IMPROVING STEM INSTRUCTION IN MN

Recommendations from the P-16 Science Instruction Workgroup for the State of Minnesota

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Executive Summary of Recommendations

The Instruction Group worked together over one year to identify improved instructional practices in elementary and secondary science, technology, engineering and mathematics (STEM) education that can be adopted by education stakeholders and disseminated through the state of Minnesota's new Math and Science Academies and other initiatives. Since Minnesota's new science standards include engineering and technology literacy, the Instruction Group concluded that its recommendations should address science, technology, engineering and mathematics (STEM) instruction as a whole.

The recommendations embody the Instruction Group's desire to: inspire schools and communities to embrace the spirit of STEM, stimulate the integration of STEM subjects with each other and with other subjects, encourage the adoption of consistently high quality STEM curricula throughout Minnesota, promote inquiry-focused teaching practices, expand hands-on STEM learning opportunities in and out of school, and excite all Minnesota students about STEM careers and STEM subjects.

As the Instruction Group discussed its ideas, it became clear that, in various recommendations, it was proposing a new system for strengthening and supporting STEM education in Minnesota. That new system has the following components:

1. STEM Liaisons would be paid by the state and would work in a single district or in groups of districts depending on the number of students. They would be knowledgeable in one or more STEM subjects and would be responsible for connecting teachers and students to STEM resources in the community and for encouraging schools and community organizations to promote the spirit of STEM in the broad community. They also would assist teachers in obtaining effective professional development and materials for inquiry-based teaching. STEM Liaisons would encourage community support for out-of-school learning opportunities and STEM competitions that engage students.

   Integrating STEM with other school subjects and in the broader community will require new resources and new expertise in the form the new position of STEM Liaison.

2. A STEM Advisory Council would be created and would operate under the Minnesota Department of Education. The Council would develop criteria for effective STEM curricula and would recommend, based on its criteria, curricula that could be chosen by school districts. The Council would also oversee the development and implementation of STEM teaching frameworks based on the state's STEM standards. In addition, the Council would supervise the development of multiple assessments designed to improve

STEM learning. Members of the Council must be teachers and researchers with a high level of expertise in STEM education in elementary through postsecondary settings.

The new STEM Advisory Council would provide statewide leadership in STEM education and play a key role in adopting STEM frameworks and identifying curricula and assessments that work.

3. State recommended curricula chosen by the STEM Advisory Council would be supported by the state. The curricula would implement inquiry-based learning with significant hands-on learning components. Districts would not be required to adopt the recommended curricula. Districts that implemented a curriculum recommended by the Council would receive state support for purchasing the curriculum and related materials and for professional development for all district staff and teachers responsible for implementing the curriculum.

   In an era of tight resources, Minnesota can improve STEM outcomes by concentrating its resources on a few curricula that are effective as opposed to trying to support teaching across a broad range of curricula.

4. Mathematics and science teacher academies have already been funded by the state to improve professional development in STEM subjects. In the new system, they would be the vehicle for providing support and training in the recommended STEM curricula. They might also handle the support for physical materials used in the curricula similar to the support provided now by the Science Museum of Minnesota for some STEM curricula.

The STEM teacher academies can be most effective if they focus on professional development for specific curricula rather than working with teachers on generic instruction.

5. The existing system of science museums and other informal learning centers and opportunities would be expanded throughout Minnesota with new distributed STEM learning centers, mobile learning laboratories and enhanced environmental learning centers.

Opportunities for STEM learning outside of school can be expanded by building on Minnesota's base of existing informal learning organizations, reaching everywhere in Minnesota.

The successful implementation of the recommendations proposed in this report will increase the number of students, especially students of color, who are qualified for, and excited about pursuing STEM fields as careers. It will also ensure that all students from pre-K through college

graduates become sufficiently proficient in STEM subjects to play meaningful roles as citizens and community members in whatever profession they choose.

Recommendations

1. **Culture: Inspire the spirit of STEM by connecting STEM education activities from preK through postsecondary education and community activities, creating a culture of STEM learning in students, schools, families and communities.**

Improving STEM activities in Minnesota schools will not be sufficient to achieve our goals. STEM should be valued in school and in the entire community. Minnesota should use a broad range of tools to convey to students, parents, teachers, and the community that the state values STEM learning and STEM fields.

2. **Curriculum: Build preK to postsecondary STEM curriculum focused on mastery of core STEM concepts and skills which are supported by frameworks that connect academic standards with classrooms and community learning opportunities.**

Minnesota STEM standards and curriculum must be benchmarked to international standards and exemplary STEM schools recognized. There must also be a concerted state effort to encourage the use of similar curriculum and fund professional development to incorporate effective curricula in schools across the state. A STEM liaison position needs to be created and funded to help teachers and administrators to communicate with other school districts to ensure that STEM instruction is consistent across districts. Schools should be encouraged to bring language arts, math, science, and social studies together to explore big ideas and issues that interest students. All stakeholders should foster a team culture among teachers and develop a STEM network among schools and school districts.

3. **Instruction: Identify and adopt effective, evidence-based instructional practices that engage students and teachers in inquiry-based learning and investigation and integrate STEM subjects with other parts of the curriculum.**

Science and engineering should be regularly taught in such a way that students acquire a meaningful understanding of science and design/engineering in a coherent sequence in elementary school. In secondary school, Minnesota should identify a smaller number of key standards so that students can acquire a deeper understanding of the subject matter and so that there will be enough time for teachers to incorporate project-based programs that inspire students to explore further inquiry. Funding should be made available to permit teachers and students 'real-life' experience in the application of STEM knowledge and skills.

4. **Teacher Preparation and Professional Development: Teacher preparation programs should adopt teaching and learning methods for initial preparation and professional**

development of teachers that develop reflective practitioners who continue to improve their knowledge and skills.

The state must support and encourage science induction programs and make more time available for teachers to work together. The science and mathematics academies should be utilized to promote STEM learning across the state. Further, the science and mathematics academies current emphasis on middle school needs to be expanded to also include elementary science instruction. The STEM liaison should assist each school to find the appropriate professional development program.

5. **Assessment: Identify and adopt methods of assessment that effectively support student learning and continuous improvement of STEM instruction.**

Minnesota needs to recognize the message assessments sent to our students and apply the principles of effective assessment to the evaluation of learning in Minnesota schools. The Instruction Group recommends training and support for instruction that engages students in STEM topics and inspires students to explore STEM in multiple environments. In order to support this recommendation, a student's knowledge and skills must be assessed using multiple tools.

6. **Learning Environments: Assure that all Minnesota students have access to quality school-based (formal) and out-of-school (informal) STEM learning environments that exemplify the value that Minnesota places upon science, technology, engineering and mathematics education.**

The student learning environment must be expanded beyond the classroom to incorporate after school and out of school programs. The STEM liaison will coordinate classes and informal learning programs. While the state should expand the learning opportunities, classrooms must have basic supplies available for their students. Equip elementary classrooms with the equipment and spaces that are needed to support inquiry and the doing of science and engineering. Equip secondary classrooms with technologically current laboratory equipment and supplies to create an appropriate STEM learning environment in their classrooms.

7. **Equal Opportunity: Develop effective methods to close the STEM achievement gap for ethnic and socio–economic groups and ensure STEM proficiency for all Minnesota students.**

Teachers should acquire the capacity during their professional preparation and through ongoing professional development experiences to engage all of their students in STEM learning by applying culturally competent pedagogies and using culturally relevant materials and curriculum. Quantitative goals must be set and tracked reducing Minnesota's ethnic achievement gap. The state and local businesses should support opportunities for students

and community mentors and advisors to participate in STEM program such as GEMS; that encourage girls to pursue STEM careers. The state should also encourage Environmental learning centers to incorporate more STEM topics in their informal learning environments to create more access for rural Minnesotans to informal STEM learning opportunities.

The list below highlights the contrast between where STEM education in Minnesota is today and where it will be if these recommendations are fully implemented.

Where Minnesota stands today;

	Where Minnesota stands today	Where Minnesota can be tomorrow
1.	STEM subjects are usually taught separately	Each STEM subject is integrated with the other STEM subjects, and also where possible connected to other important content areas such as literacy
2.	Our science standards emphasize a long list of content topics	Minnesota science standards are limited in number and focus on the "big ideas" of science
3.	Too few students pursue STEM study after high school and enter STEM careers	Many students pursue STEM study after high school and pursue STEM careers – notably including people of color and women
4.	Students struggle with posing scientific questions, searching for answers to those questions and applying what they learn to practical problems	Students can form strong hypotheses, test them and apply what they learn
5.	Students rarely know their own strengths and weaknesses at an actionable level in STEM	Students understand their own strengths and weakness in the STEM fields and know what they need to do to improve
6.	Science is too often books and charts on a screen that don't engage students' imagination	Students wonder at the natural and design world
7.	STEM subjects seem disconnected from many students' everyday lives	Students understand how their current and future lives are influenced by STEM problems and solutions
8.	Learning often takes place in isolation	Teaching and learning is collaborative
9.	Academic content is rarely integrated with "21st Century Skills"	Students build 21st Century skills such as deductive reasoning and problem solving while they also master content knowledge

Background

This report is being submitted by the Science Instruction Working Group created by the Minnesota P-16 Education Partnership. The MN P-16 Education Partnership is a voluntary organization made up of the statewide education groups in Minnesota, plus others from government, business, and other private sectors. Robert Bruininks, the President of the University of Minnesota, was the chair of the Partnership during the work on this report.

For 2008-2009 the P-16 Partnership created four working groups to advance the work of the partnership. Each working group was assigned a charge:

- The Postsecondary and Workforce Readiness Working Group should develop a clear and concise definition of readiness for postsecondary education and high-skill, high-wage employment in Minnesota and a plan to disseminate that definition across the state.

- The Data System Working Group should coordinate and complete the implementation of a common student identifier that follows students in Minnesota from kindergarten through the completion of postsecondary education.

- The Science Standards Working Group should develop broad recommendations for strengthening and enhancing Minnesota's K-12 academic standards in science.

- The Science Instruction Working Group should identify policies and practices that will increase the capacity of teachers, principals, mentors and other adults to help students from all backgrounds meet and exceed state academic standards in science and develop a lifelong interest in science and related fields.

The Science Readiness group completed its work in the fall of 2008. They built a platform of findings and recommendations that provided a sound starting point for the work on science instruction. The Readiness group recommended that Minnesota move away from a large number of individual content standards to an approach that will foster a deep understanding of the essential core ideas and practices of science.

The Science Instruction Working Group ("Instruction Group"), the authors of this report, respected and built on the recommendations of the Readiness group as it responded to its own charge from the P-16 Partnership. The full charge assigned to the Science Instruction group is listed in Appendix A. Since Minnesota's new science standards include engineering and technology literacy, the Instruction Group concluded that its recommendations should address science, technology, engineering and mathematics (STEM) instruction as a whole. The decision

to extend the Instruction group's work beyond science alone was reinforced by its conclusion that good instruction requires increased integration of learning across disciplines.

The Instruction Group particularly worked to identify improved instructional practices in elementary and secondary science education that can be disseminated through the State of Minnesota's new Math and Science Academies and other professional development initiatives.

Introduction and Process

Since the 2007 National Academies report *Rising Above the Gathering Storm,* Americans and Minnesotans have heard increasingly insistent calls for improving outcomes from STEM instruction. Numerous national groups have submitted their own recommendations. For most of these reports, the focus has been on maintaining or increasing the number of U.S. students who are well-qualified to pursue careers and who become part of a technologically and scientifically sophisticated workforce. It is framed as a challenge to America's competitiveness in a global economy.

It is just as important to pay attention to the scientific literacy of all Americans. Climate change is just one of the scientifically complex issues that confront policymakers and the public today. Citizens will have difficulty exercising the rights and responsibilities of self-government if they lack even a basic understanding of scientific understanding and processes. Parents will be less likely to encourage their children to become scientifically literate if they themselves are ill at ease around science.

The Instruction Group concluded that there are two goals for teaching STEM in Minnesota's schools:

1. Increase the number of students, in particular, students of color, who are excited about STEM fields as potential career options and who are well-prepared to pursue those options in college and beyond.
2. Ensure that all students from pre-K through college graduates become sufficiently proficient in STEM subjects to play a meaningful role as citizens.

The Science Instruction Working Group is made up of teachers, researchers, business people, and other education professionals. The Instruction Group met over the course of eleven months.

In order to facilitate the discussion and the development of recommendations, the Group divided into four subcommittees with each subcommittee focusing on a specific topic: professional development, curriculum, learning environments, or assessments. The subcommittees met on their own to develop recommendations that were subsequently considered by the entire Instruction group.

Along with the subcommittees, the larger group also discussed professional development, curriculum, learning environments, and assessment for the STEM student, teacher, and community. However, the discussion often went further to include defining and encouraging the spirit of STEM, the qualities of a successful STEM student, the challenges for teachers, diversity in STEM, and the need for a STEM supportive community.

The broad range and depth of these discussions is captured in the recommendations in this report.

Vision

The P-16 Science Instruction Group selected the framework developed by the Partnership for 21st Century Skills as a way to organize its thinking and ensure a comprehensive approach to its work. The framework focused the Group's attention on four areas: standards and assessments, curriculum and instruction, learning environments and professional development. Standards are not discussed in this report because they were the responsibility of a separate working group.

As one step in developing conclusions and recommendations the Group set out its vision for student success in STEM.

Success for students, teachers and schools is realized when:

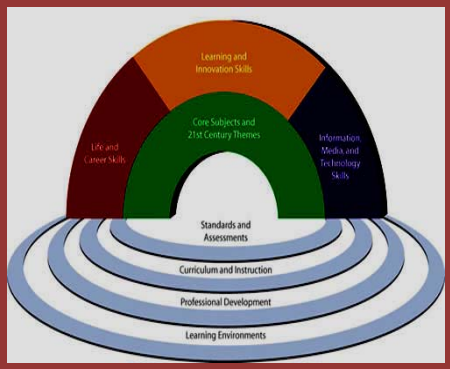
- Students become genuinely interested in science and technology and are motivated by the relationships that they develop with their teachers as they explore scientific questions.
- Students become increasingly competent in science, technology, engineering and mathematics (STEM), are well-prepared for the material that will be covered in the following year and are motivated to take more advanced courses in STEM.
- Students and teachers have the ability to pose meaningful scientific questions and can search for the answers to those questions and apply what they learn to practical problems.
- Students and teachers are able to reflect on their own learning and recognize their own

Framework for 21st Century Learning

The framework presents a holistic view of 21st century teaching and learning that combines a discrete focus on 21st century student outcomes (a blending of specific skills, content knowledge, expertise and literacy) with innovative support systems to help students master the multi-dimensional abilities required of them in the 21st century.

The key elements of 21st century learning are represented in the graphic and descriptions below. The graphic represents both 21st century skills *student outcomes* (as represented by the arches of the rainbow) and 21st century skills *support systems* (as represented by the pools at the bottom).

While the graphic represents each element distinctly for descriptive purposes, the Partnership views all the components as fully interconnected in the process of 21st century teaching and learning.



http://www.21stcenturyskills.org/index.php?option=com_content&task=view&id=254&Itemid=119

strengths and weaknesses.

- Students and teachers experience the wonder of the natural and designed world.
- Learners can connect what they are learning to their own interests and experiences and can see how they can use their growing knowledge to make a difference in their communities.
- Students have the ability to transfer knowledge from topic to topic and to analyze and respond to situations that they have not encountered before.
- Students and teachers collaborate with one another and encourage team work.
- Students achieve mastery and confidence in quantitative, qualitative, inductive, and deductive reasoning.
- Students gain the ability to think critically and to design workable solutions to important problems.

"Spirit of STEM"

Another step to developing conclusions and recommendations was to ensure that the 'spirit' of STEM is valued and cultivated for all stakeholders. This applies not only to the teachers and students of STEM but to all teachers, all students, school administrators, parents, school boards, and the greater community.

The spirit of STEM is a curiosity and wonderment fostered by STEM education combined with respect for the subject and those who study it. Further, the spirit of STEM requires that the leaders in STEM education create an environment where support for STEM is visible and compelling and STEM is understood to be a priority.

In Minnesota today, STEM learning is isolated from the rest of the curriculum. Teachers who are not science, technology or engineering specialists shy away from the subjects and give students the impression that this learning is only for the students who are "advanced", already interested in the subjects or have adequate reading and mathematics skills. Science, when integrated with other STEM subjects, can be exciting for students and teachers. Engineering instruction is in its infancy, a perfect time to integrate its study with other subjects. Mathematics and technology are tools that are seldom integrated within an overall STEM curriculum.

Yet the world for which our students are being prepared is driven both economically and culturally by STEM. The environment in schools needs to better reflect the world outside of school in which a successful citizen must function, where STEM impacts almost everything. Classrooms must have equipment, both low tech and high tech, and space that allows students to

investigate and solve concrete problems that will stimulate their human propensity for wonder and exploration. Impactful STEM education results from the use of the available resources to engage students in investigation, analysis, design, and evaluation. When the doing of STEM is integrated with other subjects, all learning gains. In a classroom environment that supports STEM learning, students should be simultaneously engaged in learning reading, writing, history, art, and music

Successful STEM learning environments embody an understanding that the importance of these subjects must be fostered throughout the entire school community. It is critical that Minnesota adopts and promotes this "Spirit of STEM" in all schools. Enthusiasm for STEM should connect the school and the community. It is crucial that local school leaders support district-wide STEM initiatives and be responsible for supporting and encouraging teachers to pursue STEM instruction throughout the curriculum while making connections to the local community to support their efforts.

STEM Propagation

Along with a heightened enthusiasm around STEM, steps must be taken to identify and disseminate effective STEM curriculum, programs, and activities. Multiple groups in Minnesota are making great strides incorporating lab time, outside exploration, and experiments into the classroom. STEM educators at local universities can provide these curricula, programs, and activities. The information about these programs needs to be reviewed collected and disseminated by a new STEM Advisory Council and by STEM Liaisons.

Identification, dissemination and cultural change around STEM will add additional responsibilities to current school staff; and this will reduce time necessary to implement change. The state should fund and support fulltime STEM liaisons in each school to facilitate change and provide ongoing coordination. The STEM liaison will provide resources for teachers and after school program personnel, connect formal and informal learning within the schools, and establish relationships with local businesses and volunteers in the community to support STEM learning experiences. All of this, combined with the extended recommendations throughout this report, will greatly advance STEM education in Minnesota.

Recommendations

The recommendations are structured to clarify the lead recommendation with more detailed sub-recommendations. Ideas and groups that exemplify some of the recommendations are highlighted in text boxes throughout the report. However, these are not the only examples supported by this group. Further, the report attempts to highlight MN organizations that exemplify the recommendations of the instruction group. However, other states are referenced where MN examples were not found or familiar to the instruction group. The larger bodies of text support and justify the recommendations.

Culture

1. **Inspire the spirit of STEM by connecting STEM education activities from preK through postsecondary education and community activities, creating a culture of STEM learning in students, schools, families and communities.**

    1.1 The state should hire and support STEM Liaisons who connect STEM subjects to other subjects and families and community groups to the schools and who encourage active participation of families in activities that promote interest in STEM education and STEM careers.

    1.2 The state should provide grants to schools that meet criteria to support the implementation of STEM programs that involve community organizations and individuals, local businesses, teachers and students and that engage community interest in the schools and support for the importance of STEM learning.

    1.3 The state, along with public and private partners, should develop a network of distributed and mobile science and engineering laboratories and activity centers that bring exciting experiences in STEM to communities across the state.

    1.4 The state, in conjunction with public and private partners, should create outreach programs that inform families about what their children are learning in school and that create opportunities for families to participate in STEM learning.

    1.5 The governor, legislators, school boards, superintendents, principals and teachers must become aware of the importance of STEM and act as leaders in advocating for STEM and forging alliances with other community leaders to support a community-wide spirit of STEM.

The 2009 Lemelson-MIT Invention Index found that an overwhelming majority of teens surveyed (85 percent) expressed interest in science, technology, engineering and mathematics. However, nearly two-thirds of teens indicated that they may be discouraged from pursuing a career in science, technology, engineering or mathematics because they do not know anyone who works in these fields (31 percent) or understand what people in these fields do (28 percent).[i]

Schools in Minnesota need to capture the interest of children and teens in STEM by encouraging the 'spirit of STEM' in their schools. Teachers, parents, and the greater community have a large role in aiding students to build on their natural interests to pursue a career in a STEM field.

The newly created position of STEM Liaison will play a key role in coordinating the activities that are offered and ensure that parents are able to participate to better understand and encourage their children's progress. Ideally, STEM Liaisons will be expert in some STEM subject matter and will be trained to help teachers integrate STEM with other subjects and integrate STEM in school with STEM in the broader community. STEM Liaisons would be paid by the state. Larger districts might have more than one STEM Liaison while in other areas one STEM Liaison might serve multiple districts and communities. An effective STEM Liaison would be a STEM cheerleader, coach and organizer. The STEM Liaisons will also form a statewide network for sharing effective practices across Minnesota.

The state should develop a grant program that stimulates districts and communities to increase the STEM education and activity resources available to families and students. The grants should be based on criteria that describe the characteristics of community programs that are likely to be effective rather than being competitive. The grants could support new STEM competitive teams or local STEM centers that provide spaces where children and adults can learn the excitement of STEM.

Minnesota is rich in STEM learning places outside school. Many of these are concentrated in the Minneapolis-St. Paul metropolitan area. To ensure that community-based STEM learning opportunities are available for all Minnesota students, the state and a variety of partners should create a network of distributed and mobile science and engineering laboratories and activity centers. This network will give students and families throughout the state opportunities to engage in a variety of hands-on STEM activities and work with to STEM professionals. Components of the network can take a variety of forms: collectors' corners in libraries where kids can bring in objects from the natural world, mobile cell laboratories that enable students to work with real cells, etc.

Consistent with the need for more integration of STEM learning in the community, districts should attend to the STEM learning needs of parents. Students will be better motivated in STEM subjects if they see that their parents are interested in STEM too. Moreover, the increasing number of immigrant families in Minnesota means that many parents may have had limited or no exposure to STEM learning when they were young. The PACES program developed by the Physics Department at the University of Minnesota is just one example of successful outreach to parents.

Creating a statewide spirit of STEM throughout Minnesota will not happen without leadership. That leadership should start with public officials like the governor and legislators and should continue through to school boards, superintendents, principals, teachers and students themselves. STEM leadership should include advocacy, finding opportunities to demonstrate the leader's own excitement about STEM and engagement with other community leaders to expand the community resources that will support STEM learning.

CAFÉ SCIENTIFIQUE

A Happy Hour Forum for Science and Culture Hosted by the Bell Museum

Across the country and around the globe, adults who share an interest in scientific research are gathering in pubs and coffee houses for informal discussions on relevant and often provocative scientific topics. Science Cafés and Café Scientifique events are a chance for adults to exchange opinions and ideas about science and related issues.

Two years ago, the Bell Museum launched its own Café Scientifique program, a happy hour program for adults that brings research from the University of Minnesota and beyond into some of the Twin Cities' most unique and atmospheric bars and restaurants. The Bell Museum's Café Scientifique explores science and natural history from distinct and surprising viewpoints, drawing connections between scientific research, culture, environment and everyday life.

The Bell Museum's Café Scientifique features guests from a variety of fields with diverse and relevant expertise. Past events have included scientific researchers, policy experts, bioethicists, community leaders, cultural historians, artists, and authors for dynamic discussions that bridge the gap between science and culture.

From first-hand stories of research and discovery, to controversial topics that challenge our ideas and opinions about the world around us, the Bell Museum's Café Scientifique puts science and culture on the menu!

http://www.bellmuseum.org/prog_cafescientifique.htm

Curriculum

2. Build preK to postsecondary STEM curriculum focused on mastery of core STEM concepts and skills which are supported by frameworks that connect academic standards with classrooms and community learning opportunities.

2.1 The state should regularly evaluate state STEM standards and recommended curricula in comparison to standards and curricula used by states and countries that have large proportions of high-performing students in STEM and to research-based recommendations from respected organizations.

2.2 The Minnesota Department of Education, in consultation with a newly created STEM Advisory Council, should fund the creation of STEM frameworks that are consistent with the Minnesota standards.

2.3 Students should learn the specific patterns of thinking and problem solving methods used in science, technology, engineering and mathematics in the context of learning STEM content.

2.4 The State, in partnership with local businesses, should publicly recognize schools with exemplary approaches to STEM learning based on a rubric describing a school with highly effective STEM instruction.

2.5 The state should commission the STEM Advisory Council to identify and support research-based STEM curricula that satisfy the Minnesota STEM standards and that can assist Minnesota schools in providing instruction that most effectively supports student learning.

2.6 Districts should ensure that the elementary curriculum incorporates inquiry-based learning.

2.7 School administrators should ensure there is time in school for inquiry-learning to occur.

2.8 The Minnesota Department of Education should offer technical support to schools and teachers who are engaged in assessing the impact of new STEM curricula on student learning.

2.9 Teachers and administrators should communicate with other school districts to ensure that STEM curriculum and instruction is consistent across districts.

As this report was being completed, Minnesota had just finished a revision of its science standards. The Instruction Group supported regular evaluations of the standards for the purpose of determining that the standards are current and reflect the best of U.S. and international thinking about effective STEM standards. STEM curricula that are recommended and/or used in Minnesota should also be regularly evaluated to ensure that they implement well-supported approaches to integration across STEM subjects and other subjects. STEM curricula used in Minnesota should incorporate an inquiry-based approach to STEM learning.

Many STEM education leaders, including SciMathMN, have recommended that the state adopt curriculum frameworks that would be consistent with the new mathematics and science, engineering and technology standards. This effort is important enough that the state should fund it rather than depend on private sector fund raising. It would be an appropriate project for the new STEM Advisory Council to oversee with advice from SciMathMN and other organizations concerned about STEM curriculum and instruction. Again, the frameworks should integrate STEM and other subjects and should incorporate inquiry-based approaches to learning.

Effective STEM curricula and teaching practice should emphasize the learning of scientific habits of mind within the context of mastering science content. As engineering and technology are incorporated in curricula and instructional practice, students should learn the specific problem-solving skills of engineering and design. The Instruction Group recommends that throughout the integrated learning of STEM, the curriculum should ensure that students learn the essential skills and habits of mind unique to these disciplines, while including the essential STEM content on which students must work.

Here is one example of the skills and habits of mind for engineering:
"In the broadest sense, technology extends our abilities to change the world: to cut, shape, or put together materials; to move things from one place to another; to reach farther with our hands, voices, senses, and minds. Engineering is a process of designing and building technological systems to achieve such changes. Engineers must take into account physical, economic, political, social ecological, aesthetic, and ethical considerations, and make trade-offs among them."
Project 2061 project for all Americans (engineering):
http://www.project2061.org/publications/articles/2061/sfaasum.htm

One of the ways to encourage higher performance in STEM subjects as they are integrated in schools and communities is to recognize schools for their success using a broad rubric that goes beyond test results. Testing cannot assess the degree of STEM integration across the curriculum nor does it effectively assess complex problem solving skills that are the essence of learning STEM habits of mind. The STEM Advisory Council could lead the development of a rubric that identifies several levels of effective STEM learning in schools and their related communities.

Schools could then be assessed against that rubric and recognized by businesses and other organizations for their efforts to thoroughly incorporate STEM in the school and the community.

Consistent with the its belief that greater integration in STEM curricula and instruction is essential, the Instruction Group recommends that the state create a STEM Advisory Council composed of experts in STEM education. The Council should be commissioned to review the available curricular options and to recommend a limited number of curricula consistent with Minnesota standards. The Council could be guided by recent studies on STEM education conducted by the National Science Foundation, the National Academy of Science and the National Research Council. The chosen curricula should then be made available to all school districts at a subsidized rate. School districts would be encouraged but not required to use one of the recommended curricula.

The adoption of recommended curricula has the potential to save money at the district level and, perhaps, in aggregate across the state, and to improve the quality of the curriculum and the support available for the curriculum to many districts. If a district chooses a state recommended curriculum, it could avoid the transaction costs incurred in trying to select a curriculum on its own. The state might also be able to negotiate volume pricing for the curriculum and related materials. The state could also concentrate professional development support on the recommended curricula, leading to improved support for teachers and greater efficiency across the system of ongoing professional development.

In Minnesota there are multiple programs that exemplify the type of hands on 'doing' curriculum recommended by this report. The Perpich Center, while not focused primarily on science, has developed effective ways to integrate science and mathematics with the arts. The practices they use in the classroom could greatly enhance the STEM curriculum. These programs are examples of instruction that embodies some of the recommendations of this report but this report does not recommend any one in particular. In Alabama, the state provides a central resource for hands-on learning materials in a way that reduces costs for districts while ensuring that Alabama students are exposed to hands-on learning opportunities.

A coordinated curriculum requires the state to offer multiple choices to the schools yet require that the same topics be taught in each grade. This permits teachers the freedom to design courses that best serve their students yet still ensure students are building their knowledge base as they move across grade levels or between schools. For example, currently what one student learns in 6th grade may not be built upon by his or her 7th grade teacher. This makes it very difficult for students to transition smoothly through the system when each school has a different science curriculum, when there is little connection between courses and unequal access to labs and books from one classroom or school to another.

FOSS (FULL OPTION SCIENCE SYSTEM) Web

FOSS is the official site for the inquiry-based FOSS science curriculum. A place for support, resources, and fun activities is a research-based science curriculum for grades K—8 developed at the Lawrence Hall of Science, University of California at Berkeley.

FOSS is also an ongoing research project dedicated to improving the learning and teaching of science. The FOSS project began over 20 years ago during a time of growing concern that our nation was not providing young students with an adequate science education.

The FOSS program materials are designed to meet the challenge of providing meaningful science education for all students in diverse American classrooms and to prepare them for life in the 21st century. Development of the FOSS program was, and continues to be, guided by advances in the understanding of how youngsters think and learn.

http://www.lhsfoss.org/fossweb/email/aboutFOSS.html

The curricula at all levels should incorporate inquiry-based learning. The need for more inquiry in STEM learning is especially acute in the elementary grades. Here is the National Research Council's definition of inquiry:

"Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. *National Science Education Standards*, p. 23"

National research council – addendum:

http://www.nap.edu/openbook.php?record_id=9596&page=R1

Teachers, in an effort to address these problems, are forced to begin each year with a review of the last. They then teach the necessary grade level subject matter, and attempt to end the year with a preview of the next year's topic. The transition is particularly difficult between school levels; elementary to Junior High, and Junior High to High School. This situation allows the teacher very little time to incorporate activities into the classroom which permit students to investigate STEM further. When students are overloaded with too much information and have no time to reflect or explore, their interest in science is likely to fade rapidly.

The Instruction group supports the P16 Science Readiness Work Group's call for fewer standards and topics to be taught, and an increase of inquiry-based projects in the classroom. The Science Readiness Group report addressed the challenge facing many Minnesotan teachers and students due to the large number of content standards. They recommended that Minnesota move away from its current broad content standards and allow teachers more time to teach topics in-depth. Students must gain a deep understanding of the core concepts of science, and be able to apply them. Fewer standards will also allow teachers more time to incorporate curriculum that encourages students to 'do science and engineering' into the STEM classroom.

A recent study written by Marc S. Schwartz supports this assertion and showed students who learned fewer topics in depth earned higher grades in college science courses than those students

who were exposed to long lists of topics.[ii] The in depth knowledge and multiple skills developed increased the students' confidence in STEM and better prepared them for future STEM courses.

As teachers and students are allowed more time in the classroom they will need to incorporate curriculum that encourages hands-on projects and curiosity from the students. There are multiple programs currently being used throughout the United States that inspire students in this manner. One example is the AMSTI program in Alabama which supplies teachers with curriculums and science kits. The kits and curriculums are tailored to fit the topic being taught at the time but allow the students all they need to dig into the topic further using their hands and minds.

In the past few decades Minnesota schools have seen an increase in their transient student population. These students face greater challenges in their studies as they struggle to settle in their new communities. To aid these students and increase support for STEM programs, it is recommended that schools and school districts use similar approaches to the STEM curriculum. This will allow for a concerted flow between the grade levels regardless of the students district and support successful instruction for all students. This will also provide a smoother transition for students who must transfer from one school to another.

Instruction

3. **Identify and adopt effective, evidence-based instructional practices that engage students and teachers in inquiry-based learning and investigation and integrate STEM subjects with other parts of the curriculum.**

    3.1 Districts, principals and teachers should ensure that elementary students are taught STEM subjects in a meaningful sequence integrated with other subjects and embedded in a coherent conceptual framework that balances thinking and inquiry skill development with subject content.

    3.2 Districts, principals and teachers should ensure that secondary students are taught STEM subjects using techniques that enhance their skills in inquiry and investigation, enable them to integrate STEM learning with other subjects, master STEM content, and prepare them for doing STEM at post-secondary skill levels.

    3.3 The state should create and support the position of STEM Liaison to support effective STEM instruction, in elementary and secondary instruction, encourage sustainable professional development aligned with the Minnesota standards and build connections with the broader community that enhance STEM instruction.

    3.4 School administrators and teachers should ensure that the teaching of mathematics science and engineering is integrated with each other and other subjects in the

program while preserving significant opportunities for hands on experience in science and engineering.

3.5 Districts and principals should ensure that elementary teachers regularly devote adequate class time to science and engineering instruction in the school day and school week

3.6 School administrators should foster a team culture that supports the integration of STEM teaching and alignment and shared responsibility across classrooms and grade levels.

3.7 Businesses, higher education institutions, school districts and informal learning institutions should create opportunities for teachers and students to apply what they are teaching and learning to practical STEM problems.

3.8 The state should encourage collaboration among universities and colleges, students and faculty to improve STEM teaching and learning.

Elementary teachers in Minnesota, like all elementary teachers, are challenged with minimal funds, large classes, and demanding curricula which focus heavily on regularly tested subjects such as language arts and mathematics. Due to these constraints science education often times occurs as infrequently as once a month.

The National Science Teachers Association (NSTA) supports the notion that inquiry science must be a basic component in the daily curriculum of every elementary school student at every grade level. In the last decade, numerous reports have been published calling for reform in education. Each report has highlighted the importance of early experiences in science so that students develop problem-solving skills that empower them to participate in an increasingly scientific and technological world.[iii]

The Instruction Group concurs with NSTA that STEM at the elementary level is crucial to future success and recommends further support for elementary school teachers to teach STEM topics with an integrated hands-on approach. This support should include identification and/or development of elementary school STEM curriculum that engages students in explorative activities and incorporates STEM into other subjects. It should include time in the class day to incorporate STEM subjects. Also, recognizing that many elementary school teachers may be uncomfortable with teaching math and science, the Instruction Group recommends well-designed, elementary specific, professional development to help elementary teachers to incorporate more engaging approaches to STEM in their classrooms. And there needs to be impactful financial support to ensure these recommendations are not only possible, but actual.

Elementary instruction: STEM needs to be regularly taught in such a way that students acquire a full understanding of STEM in a meaningful sequence. It is recommended that infusing STEM instruction in this historically literacy-focused arena be approached in an integrated manner and embedded in a coherent conceptual framework that supports the effective introduction of STEM into the elementary classroom, balancing subject content with thinking and process skill development.

Secondary instruction: Provide support for secondary schools to incorporate effective learning technology into STEM instruction and to make these resources available to all STEM classrooms and all students. Connect the curriculum to local interests and local resources and needs. Consider the community as a vital resource in supporting STEM learning and the application of STEM learning in creative ways.

Secondary school teachers must also be supported to incorporate STEM projects that require students to apply their knowledge in hands-on, inquiry-based projects. STEM instruction goes beyond basic content knowledge transfer to teach students skills and approaches that can be applied to multiple areas in their lives. In order to permit teachers the time to teach these real skills the curriculum must be scaled back to allow more time to apply multiple learning approaches. Students need the time to question and test their STEM projects and hypothesis.

A recent study written by Marc S. Schwartz supports this assertion and showed students who learned fewer topics in depth earned higher grades in college science courses than those students who were exposed to long lists of topics.[iv] The in-depth knowledge and multiple skills developed increased the students confidence in STEM and better prepared them for future STEM courses.

Another challenge facing many STEM teachers is that students do not understand why they need to learn science, technology, engineering, and mathematics. They do not see how it is applicable to 'real life'. Teachers on the other hand, often know a lot about the subjects they teach but have no 'real life' experience in their field.

It is therefore recommended for the success of Minnesotan STEM students that they have the opportunity to apply their skills to practical 'real life' STEM problems. They also must be taught what jobs are available for people with STEM skills. Teachers will be better able to teach this 'real life' knowledge in their classrooms if they themselves have had some time working in a STEM field.

Elementary personnel and parents must realize that science is basic. Elementary school science should Excite children's natural curiosity foster an interest in the student's world & in themselves Provide opportunities to engage in scientific methodology Elementary science should develop the processes of science.

Northwest Technical College. Minnesota Curriculum Model: An Overview. Presented by. Barb Lee Schueppert. Director of Institutional Effectiveness

What is getSTEM?

www.getSTEM-mn.com or "getSTEM," is a web portal designed to connect Minnesota educators with science and technology businesses, in order to better prepare students for post-secondary education programs and careers in science, technology, engineering, and math (STEM). getSTEM is a partnership between the Minnesota High Tech Association (MHTA) and the Minnesota Department of Education and supported by a grant from the National Governors Association along with sponsoring businesses including: Thomson Reuters, Microsoft, 3M, Inetium, and Ecolab.

getSTEM Vision:

Educators have expressed the desire to use real world business examples of science, technology, and engineering applications in their lesson plans and classrooms. Students frequently ask, "When will I use this in real life?" Teachers want and need to provide answers of workforce relevance. In doing so, teachers provide students with a better understanding of how Science, Technology, Engineering, and Math (STEM) topics are applied in the "real world."

From time to time businesses are not only willing to provide expertise, classroom visits or field trips to their companies, but are also willing to share financial resources or make equipment donations to schools and educators.

As a central location or method for communication, teachers and businesses have the opportunity to openly share resources and STEM opportunities. The getSTEM web portal design is different from a standard static website, as it is interactive and allows participants to communicate in an open dialogue.

By fostering personal relationships and identifying mutual goals, local schools and businesses will help one another and develop students within their communities - the same students who are their future workforce.

The Instruction group encourages support for grants and opportunity for STEM teachers to work in STEM related fields and share their experience with their classroom. Presentations by STEM businesses and mentoring opportunities are also encouraged. Students need to know what opportunities STEM makes available to them. They also must have experience applying their skills in 'real life' situations.

This report offers many examples of programs that already exist in Minnesota that permit students the opportunity to apply their skills in competition or in activities with their peers. However, many of these programs are only available to a small subset of our state population. It is to the states advantage to make these programs available to all students. With equal access to opportunity the state will not only highlight STEM as a priority it will also help alleviate the growing achievement gap.

Another way to educate students on the importance of STEM and apply it to 'real-life' is to integrate STEM learning into other parts of the curriculum.

There has never been a more important time to prepare students for a future in STEM fields. The US economy is shedding industrial jobs and undergoing a rapid change. The sections of the economy that are growing and that are emphasized in the current Federal stimulus package are education, health care, alternative forms of energy and "green technologies:" As this transition takes place the importance of inquiry-based STEM education and the

integration of these subjects in other disciplines become more important than ever for students.

Integrating science, technology, mathematics, and engineering, with other parts of a student's curriculum will result in a richer understanding of the concepts in each discipline and will prepare our children and youth for a rapidly changing world that is driven more and more by science and technology. While this integration may be natural among elementary schools it will require more coordination and effort in secondary and post secondary where classes are more segregated.

The challenge aside, there have been multiple initiatives in the past few years to support this assertion - Project 2061: Education for a Changing Future[v], the Holmes Group, and Project Synthesis, all suggest students need to understand how science, mathematics, and other subjects depend on one another in order to be informed citizens. In order to enable such an approach in the school without mandating mixed curriculum it is recommended that a team culture be encouraged among teachers.

As with architect, engineers, and doctors, teachers have specific areas of expertise yet are tasked with a shared goal, to produce good citizens. If the math teacher is able to collaborate with the art teacher they both will better engage their students and find ways to use art to illustrate science ideas and use science to enhance art and design, engaging students more effectively in both subjects.

Whereas currently teachers will meet with their peers in the same field, a more inclusive environment is recommended where teachers from all fields are able to meet and share curriculum and approaches with one another. Our concept of what it means to be an educated person continues to change but it is clear that we must all work together to ensure that our students can experience the connections among fields of study

About Project Kaleidoscope

Project Kaleidoscope (PKAL) is one of the leading advocates in the United States for what works in building and sustaining strong undergraduate programs in the fields of science, technology, engineering and mathematics (STEM).

PKAL is an informal alliance taking responsibility for shaping undergraduate STEM learning environments that attract undergraduate students to STEM fields, inspiring them to persist and succeed by giving them personal experience with the joy of discovery and an awareness of the influence of science and technology in their world.

From the work of the extensive PKAL community, resources are available that can be adapted by leaders on campuses across the country working to ensure robust STEM learning of all their students.

http://www.pkal.org/collections/About.cfm

Minnesota State Colleges and Universities has been selected to be one of four systems nationwide to partner in a National Science Foundation grant to build and sustain regional networks or faculty and administrators committed to improving science, technology, engineering and math (STEM) teaching and learning.

Leadership for the grant is provided by Project Kaleidoscope, a nationwide informal alliance of colleges and universities committed to building and sustaining strong undergraduate STEM programs.

http://pkal.project.mnscu.edu/index.asp?Type=NONE&SEC

and can use ideas from many sources to develop effective solutions to complex and rapidly changing problems.

Collaboration should not stop at the individual school level. The creation of a STEM network between schools and school districts should be developed. Minnesota is a vast, diverse state and STEM teachers will benefit from the experience of their peers and the applications of curriculum to different demographics. This exchange of information will also aid students who transfer from school to school as teachers will have a better working knowledge of their previous experience. The Kaleidoscope Project is a great example of these networks at a postsecondary level.

The STEM liaison, a position with multiple roles in this report, will aid schools in incorporating hands-on, inquiry projects in their classroom. The STEM liaison will further be able to connect schools with the most appropriate professional development and curriculum to meet these goals. The STEM liaison will also be able to connect teachers across schools and subjects so they can share ideas and improve upon their instruction. During this changing time in the US economy it is crucial that teachers expose students to the influence that STEM has in all areas.

Another challenge facing many STEM teachers is that students do not understand why they need to learn science, technology, engineering, and math. They do not see how it is applicable to 'real life'. Teachers on the other hand, often know a lot about the subjects they teach but have no 'real life' experience in their field.

It is therefore recommended for the success of Minnesotan STEM students that they have the opportunity to apply their skills to practical 'real life' STEM problems. They also must be taught what jobs are available for people with STEM skills. Teachers will be better able to teach this 'real life' knowledge in their classrooms if they themselves have had some time working in a STEM field. Integrating science, technology, mathematics, and engineering, with other parts of a student's curriculum will result in a richer understanding of the concepts in each discipline and will prepare our children and youth for a rapidly changing world that is driven more and more by science and technology. While this integration may be natural among elementary schools it will require more coordination and effort in secondary and post secondary where classes are more segregated.

Teacher Preparation and Professional Development Teacher

4. **Preparation programs should adopt teaching and learning methods for initial preparation and professional development of teachers that develop reflective practitioners who continue to improve their knowledge and skills.**

4.1 The State should enhance preparation and professional development for all educators who provide STEM instruction and ensure funding is adequate to support the science academies and other professional development.

4.2 Universities must ensure future elementary and secondary teachers learn skills to teach STEM subjects that are integrated in the curriculum.

4.3 Universities and school districts must support and encourage STEM-focused instruction programs that increase retention of teachers in STEM fields.

4.4 The State should make additional teacher preparation and professional development that focuses on culturally appropriate teaching methods available to all school districts.

4.5 Districts and schools should provide time for teachers to work together to integrate STEM content and skills across the curriculum and to evaluate the results using instructional practices designed to enhance STEM learning.

4.6 The State should require current elementary and secondary teachers to take courses that focus on teaching STEM subjects integrated in the curriculum.

4.7 The State should create and promote professional development strategies that encourage school boards, superintendents, district administrators, principals, teachers, teaching assistants, informal learning personnel and community volunteers to nourish a spirit of STEM in schools and through the community.

4.8 The State should use professional development such as the Science and Mathematics Academies to promote STEM learning. And customize STEM professional development for elementary and secondary teachers

4.9 The Legislature should commission and fund a program that analyzes and evaluates current STEM teaching practice in Minnesota, including the time spent on STEM instruction, curricula used, the range of teaching practices and the quality of the school environments in which STEM instruction is delivered in Minnesota schools.

The state should strongly encourage districts and schools to use the effective practices identified in the study.

4.10 STEM Liaisons should assist each school to evaluate the results of the Department of Education study and help implement improvements in STEM instruction.

4.11 The State should identify and adopt professional development practices that prepare teachers to play leadership roles in improving STEM learning that can be sustained over time.

4.12 That State, in partnership with local businesses, should provide encouragement and incentives for teachers to participate in professional organization devoted to quality STEM teaching.

Teacher Preparation

Teacher experience and knowledge is critical to improving STEM instruction. Yet the retention rate of STEM teachers is in dire straits. Currently, 50% of teachers leave the profession within the first 5 years**;** as it takes 4-5 years to become an effective teacher the situation is creating less than ideal instruction for students. [vi]

Teachers leave the profession for a variety of reasons as documented in national data. [vii] Additional, movement of teachers between schools; diminishes effective instruction. Movement tends to be from high need schools to traditionally stable schools. [viii] The result is that high needs schools often have the least seasoned and experienced teachers.

This report recommends inquiry and investigation instruction in the classroom; however, well trained teachers are integral to successfully implement this type of instruction. A study of 120 first year teachers found that those supported in science-focused induction programs implemented significantly more reform-based practices including inquiry-based labs.[ix]

It is crucial that the state work to keep STEM teachers in the profession and the use of appropriate induction programs may help.

Minnesota Private Colleges

College of St. Catherine has a new STEM certificate and minor to help future teachers gain expertise in the four STEM disciplines. The focus is for K-12 students to build a foundation of knowledge while building their skills in problem-solving and logical thinking is critical.

St. Kate's minor program instills teachers with the knowledge, relevance and excitement of STEM .

The College of St. Scholastica increases access to tutoring and research opportunities.

St. Olaf has incorporated programs to involve students in 'real-life' work projects and research programs.

http://www.minnesotamonthly.com/media/Minnesota-Monthly/February-2008/Postulating-Theorems-and-Formulating-Equations/

MUSE in Minnesota: Materials and Understanding for STEM Education, a statewide K-12 professional development initiative.

http://www.smm.org/schools/profdev/muse/

BrainU is a professional workshop designed to update teachers on the latest in neuroscience research and provide curriculum materials for using neuroscience topics in support of the Minnesota Intermediate and Middle level standards.

http://www2.neuroscience.umn.edu/brainscience/who.htm

TIES, Teaching Institute for Excellence in STEM education is the country's foremost innovator bringing STEM School design, STEM curriculum, and STEM instructional support to schools, districts, states and the federal government.

http://www.tiesteach.org/

The STEM Equity Pipeline provides professional development using national experts on gender equity in Science, Technology, Engineering and Math (STEM) education through webinars, webcasts and online courses.

http://www.stemequitypipeline.org/ProfessionalDevelopment/Default.aspx

Over 90% of beginning teachers have access to an induction program but these programs vary in their effectiveness. While the format and quality of these programs varies widely there are common elements;

- Assignment of a mentor, who may or may not be in the same field, and supportive communication with a principal or department chair.
- The addition of common planning time with teachers in the same field and seminars for beginning teachers significantly improved teacher retention and the induction package.
- The further addition of participation in an external network of teachers, reduced preparations, and being assigned an aide, are also statistically significant.

Professional Development

It is widely accepted that what the teacher knows has the greatest effect on the student's ability to learn. Professional development and teacher education policies have the potential to greatly impact teachers' abilities to teach, ergo students' abilities to learn.[x] It is therefore crucial that teachers receive the professional development they need to remain informed professionals and to master the content of the areas they teach.

The National Science Teachers Association (NSTA) reported in their article *Rising Above the Storm* that ongoing professional development for science teachers is critical to ensuring a quality teacher for every student.[xi] NSTA is one of many science associations that offer professional development programs through summer programs, learning centers, conferences, and web seminars.

The Science Museum of MN, The Bakken Museum, The Works, the University of MN, the College of St. Catherine (see side bar) and many other MN universities and museums offer professional development programs that encourage instruction skills supported by this report. This report does not recommend one specific program but encourages funding to be used to support those

programs that prepare teachers to use hands-on instruction that inspires students to pursue STEM careers.

Teachers should be encouraged to take advantage of internship opportunities and summer programs with local STEM businesses to experience the ‘real world’ situation and apply their skills in different ways.

Minnesota is encouraged to tap into these various opportunities, both locally and nationally. Additionally, the state must go beyond structured professional development to create other opportunities to allow teachers to improve their approach to STEM instruction.

Teachers more than anything need time, purposely generated, to meet with other teachers in their field to share ideas and critiques of instructional practices. Through peer mentoring they will be able to apply and improve upon practices learned in more formal settings. The STEM liaison will be able to aid teachers in finding appropriate mentor relationships and the time to meet.

Assessment

5. Identify and adopt methods of assessment that effectively support student learning and continuous improvement of STEM instruction.

5.1 The State should develop a rubric for schools and the broader community that describes the key elements for STEM learning success.

5.2 The State should commission the STEM Advisory Council to identify and recommend multiple assessments districts may use to evaluate student progress in STEM skills and content.

5.3 Districts and teachers should use multiple assessments based on the principles of effective assessment to evaluate teaching and learning in STEM subjects.

In order to inspire inquiry and curiosity in STEM through hands-on activities the assessment of student achievement must change. The purpose of the Minnesota Comprehensive Assessments – Series 2 (MCA-II) is to measure Minnesota students' achievement with regard to the Minnesota Academic Standards.

While the MCAs are useful assessments, they cannot fully assess what happens in an inquiry and investigation inspired classroom. In an inquiry focused classroom there needs to be measurement of the progression of learning, achievement, competencies, and creativity.

This type of classroom is best measured by multiple assessments. Progression of learning can be measured through journaling, lab-books and project-based learning. A measurement of achievement or an end of course assessment could be the MCAs. Competencies needs to be assessed through the measurement of skills, reasoning, and processes. Lastly, creativity should be measured as part of the science assessments in projects, journaling, and participation.

> Experience has shown us, in education, what gets measured gets taught. Science and mathematics are fundamental skills. They teach us to think critically and analytically. Therefore, assessments must measure more than simple recall. They must measure problem-solving skills. Measurements should support student learning that enhances the application of knowledge.
>
> National Science Board
>
> "America's Pressing Challenge –

Field-tested Learning Assessment Guide (FLAG) web site

The Field-tested Learning Assessment Guide (FLAG) web site was constructed by the College Level One Team, as a resource for Science, Technology, Engineering and Mathematics (STEM) instructors.

Even the most dedicated college faculty often discover that their students haven't learned what they were trying to teach - and that much of what students learn they quickly forget after the final exam.

Traditional testing methods have been limited measures of student learning, and equally importantly, of limited value for guiding student learning. These methods are often inconsistent with the increasing emphasis being placed on the ability of students to think analytically, to understand and communicate at both detailed and "big picture" levels, and to acquire life-long skills that permit continuous adaptation to workplaces that are in constant flux. Moreover, because assessment is in many respects the glue that links the components of a course - its content, instructional methods, and skills development - changes in the structure of a course require coordinated changes in assessment.

This site has a variety of assessment tools to assess beyond a written test. These innovative assessment methods emphasize deeper levels of learning and which give instructors valuable feedback during a course.

http://www.flaguide.org/intro/intro.php

The multiple assessments should also customize the problems to fit the experiences of the students it is assessing; the students' social framework must be part of the assessment. For example, an acre of wheat may be easily understood by a rural student but one who has lived in the Twin Cities or moved from a large city such as New York may not have the same point of reference.

Simply stated, good assessment of student learning in science requires multiple assessments and multiple indicators of achievement.

Learning Environments

6. Assure that all Minnesota students have access to quality school-based (formal) and out-of-school (informal) STEM learning environments that exemplify the value that Minnesota places upon science, technology, engineering and mathematics education.

6.1 The state, districts and schools should provide an elementary classroom environment that promotes the effective learning of STEM. This environment must include adequate space, equipment and supplies to allow students to actively engage with subject matter content in a manner appropriate to their grade level.

6.2 The state, districts and schools should outfit secondary classrooms with adequate space, technologically current laboratory equipment and supplies in order to create an appropriate STEM learning environment.

6.3 The state, districts and schools should provide time and collegial space for teachers to collectively plan, coordinate and assess STEM curriculum and activities across and between grade levels as well as across STEM disciplines.

6.4 The state and districts should ensure that schools acknowledge and incorporate the cultural and ethnic backgrounds, history, values and life experiences of all students and their parents plus consider the economic resources of families, all of which impact the ability of students to be successful in science, technology, engineering and mathematics.

6.5 The state, schools and community leaders should develop partnerships between the schools and other youth-serving organizations to expand STEM learning opportunities for all students both in classroom settings and outside the school day.

6.6 The state should provide support for collaborations between schools, universities, industry and informal science education organizations to give teachers continuing contact with state of the art ideas in STEM, the use of technology and current educational practices.

6.7 The state, in collaboration with businesses and communities, should provide financial support for teachers and students in all districts to participate in formal and informal STEM activities with universities, museums, STEM competitions, after-school programs and other informal STEM learning related to the broader community.

6.8 The state should provide support to existing regional environmental centers to develop and deliver programming that enriches STEM curriculum in the schools and provides professional development opportunities for elementary and secondary teachers.

6.9 The state, districts and the business community should expand internships for students and teachers with local businesses so they may learn and apply STEM knowledge and skills.

Schools are the primary learning environment for STEM education. It is imperative that schools exemplify the spirit of STEM for students and the community. Enthusiasm for STEM learning should flow from the classroom throughout the school to after school programs and connect to informal STEM programs that purposefully involve the whole community. Local school leaders should support STEM initiatives and Principals should be responsible for supporting teachers to pursue STEM instruction and to connect students with the local community.

In Minnesota today, students learn in a classroom that may or may not have lab access or tools, may or may not have adequate safety measures, and may or may not have the space to apply inquiry based learning and investigation or pursue engineering design projects in the science classroom. These are integral parts of the student learning environment. However, the learning environment is much more than the tangible things placed around a school or a classroom, the environment is also the attitude of the school, teachers, and students towards STEM.

Multiple groups in Minnesota are making great strides incorporating lab time, outside exploration, and experiments into the STEM students learning environment. It is important to learn from these programs and make them available to all students. The state should recognize the role that the in-school and out-of-school learning environment can play in enhancing the opportunity for a student to 'do science and do engineering' and support a full time STEM liaison. A full time STEM liaison in schools will aid in providing resources for teachers and after school program personnel, connecting formal and informal learning within the school, and establishing relationships with local businesses and volunteers in the community to provide additional STEM experiences.

In-classroom

Currently teachers have little time and few resources to create an environment that encourages successful STEM learning. As mentioned earlier in the report, the teacher, school, school district, student and community all play a large role in creating this environment. Teachers may decorate their classrooms to create a more inviting learning environment or bring in community members who work in STEM fields to share their experience with students. While, the teacher has some responsibility to make the best of what they have available, there is little doubt that teachers wanting of minimal supplies are at a gross disadvantage.

There is no substitute for hands-on scientific experimentation and hands-on engineering design projects. Each school – including elementary schools – must include the facilities and materials to enable this.

Access to technology can help instructors create a positive STEM learning environment. A basic computer with a projector screen in a classroom can expose students to images and activities that make STEM topics applicable to their daily lives.

Beyond the basic use of the internet there are also computer programs available that allow students to simulate dissections, build engineering projects, or use math in a fun interactive way. These programs are available for all students of all ages and allow teachers to create an interactive STEM environment with minimal space. These must not however be considered a substitute for hands-on science and engineering education.

We believe that our programs engage kids in math, science, and technology at the just the right time. We know that kids take their participation in INSciTE programs seriously because "competition" is a big part of what we do. The Kids learn problem solving skills in a fun, collaborative environment. Our kids learn from real life experts- teachers, scientists, and engineers!

http://www.hightechkids.org/?2-1-1042

Out of Classroom

After school programs can expand STEM learning opportunities. These afterschool programs may vary widely; domestic courses, creative outlets, sports, or academic competition; however, all are able to incorporate STEM lessons into their activities.

There are multiple organizations that organize competitions for students, such as; destination Imagination, FIRST LEGO League, Minnesota MathCounts, Minnesota Science Olympiad, Science Bowl and the Solar Boat Regatta

Other great programs can be found on the High Tech Kids website. This nonprofit is a catalyst organization; providing infrastructure, programs, training, and other competitive events to support educators, volunteer technical professionals, and parents, acting as coaches, mentors and competition judges in their interactions with children.

There is a large variety of after school STEM programs available at many different schools. All of these programs are a great complement to formal STEM education. It is important that these ideas are shared so that schools can learn from each other and benefit their students. The STEM liaisons will aid in connecting districts and schools to programs.

Out of School

The out-of-school environment can further enhance what students are learning in and out of the classroom.

Minnesota has an abundance of informal STEM programs and organizations; the Bakken Museum, Bell Museum of Natural History, Como Zoo and Conservatory Society, Duluth Children's Museum, Minnesota Children's Museum, Minnesota Zoo , the Science Museum of Minnesota, and The Works (see side bar).

Minnesota also has many organizations that combine art and science to peak student creativity and STEM knowledge. Leonardo's Basement is a great example of an innovative educational organization for children and their families. They have created an imaginative learning environment where girls and boys ages 6 to 16 design and build their creative ideas, mixing art, science and technology. The combination of subject matter and interests engages students that may otherwise have withdrawn from STEM subjects.

In addition to Minnesota's rich array of museums and non-profit organizations, it is also a state endowed with natural resources. There are many environmental learning centers located throughout the state that could add programming to bring STEM curricula to thousands of young people. A trip to rural areas of the state to learn in a hands-on, natural environment can give a very different perspective of practical applications of STEM instruction. Examples of environmental learning centers include Audubon Center of the North Woods, Eagle Bluff Environmental Learning Center, Red Wing Environmental Learning Center and Wolf Ridge Environmental Learning Center.

A few of these centers currently integrate STEM instruction into their programs which complements the student's in-school learning environment. These centers are utilized by some schools, communities, and parents through day trips and overnight adventures.

The focus of these centers is primarily on biology but some programs have expanded into other areas. These centers need to be supported and encouraged to further incorporate STEM topics into their repertoire.

The Instruction Group also encourages better funding to the centers in order to ensure access to all Minnesota STEM students. A trip to rural areas of the state to learn in a hands-on

THE WORKS
A HANDS-ON MUSEUM

The Works is a "hands-on, minds-on" museum that makes learning about science and engineering interesting, understandable and fun. A non-profit community organization, The Works creates successful, inspiring, hands-on learning experiences for kids. Our unique exhibits and educational programs demystify science and engineering, and inspire interest and confidence in learning. The Works has provided kid-friendly STEM (Science, Technology, Engineering, and Math) programs since 1995.

http://www.theworks.org/fb/about/what_is_the_works.html

environment, practical application of STEM instruction is an experience many poorer school districts cannot afford to offer but would greatly benefit.

Equal Opportunity

7. **Develop effective methods to close the STEM achievement gap for ethnic and socio – economic groups and ensure STEM proficiency for all Minnesota students.**

   7.1 To ensure equity for all, the State, districts, teacher preparations programs and professional development providers should ensure that teachers have culturally relevant, culturally competent teaching methods, and culturally relevant curriculum.

   7.2 The State should allocate additional resources to ensure the STEM success of African American, Latino and Native American students.

   7.3 Districts and teachers should adopt effective strategies to ensure STEM success of African American, Latino and Native American students.

   7.4 The State and districts should create specific initiatives to increase the number and percentage of STEM educators from underrepresented groups.

   7.5 Districts and administrators should ensure that ELL students have equal access to the full range of STEM learning opportunities.

   7.6 The State should ensure that Rural and urban based school districts and communities should have equal access to formal and informal STEM learning.

   7.7 Businesses, community organizations, school districts and teachers should encourage and support girls and young women to pursue engineering and related subject's education and careers.

   7.8 The State and businesses should enhance support for formal and informal STEM learning opportunities in low income school districts and for low income students.

   7.9 The State and community should provide additional opportunities for students and community mentors and advisors to participate in STEM programs such as Gise or GEMS, and competitions such as FIRST LEGO League, and Destination Imagination. These activities should receive the same kind of financial support and recognition currently enjoyed by athletics.

Minnesota's achievement gap is particularly wide with respect to race. The Education Trust, a Washington, D.C.-based nonprofit group, compared the performance of all 50 states on the 2003 math exam. On average, African American students are scoring 35-48 points less than white

Forestry and Wildlife Week at the White Earth Math and Science Academy, a five-week enrichment program held each summer on the White Earth Indian Reservation in northwestern Minnesota.

By presenting students with activities that are fun and educational, the academy has raised math and science performance, reduced dropout rates, and ultimately prepared students for a successful career, all while honoring and nurturing traditional practices and values.

Topics range from gardening to rocketry. Five years ago, Extension forestry specialist Charlie Blinn and forestry educator Eli Sagor added GPS as a way to tap into the appeal of technology.

http://www.extension.umn.edu/source/fall08/fall08-04.html

students in 8th and 11th grade math tests. The study found only Wisconsin had a slightly wider gap than Minnesota between white and black test scores.[xii]

The wide achievement gap combined with the changing state demography necessitates the state act on this issue in all subject areas; however, STEM is one area that needs particular focus.

In Minnesota the majority of non-white students are growing up in lower income school districts. While community involvement is critical in these districts, it is often the teachers who are the only adult tasked with engaging students to actively participate in their education. Many suffer from lack of parent and community involvement due to sporadic work hours, lower proficiency in English, less education, or other hindrances due to poverty. Specific initiatives must be undertaken to identify, understand and mitigate the barriers to parent and community involvement. However, the teachers often do not have the experience or the professional development and preparation to enable them to engage students through culturally competent teaching and culturally relevant curriculum.

Minnesota has a very clearly delineated set of "Standards of Effective Practice" based upon its 1987 Human Relations Rule and the INTASC standards in knowledge, disposition, and performance. (Rule 8710.2000 subpart 4 (A-Q) (Standard 3, diverse learners)) (Appendix E).[xiii]

The teacher must:

- Know about the process of second language acquisition and about strategies that support students whose first language is not English; understand how to recognize and deal with dehumanizing biases, discrimination, prejudices, and institution and personal racism and sexism;
- Use information about the students' families, cultures, and communities as the basis for connecting instruction to students' experiences;
- Develop a learning community in which individual differences are respected.

While this is an important statute and effort by the state there must be more professional development and teacher preparation that focuses on cultural competent teaching and curriculum

that is culturally relevant. It is also imperative to increase the number and percentage of STEM educators from the targeted ethnic groups.

It is also crucial that efforts are made to further engage the community and the parents of these students. If parents are not engaged or are intimidated by the subject matter the student will not have the support they need to succeed. Further if the community embraces a negative perception of those students pursuing STEM, STEM education in the community will not flourish.

Recommendation have been made earlier in this report to engage the community and support teacher preparation and training. This recommendation is in concordance with these yet stresses the support for culturally competent teaching and culturally relevant curriculum to narrow the achievement gap in Minnesota. Another recommendation made earlier to encourage the many Environmental learning centers to incorporate STEM lessons in their informal curriculums will also increase access to STEM activities in rural areas.

Another area where the gap has been fast closing in recent years is one of women in STEM. However, the gap has primarily closed in the area of biology but remains in the other sciences, math, and engineering. In particular, there are very few women entering STEM careers upon completion of college.

Girls in Engineering, Mathematics, and Science (GEMS) and Guys in Science and Engineering (GISE) are after-school and summer programs designed specifically for 4th - 8th grade girls and boys (respectively) in the Minneapolis Public School District with the goal that students will have measurable and significant gains in mathematics and science. Inaugurated in 1997, the success of GEMS prompted the development of GISE in 2006.

GEMS and GISE are supported through the collaborative efforts of the Minneapolis Public School District, the Minneapolis Federation of Teachers, and Achieve!Minneapolis. Principal benefactors and community partners include The Medtronic Foundation, The Cargill Foundation, ADC Foundation, The Best Buy Children's Foundation, Lockheed Martin, Mortenson Family, NASA, and Augsburg College.

http://www.gems-gise.org/index.html

Men outnumber women, 73% vs. 27% overall, in all sectors of employment for science and engineering. Gaps between men and women are larger in business and industry, 79% men vs. 21% women, and in federal government jobs, 73% vs. 27%. However, women do outnumber

men in educational institutions such as K-12 schools, 2-year colleges, junior colleges, and technical institutes, where they have lower salaries and lower prestige.[xiv]

This is an area that must be continued to be addressed and programs such as gems, in side bar, must be supported to continue to engage girls in STEM and encourage their pursuit of STEM careers. Hands-on STEM instruction must begin in elementary school to reach both girls and boys before gender expectations about STEM fields are ossified.

PACES: PARENTS AND CHILDREN EXPERIENCING SCIENCE

PACES is a program designed to promote science education in under-represented communities in a format where parents model learning for their children. This format will allow young children (pre-k through 3rd grade) to see their own parent valuing an educational experience and finding that science is fun and exciting. The goal is to insure that the parent and child will view themselves as confident co-learners of science. The emphasis would be on parents and children jointly making observations and generating questions. It is intended to be a format where parents would model the curiosity, focused involvement and enjoyment of learning. The program will be mobile. All materials and teachers will go to the communities where parents and children can be brought together.

The program is focused on communities that are economically disadvantaged and exhibiting the greatest disparities in academic achievement among their students.

http://www.physics.umn.edu/outreach/paces/

Members of the P-16 Instruction Workgroup

Co –Chair: Liesl Chatman – Science Museum of Minnesota
Co – Chair: Steve Kelley – Hubert H. Humphrey Institute of Public Affairs
Co – Chair: Judith Ramaley-Winona State University

Phil Anderson – Anoka Ramsey Community College
Elia Bruggeman – Chicano Latino Affairs Council
Gregory Childs – St. Paul Public Schools
Rose Chu – Metro State
Cindy Conger – Orono Schools
Andrew Ferstl – Winona State University
Leslie Flynn – University of MN
Carolyn Fruin – Eastview High School
Mike Hess - Medtronic
Todd Hauschildt – West Managed Technology Services
Nicole Harmer – Brainerd High
Claire Hypolite – Minneapolis Public Schools
Ken Jeddeloh – Science Education Partnership
Steve Jevning – Leonardo's Basement
Timothy Jump – Benilde-St. Margaret's School
Edward Kang – Lockheed Martin
Michele Koomen - Gustavus
Matt Kucharski – Padilla, Speer and Beardsley
John Lecompte – St. Paul Public School Districts
Deb Luedtke – Minnesota Department of Education
Tamara Moore – University of Minnesota
Bruce Munson – Department of Education
Jeannie Ness – Medford Schools
Karen Oberhauser – University of Minnesota
Fred Rose – Honeywell
Gillian Roehrig – University of Minnesota
Ann Sangster – Elk River
John Schultz – Hopkins School
Rebecca Schatz – The Works
Bhaskar Upadhyay– University of Minnesota
Steve Walvig – Bakken Museum

Shannon Kojasoy – Research Assistant, HHH
Julie Sweitzer – University of Minnesota

Appendix, Bibliography, and End Notes

Appendix A:

Guiding Questions

1. What are the elements of effective instruction in science at the elementary, junior high/middle and senior high levels?
2. What science curricula and instructional materials are aligned with and effective in helping Minnesota students meet and exceed state standards in science?
3. What are the characteristics of high-quality professional development in science for teachers and principals, and what effective programs currently exist in the state?
4. How can science be used to help students develop "21st Century Skills" such as creativity, collaboration and critical thinking?
5. How can schools create integrated approaches to the teaching of science, so that scientific knowledge and skills are also taught through math, literacy and other subjects?
6. What in-school strategies and structures promote student success in science? Examples could include increasing the amount of instructional time devoted to science, staffing elementary schools with teachers who specialize in science instruction and using technology to help students master difficult scientific concepts.
7. How can out-of-school-time be used effectively to strengthen student interest and success in science? Examples could include mentoring and summer enrichment programs.
8. How can teacher preparation programs, the licensure process and other strategies be utilized to increase the supply of highly-qualified science teachers?

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