reports that direct and deliberate leadership support is needed to ensure the success of collaborative teaching and that teachers have the same planning times and appropriate professional development and visibility of results. Adams and Hamm

(1990) and Lord (1994) find 12 distinct benefits to cooperative learning among students, ranging from improved achievement to increased empathy and student retention. Wenglinski (2000) adds that applying concepts in context increases critical thinking and improves mathematics performance. Basili and Sanford (1991) and Watson (1991) demonstrate the benefits of collaborative learning in specific disciplines, while Pedersen and Digby (1995) provide the necessary theory behind the success of cooperative learning.

Content and Pedagogical Strategies

"Strategic Alliance" also addressed important content and pedagogical issues that remain centers of debate among educators. The National Science Board (2002) reports there is still a debate over "drill and practice," conceptual understanding, and skill application as instructional practices. Whole-group instruction and a reliance on worksheets are still common, although most teachers do report using small-group instruction. (In my experience with secondary education, small-group instruction needs to be more formally structured, and teachers need to learn how to plan, lead, direct, and assess learning through small-group activities.) NSF also reports, based on the TIMSS study, that using the more engaging techniques advocated by NCTM is somewhat superficial (pp.1-30), and data about the success of these approaches is still thin.

The standards movement has resulted in a new vision for the teaching of mathematics (and science), but there seems to be little action. Schmidt, McKnight, and Raizen (1997) suggest that the U.S. approach covers more topics than international counterparts; teachers typically complete one topic before beginning another and deepen the study of the topic at each more advanced grade level. U.S. educators use a "spiral" approach, elaborating and extending topics over time, resulting in redundancy and limiting depth. The goals, in the United States, are to: (a) increase the depth of concepts and principles at each level; (b) expand and further explore careers and educational paths at each level; (c) increase field experiences at each level, extending their content, purpose and depth; and (d) engage teachers and students in changing the visions and goals for themselves at each level, modifying their portfolios as they grow and change.

Although science curricula have improved, textbooks still have inadequate depth and development of topics, challenging expectations, repetition, and new information (Flanders, 1987). This perspective is reinforced in a 1999 study by the American Association for the Advancement of Science (AAAS). Science literacy is also poorly addressed or achieved, often reducing the concept to "technical terms."

"Strategic Alliance" provides a multilevel approach for progressive teacher growth, each level reinforcing and extending the previous one. We offered many opportunities to perform through observed pilots in the classroom, using a strong and closed-loop feedback system to learn from what occurred, and then a networking model to share across teachers, groups, and schools. Our teachers were more likely to understand the learning theory underlying the teaching standards; our improvements were more likely to persist beyond the grant period. Teachers became comfortable using technology as a learning and teaching tool.

Previous Research and Development in Illinois

"Strategic Alliance" was built on more than a decade of research and development in northern Illinois. Our effort was a "culminating" initiative and was designed and developed based upon several complex projects, many of whose models, practices, strategies, techniques, and processes were either adopted or extended by us. They enabled us to provide yet another layer of possibilities in the process of working with schools to improve mathematics, science, technology (MST), and ultimately to include English (E) education at the secondary level in Illinois (MSTE).

Many of these projects anticipated trends in professional development, in that they provided integrated, interdisciplinary, multileveled programs that followed teachers into the classrooms to pilot. They were also strong in feedback, met individual and district needs, and usually provided the teachers with technology and other tools required for professional development. Interdisciplinary since 1983, they always included mathematics, sciences (especially physics), and a variety of technology or vocational disciplines, usually including chemistry and English (since 1994), and recently geology and environmental science. We worked with each discipline as individual knowledge taxonomy and also as a vehicle for learning or applying the other disciplines or interdisciplinary concepts and principles; thus each participating discipline had two purposes for being included.

It is helpful to understand the line of progression, for in working with educational reform or improvement, clearly there is an evolution of models and strategies, and of contexts across which those models and strategies become useful. Our study, it is hoped, will enlighten others about that progression as well as the models, strategies, results, and outcomes.

Our work began with a major statewide initiative (1984-1988), which had eight schools develop, design, and pilot new technological curricula across areas of importance at the time (e.g., computer-aided drafting, healthcare, electronics). An additional initiative included the area of manufacturing technology. The products and models developed were an attempt to provide articulated Illinois secondary schools and community colleges with well-developed, industry-validated, and MSTE-based curriculum products that could be easily adapted or directly adopted. The strategies for development involved secondary teachers with community college, university, and industry experts. Schools then field-tested the curricula and revised them based upon the results; the state published the materials for dissemination. There has rarely, if ever, been such an in-depth and widespread attempt at dissemination and staff development in Illinois, possibly in the nation.

Once the curriculum products were revised (based upon the pilot data) and published, there were approximately two years where staff development occurred regionally statewide. Project teams delivered workshops throughout Illinois on seven new curricula. All staff development involved participants using new technology and software in conjunction with the new curricula.

The results were positive for three reasons: the curriculum was validated by industry and endorsed by the state; it was delivered through hands-on activities with the new technology and software (with purchasing information accessible for administrators); and the participants' response was favorable because the workshops brought them not only the published curricula products but also the technical experts who developed the software and applications, industrial representatives, and the vendors through which it could be purchased. The curricula were generic in the technology and software requirements, an attempt to make them time-future in nature rather than quickly dated. This occurred through special funding, legislated as Education for

Technology Employment (ETE); the manufacturing technology (MT) projects were funded through the Illinois State Board of Education.

There were no “student learning standards” at the time nor any focus on integrated interdisciplinary curriculum. The curriculum products were a first attempt to lead MSTE teams into an analysis that went beyond the technological content and desired requirements to identify and align the inherent MSTE content and then build the curriculum in such a way as to acknowledge and include it. As with “Strategic Alliance,” these efforts acknowledged the importance of the MSE content alongside the T content if students were to become technologically and scientifically literate, equally capable in their MSE knowledge and skills, and move on to higher education (especially into technical programs requiring higher levels of MS) and then to technical careers.

Articulation and industrial partnerships were also critical components of that first initiative. The curriculum products were either grades 11-12 and aligned with 13-14, or were directly 11-14 in content and application. Industrial partnerships were critical in the curriculum-content identification, validation, and dissemination aspects. Those developing the products were brought to campus or a central site for the intense curriculum development aspect, and then validation occurred. Development and field testing occurred statewide, data were reviewed and revisions made, documents were published, and dissemination was taken statewide. The ETE project focused on six technical areas, and the follow-up project added MT from a systems perspective.

These products, probably still useful because they are generic, are still available through the Illinois Office of Education Services at 800-252-4822.

In continuing our work, the next project, PHYS-MA-TECH (1989-1992), was a direct result of the ETE and MT projects and focused on the development of an integrated mathematics, physics, and technology curriculum using somewhat different models. Its curriculum and research results are still viable today and discussed at length in Chapter 32. From that point forward to the Rockford project (1992-1995), a variety of smaller activities occurred with small and rural regional schools. Those results, although not included here, did confirm the positive directions of the PHYS-MA-TECH project. The MSTE teaching teams came from a wide variety of districts and schools. For four years, teacher teams from small and rural schools came to campus for three or four weeks during the summer, developed their educational products and processes, and then returned to pilot them the following school year.

Some of the foci mentioned below were inherent in the PHYS-MA-TECH initiative, but the most recent projects made a more in-depth and aggressive attempt to engage teachers in complex changes beyond the integrated curriculum, team teaching, and interdisciplinary instructional delivery. They focused equally on teaching models, additional delivery strategies, metacognitive processes and skills, learning styles, multiple intelligences, and more formal performance-based assessment. Simultaneously (1992-1997), the Chicago Public Schools (CPS) participated in a wide variety of staff development activities focused primarily on the improvement of mathematics and science education linked with vocational education. From those activities, a more formal, five-year initiative grew through federal Perkins grants for Chicago.

The collaboration with 36 Chicago public schools concentrated on broadly improving MSTE education, with special emphasis on 21 of the schools. Evaluation of the work accomplished in the first year of the Perkins-funded initiatives showed good efforts but great gaps between goals and accomplishments. Using that as a needs assessment, we analyzed what was required to move the schools forward to accomplish the Perkins goals and worked with central administration to design, deliver, and pilot a staff development program for approximately 150-200 teachers in MSTE teaching teams for each of five years.

The accomplishments of those teams, in spite of a strike, late school-year start, massive retirements and teacher transition across schools, and administrative changes were quite remarkable. A great deal was accomplished and documented through in-depth evaluation reports. The 21 evaluations included pretest and posttest results of student achievement; qualitative student and teacher data; and interview data from each school's local school council, industry advisory boards, administrative personnel and counselors, teachers and students, and school portfolios. After that first year, the portfolios improved greatly. Once the "new" staff development program was put into place, goals were more clearly established and expectations became more focused.

A broad and deep evaluation included many data types. Significant positive indicators suggested that integrated curricula, interdisciplinary teaching teams, block scheduling, and teaching and learning strategies could increase urban and underprivileged student learning of MSTE and actually improve school attendance. However, administrative transitions prevented the possibility of collecting a second data set, nor was publication possible.

There were some unique and successful staff development and evaluation models designed for working with such a large group of teachers in a complex district at a time when there was change each and every year. It was a privilege to work with the CPS teachers; they were a dedicated, respectful, and engaging group who truly wanted to improve teaching and learning.

The Rockford Project

When PHYS-MA-TECH ended, as well as our work in Chicago, we had a desire to continue our work in a complex urban community with similar issues. The PI contacted the Rockford Public Schools (RPS). Rockford's approximately 27,000 K-12 public school students are representative of the nation: inner-city, urban, suburban, and rural students with roughly 42% nonmajority (approximately 29% African American, 10% Hispanic, and 3% Asian). Few enroll in MS classes beyond those required for graduation. Only 14% of the eligible pool continue into higher-level courses, decreasing the number even more. Our goal was to improve MS success rates and increase the rate of enrollment into higher level MS courses for all students, especially for young women and other under-represented groups. In a politically charged district, at times this was a challenge. However, we believe that our responsibility is to partner with districts in need to help rebuild trust and improve education.

Concurrent with the NSF-funded initiative, "Strategic Alliance," two regional projects comprised of teams from regional districts were also ongoing. One round of their pilots is reported here.

Importance of Long-Term Effort

It takes many initiatives and much dedicated effort to accomplish educational improvements of any kind in a complex scenario across very different educational entities. Further, the best change occurs when the effort happens through true partnerships. It is a primary responsibility and mission of higher education to initiate and help lead change in K-12 districts, since that is where the research and practice take place. The combination of theoretical experts with experts in practice can engender phenomenal results.

Social science or experimental studies in schools are very complex contexts for controlled studies. There are many limitations, extraneous variables, and contextual issues with which to contend. Human and organizational characteristics make them challenging to accomplish, yet also much more interesting, necessary, and rewarding. It is very unlike setting up experiments in more easily controlled laboratories. This is not meant to dismiss our work as lacking value, but merely to acknowledge its limitations.

It is important to note that with many of the initiatives, there was an agreement not to publish any results other than those aspects required by funding agencies. This was a trust issue; therefore, much less was published than should have been. However, we attempt here to present the context, chronology, and general perspective. That does not directly address the need for empirical evidence for evaluation purposes. However, the mixture of what can now be published with the "confirmation" of positive implications over the span of 23 years may have meaning, if only to confirm the need for more tightly controlled empirical studies.

Some of the most important outcomes of the work discussed here lie in teacher renewal, changed attitudes, revived enthusiasm, sharpened vision, rededication to mission, and more. While acknowledging the great need for empirical results, we must also give adequate attention to the more qualitative. Developing practices based upon significant research would clearly tell the educational world that it must better attend to building relationships and partnerships, renew energy and dedication, add breadth and depth of disciplinary and interdisciplinary knowledge and skills, and build more friendly learning and teaching environments.

Therefore, we would encourage those who would find and identify faults, limitations, or missing elements in the research and development presented here as opportunities to further the work with greater controls. Identifying what needs to be done beyond the work presented here and following through to accomplish that work would be a reward for my colleagues and me.

Organization of This Report

This report on "Strategic Alliance" has three main sections that present the initiative's basic principles and goals, the methods to accomplish the goals, program leaders' perspectives, research methods and results, and reflections about the external evaluation.

Part I. Overview. After an introductory chapter that describes the nature and aims of the project and provides background and context, Chapter 2, *Learning – What Does It Mean?*, defines our goals and strategies. Chapter 3, *Partners in Change*, establishes the leadership foundation for our work with the schools; the next chapter, *Organizational Learnings*, offers reflections from the perspective of leadership strategies, techniques, processes, and outcomes. Chapter 5, *Operating Philosophy and Project Strategies*, along with the succeeding chapters, *Operational Models* and *Program Scope, Content, and Sequence*, complete the foundational discussion and establish the framework and belief system for the project. Finally, Chapter 8, *Challenges and Lessons Learned*, describes the major difficulties and offers lessons learned for the benefit of those who may want to replicate all or part of what we did.

Part II. Program. The first six chapters describe core elements of the program, such as articulation (Chapter 9), interdisciplinary teaching (Chapter10), interdisciplinary curriculum (Chapter 11), and student performance assessment (Chapter 12), teaching models (Chapter 13), and instructional technology (Chapter 14). Then chapters 15-30, written mainly by program leaders, focus on discipline-specific program elements, covering content, strategies, outcomes, opinions about experiences, and in some cases recommendations for replication. Three chapters focus on elements of the program that were multi- and interdisciplinary in nature and represent a fusion of content and delivery. Chapter 31 describes the roles and importance of counselors.

Part III. Research and Evaluation. Chapter 32 presents the original basis for the research in this project, revealing the results of the PHYS-MA-TECH study. Chapter 33 reviews the results of the Rockford classroom pilots, presents the methodology, and discusses the research limitations. In Chapter 34, the external evaluator discusses evaluative aspects, accomplishments, and outcomes. Finally, Chapter 35 presents what the teachers had to say.

The full report, including research data and evaluations, is accessible at www.strategicalliance.niu.edu.

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