ESTABLISHING PURPOSEFUL K-12, COLLEGIATE, & INDUSTRIAL EDUCATIONAL PARTNERSHIPS IN MATH, SCIENCE, AND TECHNOLOGY

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Abstract

The challenge of an education befitting a technologically knowledgeable workforce involves two fundamental components. It involves the preparedness of students implying a suitable education and the preparedness of the teacher. In order for teachers to keep pace with knowledge and skills akin to a technological age, they need resources for their students and themselves in the form of professional development. Therefore, this study sought to develop a needs assessment tool to acquire data to more effectively facilitate educational partnerships between K-12 and higher education systems, and engineering or technology-based businesses or industries.

This research project involved developing and electronically administering two surveys —one for a sample of K-12 teachers in Iowa and one for a sample of technologically based business and industry in Iowa. The survey for teachers consisted of a self-assessment of content knowledge and utilization of best practices, and a composite of desirable partnership activities related to science, math, and technology. A second survey inventoried business/industry K-12 educational partnership activities and participation. The survey asked business/industry to identify their participation in various partnering activities and their view of the level of importance and effectiveness of those activities, as well as the resulting value that those partnering activities might have for their business/industry.

Scores for partnering activities deemed "important" by teachers had similar correlations to the same list of activities for business/industry suggesting that it is the 'right time' to develop partnering relationships. However, participation in partnering activities was low. Barriers to educational partnering were explored and recommendations for further study are included.

Introduction

In today's economic climate, it is easy to lose sight of the fact that a knowledge economy is especially dependent on, and thus vulnerable to, deficiencies in the talents and knowledge of the available workforce. The last decade alone has seen unprecedented and unanticipated changes in the nature of work itself in fields such as information technology and biotechnology as noted in *Technically Speaking* (National Academy of Engineering & National Research Council, 2002). To ensure that the workforce of tomorrow possesses the necessary competencies and knowledge, educators must train workers to succeed in jobs that are not yet imagined.

In a technological era where education, employment, and economics are intertwined, it is increasingly apparent that a partnership approach to public school reform has appeal (MacDowell, 1989). Business and education partnerships can benefit while improving the intellectual power of the nation. This advancement in educational experiences should be evidenced in higher student achievement and improved workforce awareness and productivity.

Public education nationally, is viewed as a powerful mechanism to enhance knowledge and improve the status of math and science-related skills. Ballen, Casey, & de Kanter (1998) in *The Corporate Imperative: Results and Benefits of Business Involvement in Education* argue that students should complete their K-12 educational experience possessing high levels of knowledge and skills in the areas of math, science and technology to compete in, and contribute to, a technological world. *Technically Speaking* (National Academy of Engineering & National Research Council, 2002), *Land of Plenty – Diversity as America's competitive edge in science, engineering, and technology,* (Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology, 2001), and, *The Long View* (National Science Foundation, 2000) also strongly advocate this claim. With adequate math, science, and technical skills, young people will not only be able to seek postsecondary education in technical fields but also successfully complete postsecondary programs and readily move into high-tech employment ranks.

Significant Reports and Policy Developments

Five major reports provide an insight to the conditions, which have influenced the current status of math, science, and technology education in our educational systems and the concept of educational partnerships. They are:

- *A Nation at Risk* (National Commission on Excellence in Education, 1983);
- *Before It's Too Late* (U.S. Department of Education, 2000);
- *National Science Education Standards* (National Academy of Science, 1996); and
- *The Condition of Education 2002* (National Center for Education Statistics, 2000).

A Nation at Risk

Beginning in the late 1800s, businesses and schools have collaborated, with these relationships becoming formalized into modern day "partnerships," a term introduced in the late 1970s (Lankard, 1995). However, a landmark study, entitled *A Nation at Risk* (National Commission on Excellence in Education, 1983), accelerated the development of these partnerships. The Commission noted that school curricula no longer challenged student achievement, that learning levels were declining, that standards and diploma requirements were too low, and that, in general, students were not devoting the necessary time and effort to their studies. The true importance of the report, however, was its urgent communication to all segments of U.S. society that failure to remedy these educational deficiencies might threaten the very roots of the nation's prosperity and freedom.

As a result, groups such as the Committee for Economic Development (CED), the National

Alliance for Business (NAB), and the Business Roundtable (BRT) published reports that became guiding principles for business involvement in education. This involvement caused businesses to feel a need to become involved resulting in the number of business/education partnerships raising from 42,200 to 140,800 from 1983-84 to 1987-88 (Grobe & Others, 1993).

Before It's Too Late

Specific to this project, a federally commissioned report entitled *Before It's Too Late* (U.S. Department of Education, 2000), more commonly known as the "Glenn Report," described the technological preparedness of tomorrow's workforce. The report predicted that the non-competitiveness of our young people in the math and science disciplines (U.S. Department of Education, 1999) will negatively impact the United States' ability to produce products and services required of a high-tech society. The commission's message is strong. Attention must be given to the education of our young people, particularly in the sciences and mathematics—"mathematics and science will [also] supply the core forms of knowledge that the next generation of innovators, producers and workers in every country will need if they are to solve the unforeseen problems and dream the dreams that will define America's future" (U.S. Department of Education, 2000, p. 4).

The Commission urges immediate action in addressing the inherent problems with our current mathematics and science education instruction. All three goals outlined in the report relate directly to the utility of this project. The goals are directed at professional development initiatives, and include:

- The establishment of a sustainable system to improve the quality of mathematics and science teaching,
- Increasing significantly the number of mathematics and science teachers and improving their training and,
- Creating an attractive work environment where teachers are supported and compensated for their commitment and participation in the essential and on-going professional development experiences (U.S. Department of Education, 2000, p. 9).

Further, action strategies to accomplish the professional training include: each state undertaking a needs assessment to determine what the teachers require, summer institutes to address the needs identified, establishing inquiry groups, leadership training, internet resources, and establishing district and business partnerships to support the necessary endeavors (U.S. Department of Education, 2000).

National Science Education Standards

In the early 1990s, science educators, scientists, administrators, and business-people came together and created what we know today as the National Science Education Standards. The intent of the *Standards* was to re-work science literacy principles and practices so they mirrored the evolution of a technological, rather than an industrial society. The underlying principles that come from this collaborative initiative were that:

- Science is for all.

- Learning science is an active process.
- School science reflects the intellectual and cultural traditions that characterize the practice of contemporary science.
- Improving science is part of a systemic education reform. (National Academy of Sciences, 1996).

It should be noted that three of four of these teaching standards would relate to various aspects of the K-12 educational partnership survey soon to be introduced.

Ultimately, the *Standards* were developed to guide change in science education. The changes within the science education system are included in *National Science Education Standards* (National Research Council, 1996). Changes include more emphasis on the following:

- Understanding and responding to individual student's interests, strengths, experiences, and needs;
- Selecting and adapting curriculum;
- Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes;
- Guiding students in active and extended scientific inquiry;
- Providing opportunities for scientific discussion and debate among students;
- Continuously assessing student understanding;
- Sharing responsibility for learning with students;
- Supporting a classroom community with cooperation, shared responsibility, and respect; and
- Working with other teachers to enhance the science program (National Research Council, 1996).

Again, these emphases appear in the surveys. It is believed that the existence of educational partnerships can be one of the catalysts, which advance the ideals outlined in the science education standards.

Condition of Education 2002 – The Federal Report

Student characteristics must also be considered in reform initiatives. Data in The *Condition of Education 2002* (National Center for Education Statistics, 2000) provides such information. The reports included in the *Condition of Education 2002* (National Center for Education Statistics, 2000) suggest a declining interest in school between 1983-2000 (as cited in University of Michigan, Institute for Social Research, 2000). Some relevant data points included in this report includes:

- In 1982, 35% of high school seniors said most of their courses were "quite or very interesting" compared to 21% in 2000. Similarly, 32% of the seniors in 2000 said their courses were "very or slightly dull," compared with 20% in 1983. However, no significant difference existed when replying to "often or always try to do their best work," with the differences ranging from 61-65% (National Center for Education Statistics, 2000, p. 72).
- Mathematics performance scores of U.S. students increased in the 90's for 4th and 8th grades; 12th grade scores increased from 1990-96, but declined between 1996-2000. The decline was reported to be associated with opportunities to "study challenging material and the degree to which students took advantage of these opportunities" (National Center

for Education Statistics, 2002, p. 57).

- Trends in science and mathematics course taking were positive with the percentage of high school graduates completing advanced coursework in mathematics and science increasing between 1982 and 1998. Females were more likely to have completed an advanced science and mathematics courses when compared to their male counterparts (National Center for Education Statistics, 2002, pg. 86).

Best Practices in Math, Science, and Technology

Much attention has been directed at the development and implementation of Best Practices in teaching math, science, and technology. The National Science Foundation has funded numerous research projects and educational initiatives. Additionally, over the past 15 years new standards for mathematics and science education have been published. Major reports from the National Council on of Teachers of Mathematics (NCTM); *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989); *Professional Standards for Teaching Mathematics* (NCTM, 1991), *Assessment Standards for School Mathematics* (NCTM, 1995); *Mathwise: Teaching Mathematical Thinking and Problems Solving* (Hyde & Hyde, 1991); *Science for All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology* (AAAS, 1989); *Benchmarks for Science Literacy* (AAAS, 1993); and *National Science Education Standards* (National Academy Press, 1996) provide a thorough description and foundation for best practice when implementing the new standards for teaching and learning.

The similarities in the standards and best practices for math and science are worth noting. Both recognize that math and science education are for everyone and require a variety of learning approaches. Both disciplines acknowledge the importance of discovery, real-world application, and group work [inquiry groups]. Common teaching approaches involve problem solving through the utilization of manipulatives (for example, blocks for younger children or currency for older youth); cooperative groups for experimentation, discussion, and critical thinking; and lab work—science and math applications in real-world, student-world situations (National Academy Press, 1997). Teaching pedagogy, which provided the foundation for this type of instruction is known as inquiry-based science and experiential learning or the application of constructivist theory.

Inquiry-Based Science

With inquiry-based/centered science approach, the real world is brought into the classroom and the lives of students (National Academy Press, 1997). The *National Science Education Standards* (1996) defines inquiry as conducting activities such as making observations; posing questions; examining sources of information; planning investigations; reviewing what is known based on experiential evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results" (p. 8). An example of inquiry-based science of math would be a lab exercise testing a variety of bubble gums for optimal bubble production and durability. Does the presence of sugar play a role? Is there a correlation between gum mass and bubble production? Does one variety of gum last longer than the others?

Experience is the key factor in inquiry-based science and can be a challenge for teachers. Further, because today's young people have less contact with the natural and technological world, and with information multiplying at the current rate, the need for the involvement of other professionals (partners in education) in the teaching process is necessary and critical (National Academy Press, 1997).

Constructivist Theory or Experiential Learning

Research dating back to Jean Piaget, a Swiss Psychologist, asserts that children learn best when the learning makes sense to them. Constructivists also believe learning is a social process and learners construct knowledge for themselves (Cummings, 2001). This type of learning is an active process and involves topics or concepts grounded in a context that students find relevant and engaging (Association for Women in Science, 2001). Further, concrete experiences and examples that industrial partners bring into the classroom are typically familiar and, therefore, rich with meaning. Consequently, this familiarity enables a young person to then comprehend, apply, analyze, synthesize, and evaluate more easily because the examples are real world, and therefore, typically carry greater meaning.

These stages of learning and the application of knowledge utilized to communicate understanding of concepts are often referred to as Bloom's Taxonomy (Anderson, & Krathwohl, 2001). For example, best practice in mathematics and science today not only includes the definition of energy but also an ability to predict consequences of misplaced energy, demonstrate some positive application, combine energy with other forces of physics and judge the quality of the outcome. These learning experiences can be accomplished through the utilization of manipulatives, guided student inquiry through groups, or real-world applications. Potentially, educational partners could bring to the classroom—via technology or in person—a product they produce, a hairdryer [manipulative] for example, and describe the mechanics, research, and development of the dryer and perhaps other common situations where energy or physics exist.

Technology in Instruction

It should be noted that the utilization of technology in the application of mathematics and science teaching practices and learning approaches, as well as in other disciplines, has progressed at an expediential rate. In a report in *Education Statistics Quarterly* (2001) entitled "Teachers Tools for the 21st Century: A Report on Teacher's of Technology," the Fast Response Survey System (FRSS), NCES, and National Assessment of Educational Progress (NAEP), and Current Population Survey (CPS), provide a picture of the uses of technology in the classroom:

- Approximately half of the public school teachers who had computers or the Internet used them for classroom instruction. Teachers used these technologies for word processing and creating spreadsheets, Internet research, practicing drills, and solving problems and analyzing data, in addition to preparatory and administrative tasks.
- Teachers used the computer and Internet to gather information for planning lessons and creating instructional materials.
- Teachers' preparation and training to use education technology was a key factor when examining the use of computers and Internet for instructional purposes. This training was

acquired via independent learning, professional development activities, and their colleagues.

Characteristics such as equipment, time, technical assistance, and leadership may act as either barriers to, or facilitators of, technology use (Smerdon, Cronen, Lanahan, Anderson, Iannotti, and Angeles, 2001).

Educational Partnering Trends

Educational partnering trends are still emerging. Partnerships like Adopt a School have evolved into more complex relationships and broad-based coalitions addressing such integral concerns as curriculum change and school restructuring. The Committee on Technological Literacy (National Academy of Engineering & National Research Council, 2002) reports in *Technically Speaking* that there is an increasing realization of mutual dependency that has strengthened partnering relationships and promoted innovative approaches such as model schools. There are continuing efforts between industry and K-12 education toward the development of workplace programs. Although measuring the results of these efforts is often haphazard, workplace partnerships continue across this nation.

Continued involvement between public education stakeholder groups can reflect business strategies that build organizational effectiveness. Future partnering will require greater efforts and more innovative thinking. It will require that companies move beyond "feel-good" partnerships with individual schools to systems-level partnerships where business expertise can help meet K-12 needs. This new partnering paradigm will require leadership at both the industry and K-12 level that requires considerable cooperation and understanding among groups that may not always agree on goals or methods (Jackson & Davis, 2000).

The Project – Inquiry and Objectives

The project focused on increasing the flow of technically skilled workers through enhanced strategic educational partnerships in the state of Iowa. It involved developing and electronically administering two surveys—one for K-12 teachers in Iowa and one for technologically based business and industry in Iowa. The survey for teachers consisted of a self-assessment of content knowledge and utilization of best practices, and a composite of desirable partnership activities related to science, math, and technology. A second survey inventoried business/industry K-12 educational partnership activities and participation. This survey asked business/industry to identify their participation in various partnering activities, their view of the level of importance and effectiveness of those activities, as well as the resulting value that those partnering activities might have for their business/industry.

Five questions that guided the study included:

- What is the confidence level of teachers in math, science, and technology content knowledge?
- Do teachers use effective teaching practices [as defined in the literature] related to math, science, and technology in their classroom?

- What kind of, if any, math, science, and technology-based expertise would teachers desire in an educational partnership?
- What are technology-based businesses and industries in Iowa doing relative to educational partnership activities or support?
- In what ways are partnering activities valuable to technology-based businesses and industries in Iowa?
- Do the partnership opportunities teachers deem important correlate with what business & industry offer and believe are important?

Population and Survey Instrument

The sample population surveyed only included the state of Iowa (teacher n=124 and business/industry n=161) with 66 teachers responding and 40 business/industry professionals responding. The respondents consisted of teachers from 16 different rural and metropolitan school districts. Teaching experience spanned 35 years, with the average years of service being 17.7 years. Twenty-four percent of the teachers had been teaching 1-10 years and 74% of the teachers had been teaching 11 or more years. Forty-two or 64% of the respondents teach grades K-6 and 23 or 35% teach grades 7-12. Forty-nine or 74% of the respondents teach mathematics. Forty-six or 70% of the respondents teach science. Twenty-five or 38% teach technology subjects. Some teachers had participated in mathematics, science, and technology outreach or in-service activities in the past three years. The business/industry surveys were distributed to business/industry representatives who attended technology-related career/job fairs, professionals on industrial advisory boards, and business/industry representatives associated with partnership groups that currently exist with the College of Engineering at Iowa State University.

Part one of the teacher survey included self-assessment questions about confidence levels and current teaching practices relative to literature-based "best practices." The second section explored types of resources teachers deem important in an educational partnership. The business/industry survey questions focused on asking about participation, importance and effectiveness of 10 types of partnering activities. Respondents were asked additional information about these 10 activities related to numbers of employees, teachers and/or students involved with each activity. In addition, the survey solicited the perception of business/industry in identifying the value of partnering activities. Previous research work in the field of educational partnerships served as the catalyst for selecting particular partnering activities for the survey.

The Results

The results of this survey suggest high confidence levels in content knowledge and skills, but more neutral confidence levels in the utilization of technology in instruction among the teachers responding to the survey. The respondent group also utilized best practice (based on current literature) teaching techniques frequently, however, utilizing computers as a learning tool was notably less frequently used. In terms of the importance of partnership opportunities for the purpose of sustaining or improving teaching practice, rating levels were high.

The results also suggest business/industry place high importance on career development and low importance on Internet resources as partnering activities while having overall means that are high indicating general lack of participation. The results also suggest that if a business/industry indicates that developing math/science/technology skills of students has value for them, they tend to perceive development of math/science/technology skills for teachers as valuable to their business/industry. It is worthwhile to note that the categories identified as most significant as related to “value” would have the most potential positive effect on K-12 education.

Data reflect a “match” between activities teachers view as important and those that business/industry view as important. K-12 respondents report confidence in their content skills while business/industry report that math/science/technology skills of students and teachers is of great value to them. Less confidence and utilization of technology in instruction was reflected than might be expected considering the emphasis the state of Iowa has placed in technology dollars for schools in the last few years. The results of the pilot surveys may lead to further study for both the K-12 education side as well as the business/industry side related to confidence in content, utilization, and partnering activities.

The Findings

K-12 Teacher Survey

In order to provide a more comprehensive picture of the needs of teachers related to potential educational partnerships, a Likert scale was developed to assess the respondents’ confidence with mathematics and science content knowledge and using technology in instruction. A six-point Likert scale was developed with 1 signifying “Great Confidence” and 6 signifying “Limited Confidence.” As noted in the data, mean scores are high—ranging from 1.56-2.04 (1=great confidence) for respondents who teach the subject. Mean scores were lower for those who did teach the subject. Generally, confidence levels for the utilization of technology in instruction are lower (2.57 for technology teachers to 2.77 for all respondents) than confidence levels of respondent’s subject knowledge and skills.

Utilization of computers as a teaching and learning tool and constructed response was utilized least frequently with a mean score of 3.36 and 3.06, respectively (1=Great Frequency; 6=Limited Frequency). The remaining practices scored in the 2 ranges signified more frequent use. When comparing years of teaching (1-10 years and 11-35 years), the utilization of manipulatives showed a marked difference between the groups. Respondents with 11-35 years teaching experience used manipulatives more frequently than those with 1-10 years teaching experience. This was also the case when comparing the grade level groups. Respondents teaching grades K-6 utilized manipulatives more frequently than those teaching grades 7-12.

The respondents were asked to rate partnership opportunities in regard to their importance in helping the respondent sustain or improve their math/science/technology teaching practices. Mean scores in the 2.0 range signified importance. Additionally, there is no significant difference between years of teaching or grade level groups. Engineers or Scientists in class could be considered significant with respondents teaching grades 7-12 reporting more importance to sustain or improve teaching practices than respondents teaching grades K-6.

Business and Industry Survey

Table 1 below reflects general information related to the means of various survey questions. Mean participation indicates whether respondents participated in particular partnering activities with a yes response valued at 1.0 and a no response valued at 2.0. Response choices for these columns were 1=<10 participants, 2=11-24 participants, 3=25-50 participants, or 4=50+ participants. Mean importance and mean effectiveness survey questions were a 5-point Lickert scale with 5=High and l=Low values.

Table 1
Means for Partnering Activities.

	Mean Participation	Mean # Teachers/Students Participating	Mean # Employees Participating	Mean Importance	Mean Effectiveness
Mentoring Teachers	1.82	1.28	1.43	3.48	3.35
Mentoring Students	1.55	1.88	1.82	3.93	3.88
Job Shadowing/Teachers	1.79	1.25	1.25	3.67	3.72
Job Shadowing/Students	1.35	1.40	1.39	3.80	3.65
Sponsor Outreach	1.55	2.44	1.4	3.92	3.92
Summer Workshops	1.89	2.33	1.0	3.47	3.50
Scientists in Classrooms	1.76	1.38	1.63	3.60	3.53
Career Development	1.25	NA	1.28	4.12	3.75
Supplies & Materials	1.70	NA	NA	3.60	3.39
Internet Resources	1.87	NA	NA	3.22	2.88

As noted in the data, the lowest mean was career development at 1.25 indicating the highest participation, while a mean of 1.82 for mentoring teachers indicated the least participation. Larger means in the categories of teachers, students, and employees indicate greater participation in activities. Some variance in means in the third and fourth columns can be explained by the nature of the activity. For instance, mentoring teachers would be expected to be a one-on-one activity while sponsoring outreach activities such as competitions would involve more participants.

Additional data in Table 1 shows the mean values for the perceived importance and effectiveness of partnering activities. Larger means reflect perceptions of greater importance and more effectiveness for some activities than for others. High levels of importance and effectiveness were assigned to outreach programs with means of 3.92 although career development exhibited the highest mean for importance. Relatively low means, importance=3.48 and effectiveness=3.35, were assigned to mentoring teachers.

The correlations between the job shadowing for teachers and mentoring teachers were significant. Supplies/materials and job shadowing for teachers was also significant. This indicates that business/industry that participate in job shadowing for teachers tend to also mentor teachers and provide supplies/materials for teachers. Further, five out of twenty correlations were statistically significant. The five included job shadowing for teachers and mentoring teachers; scientists in the classrooms and mentoring teachers; outreach programs and mentoring students; scientists in the classroom and job shadowing students; and career development and job shadowing for students. The highest correlation was job shadowing for students and mentoring students. Internet resources and supplies/materials had a low correlation.

Mentoring teachers, mentoring students and outreach programs correlated more often with other activities exhibiting the tendency of respondents to view those partnering activities as more effective.

Information in Table 2 summarizes the survey questions asking respondents to identify the value various partnership benefits have for their business/industry. Respondents determined the value of five categories on a 5-point Likert scale. The results suggest that if a business/industry indicates that developing math/science/technology skills of students has value for them, they also tend to perceive that development of math/science/technology skills for teachers and student career development are valuable. It is worthwhile to note that the categories identified as most significant would have the most potential positive effect on K-12 education.

Table 2
Correlations Between Perceived *Values* of Partnering

	DMSTS	DMSTT	SCD	CS	A & P
DMSTS					
DMSTT	.64*				
SCD	.49*	.23			
CS	.00	-.08	.27		
A & P	.26	.39	.27	.39	

**p<.001*

Key for Table 8: DMSTS-Developing Math/Science/Technology Skills for Students; DMSTT-Developing Math/Science/Technology Skills for Teachers; SCD-Student Career Development; CS-Community Service; and AP-Advertising and Promotion

Common Interests?

Mean scores for partnering activities deemed "important" by teachers had similar correlations to the same list of activities for business/industry. This match of associated levels of importance would lead one to believe that partnering could flourish if the means to deliver it to K-12 teachers could be determined. It would appear that a probable barrier to participation may simply be that business/industry need personnel within their ranks that are assigned to or have the desire to lead K-12 partnering activities. When there is correlation between what K-12 education and business/industry view as important, it would appear that it is the "right time" to develop partnering relationships.

Recommendations

Based on the literature reviewed and survey data, the preparedness of a future workforce will not be adequate for high tech fields, however, suitable educational partnership activities can play a vital role in supporting K-12 math, science, and technology education. To continue to advance the development and potential of educational partnerships, the following recommendations are made:

- Investigate why participation in partnering activities is so low when K-12 and business/industry agree the activities are important and have value;
- Explore further the utilization of technology in K-12 instruction in Iowa;
- Research leadership models and strategies necessary for implementation of educational partnerships as they relate to:
    - Math, science, and technology teaching in K-12 education; and
    - Business/industry educational partnerships, specifically:
        - Roles and responsibilities,
        - Human resource dimensions, and
        - Sustainability
- Enlist the interests of economic development agencies, school boards, and state and federal organizations committed to the advancement of a technologically skilled workforce.

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Bibliography

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy.* New York: Oxford University Press.

American Association for the Advancement of Science. (1989). *Science for all Americans: A project 2061 report on literacy goals in science, mathematics, and technology.* Washington, DC: Author.

American College Testing Program. (2001). *High school profile report, high school graduating class of 2001.* Iowa City, IA: Author.

Anderson, L.W. & Krathwohl, D. (Eds). (2001). *Taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.* New York: Longman.

Balen, J., Casey, J. C., & de Kanter, A. (1998). *The corporate imperative: Results and benefits of business involvement in education.* [On-line]. Retrieved from http:// www.ed.gov/pubs/CorpImp/cover.html

Bureau of Labor and Statistics (1999, November). BLS News Release 1998-2008 employment projections. Retrieved April 12, 2001 from http://www.bls.gov/news.release/ecopro.nr0.htm

Coles, A.D. (2000, May 3). Throng of scientists, engineers to venture into middle schools. *Education Week.* [On-line]. Retrieved from http:// www.edweek.com/ew/ew_printstory.cfm?slug=34nsf.h19

College of Engineering. (2000). *College of Engineering - Blueprint for Excellence.* [Brochure]. Ames, IA: Iowa State University.

Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology. (2001, September). *Land of Plenty – Diversity as America's competitive edge in science, engineering, and technology.* Report of the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology.

Conference Board. (1998). *Innovative public-private partnerships: Educational initiatives.* New York: The Conference Board.

Conference Board. (1994). *Partnerships for a prepared work force: A conference report.* New York: The Conference Board.

Cummings, K. (2001). What is constructivism? *American Women in Science Magazine,* 30(3).

Evans, T. W. (2000). The new mentors. *Teachers College Record, 102,* 244-263.

Gladstone, B., & Jacobsen, D. M. (1999). Educational partnerships in rocky view school division, part 1. *International Electronic Journal for Leadership in Learning.* [On-line]. Retrieved from http://www.acs.ucalgary.ca/~iejll/volume3/gladstone.html

Gorman, C. (1998). *Investing in science literacy: Competing in the global, knowledge-based economy.* [On-line]. Retrieved from http://www2.conferenceboard.ca/cben/scilit.htm

Grobe, T. (1993). *Synthesis of existing knowledge and practice in the field of educational partnerships* (Report No. PIP-93-1102). Washington, DC: Office of Educational Research and Improvement. (ERIC Document Reproduction Service No. ED362994)

Harkavy, I., & Puckett, J. L. (1991). Toward effective university-public school partnerships: An analysis of a contemporary model. *Teachers College Record, 92*(4)

Hyde, A. A., & Hyde P. R. (1991). *Mathwise: Teaching mathematical thinking and problems solving.* Portsmouth, NH; Heinemann.

Jackson, A. W., & Davis, G. A. (2000). *Turning points 2000: Educating adolescents in the 21st century*. New York: Teachers College Press.
Kaufman, R, Herman, J., & Watters, K. (1996). *Educational planning.* Lancaster, PA: Technomic.
Knuth, R. A., Jones, B.F., & Basendale, S. (1991). *What does research say about science?* North Central Regional Educational Laboratory. Retrieved from http://www.ncrel.org/sdrs/areas/stw_esys/3science.htm
Kubota, C. (1993). *Education-business partnerships: Scientific work experience programs.* ERIC/CSMEE Digest. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education, The Ohio State University. (ERIC Document Reproduction Service No. ED359045)
Kuo, E. W. (1999). *Creating beneficial institutional collaborations.* Washington, DC: Office of Educational Research and Improvement. (ERIC Document Reproduction Service No. ED427818)
Lankard, B.A. (1995). *Business/education partnerships*. [On-line]. Retrieved from http://www.ed.gov/databases/ERIC_Digests/ed383856.html
Larson, K., Rogstad, A., & Smith, N. (1998). *The formula for success: A business leader's guide to supporting math and science achievement* (Report No. SAI-98-3028). Washington, DC: Office of Educational Research and Improvement. (ERIC Document Reproduction Service No. ED419914)
Ma, L. (1999). *Knowing and teaching elementary mathematics: Teacher's understanding of fundamental mathematics in China and the United States.* Mahwah, NJ: Lawrence Erlbaum.
MacDowell, M. A. (1989). Partnerships: Getting a return on the investment. *Educational Leadership*, *45*(2), 8-11.
McEwan, E. K. (2000). *The principal's guide to raising math achievement.* Thousand Oaks, CA: Corwin Press.
Melsa, J. L. (2001). *Iowa: Thriving in the new economy.* Ames, IA: College of Engineering, Iowa State University.
Moe, A. J. (1995). The Lehigh Valley business-education partnership: A five-year collaboration to enhance the quality of K-12 education. *New schools, new communities, 11*(3), 32-40.
National Academy of Engineering, and National Research Council. (2002). *Technically speaking: Why all Americans need to know more about technology.* Washington, DC: National Academy Press.
National Academy of Science. (1996). *National science education standards.* Washington, DC: National Academy Press.
National Academy of Science. (1997). *Science for all children: A guide to improving elementary science education in your school district.* Washington, DC: National Academy Press.
National Assessment of Educational Progress. (1997). *Mathematics: A report card for the nation and the states.* Washington, DC: National Center for Educational Statistics.
National Center for Education Statistics. (2000). *Condition of education, 2000.* [On-line]. Retrieved from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=200062.
National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform.* [On-line]. Retrieved from http://www.ed.gov/pubs/NatAtRisk/index.html

National Council of Teachers of Mathematics. (1995). *Assessment standards for school mathematics.* Reston, VA: Author.
National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school Mathematics.* Reston, VA: Author.
National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics.* Reston, VA: Author.
National Research Council. (2001). *Building a workforce for the information economy.* Washington, D.C.: National Academy Press.
National Science Foundation. (2000). The Long View [On-line]. Retrieved from http://www.eng.nsf.gov/pubs/longview.htm
National Science Foundation. (1997). The challenge and promise of K-8 science education reform [Monograph]. *Foundations, Volume 1.* Arlington, VA: Author.
National Science Foundation. (1997). Inquiry: Thoughts, views, and strategies for the K-5 classroom [Monograph]. *Foundations, Volume 2.* Arlington, VA: National Science Foundation.
National Science Foundation; Directorate of Education and Human Resources, Division of Elementary, Secondary, and Informal Education. (1997). The challenge and Promise of K-8 Science Education Reform [Monograph]. *Foundations – A monograph for professionals in science, mathematics, and technology education, 1*(Chap. 2). Arlington, VA: Author.
National Science Resource Center; National Academy of Sciences; Smithsonian. (1997). *Science for all children - A guide to improving elementary science education in your school district.* Washington, D.C.: National Academy Press.
Office of Educational Research and Improvement, U.S. Department of Education (1997). *Attaining excellence: A TIMMS resource kit.* Washington, DC: U.S. Government Printing Office.
Ringstaff, C., & Kelley, L. (2002). *The learning return on our educational technology investment.* San Francisco: WestEd Regional Technology in Education Consortium.
Smerdon, B., Cronen, S., Lanahan, L., Anderson, J., Iannotti, N., & Angeles, J. (2001). Teachers' tools for the 21st century: A report on teachers' use of technology. *Education Statistics Quarterly.* [On-line]. Retrieved April 4, 2001, from http://nces.ed.gov/pubs2001/quarterly/winter/elementary/e_section5.html
Stevenson, H. W., & Stigler, J. W. (1992). *The learning gap.* New York: The Free Press.
Stigler, J.W., & Hiebert, J. (1999). *The teaching gap.* New York: The Free Press.
Stigler, J. W., & Hiebert, J. (1997, January). Understanding and improving classroom mathematics instruction. *Phi Delta Kappan*, 79 14-19. [On-line]. Retrieved from http:// www.pdkintl.org/kappan/kstg9709.htm
Stone, N. (1991) Does business have any business in education? *Harvard Business Review*, *69(*2), 46-62.
Thornburg, S. (2002). The new basics: Education and the future of work in the telematic age. Alexandria, VA: Association of Supervision and Curriculum Development.
U.S. Department of Education. (2000). *Before it's too late.* Jessup, MD: Education Publications Center.
Warden, J. E. (1986). *Establishing partnerships between the business community and rural schools.* Washington, DC: Office of Educational Research and Improvement. (ERIC

Document Reproduction Service No. ED287650)

Zemelman, S., Daniels, H., & Hyde, A. (1998). *Best practices: New standards for teaching and learning in America's schools.* Portsmouth, NH: Heinemann.